TUGAS AKHIR

PERENCANAAN DAN MODIFIKASI STRUKTUR TOWER 5 METRO SEJAHTERA RESORT APARTMENTS di SURABAYA DENGAN DAKTILITAS PENUH

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BSTRAK TUGAS AKHIR

PERENCANAAN DAN MODIFIKASI STRUKTUR
TOWER 5 METRO SEJAHTERA RESORT APARTMENT DI SURABAYA
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Kita sering mengetahui banyaknya gedung bertingkat yang mengalami kerusakan parah akibat gempa. Kerusakan struktur bangunan memang tidak bisa dihindari, namun yang penting adalah bagaimana dapat mengurangi akibat dari bahaya gempa, yaitu keselamatan terhadap pengguna bangunan.

Konsep desain kapasitas adalah salah satu desain yang memberi solusi dari perilaku struktur. Saat terjadi gempa struktur seolah memberi 'tanda' akan adanya gagal elemen struktur. Dengan perilaku ini diharapkan orang yang sedang berada di dalam bangunan sempat menyelamatkan diri saat terjadi gempa.

Konsep dari desain kapasitas adalah terciptanya mekanisme *Strong Column Weak Beam* (SCWB). Yaitu perilaku struktur dimana saat menerima beban latetal yang besar, elemen yang mengalami leleh pertama adalah balok (balok induk). Dan kemudian diikuti oleh leleh kolom. Dalam desain kapasitas, elemen balok direncanakan menerima beban sampai kapasitas elemen. Yaitu kuat nominal elemen dikali dengan Φo (faktor mutu tulangan) dan ωd (faktor pembesaran dinamis). Dan elemen kolom direncanakan berdasarkan kapasitas balok. Perbandingan desain ini memberikan perilaku yang berbeda, yang menyebabkan elemen kolom tetap dalam keadaaan elastis.

Di sisi lain, ujung kolom yang diijinkan untuk terjadi sendi plastis adalah di ujung bawah kolom (kolom antai dasar). Hal ini karena di tempat ini ujung kolom menerima beban momen yang cukup besar, sehingga emungkinan terjadi sendi plastis kolom tidak bisa dihindari. Selain itu adalah di lantai paling atas (*roof*), karena di evel ini beban tekan kolom relatif lebih kecil dibanding kolom di level bawahnya.

Perencanaan dengan desain kapasitas (daktilitas penuh) memerlukan persyaratan pendetailan penulangan) di tempat atau daerah elemen yang diharapkan untuk terjadi sendi plastis. Elemen balok diijinkan untuk mengalami plastis di daerah sejarak 2 x tinggi balok dari muka tumpuan. Di tempat ini diperlukan enulangan dengan persyaratan khusus, misalnya jarak minimum antar tulangan geser, tidak diperkenankan erdapat sambungan antar tulangan. Demikian juga pada elemen kolom sampai jarak sesuai dengan peraturan.

BAB II

PERENCANAAN ATAP

2. 1. DESAIN DAN PERENCANAAN

- Digunakan kuda-kuda atap konstruksi baja,
- Perhitungan dengan menggunakan desain elastis,
- Konstruksi atap tidak direncanakan memikul gaya gempa,
- Kemiringan atap direncanakan sebesar = 35^0
- Mutu baja BJ 37 atau Fe 360, tegangan dasar $\overline{\sigma}$ = 1600 kg/cm^2
- E = 2,1. 10^6 kg/cm^2

2.2. PERHITUNGAN ATAP A

2.2.1. Perencanaan gording A

Coba dengan profil C 150x75x20x4,5

A = 13,97 cm^2	q = 11 kg/m'	
h = 15 cm	b = 7,5 cm	c = 2 cm
cy = 2,5 cm	ey = 5 cm	tb = ts = 0,45 cm
Wx = 65,2 cm^3	Wy = 19,8 cm^3	
Ix = 489 cm^4	Iy = 99,2 cm^4	

Jarak antar gording :

jarak horisontal = 100 cm

jarak miring $= \frac{100}{\cos 35} = 122$ cm

L gording (jarak antar kuda-kuda) = 600 cm

Jarak penggantung gording $= \frac{600}{3} = 200$ cm

☐ **Beban yang bekerja**

- **Beban mati**

- Berat penutup atap dan genting = 50. 1,22 = 61 kg/m'

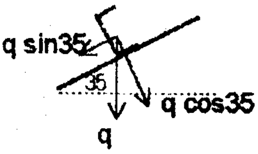
- Berat sendiri profil = 11 kg/m'

------------- +

q mati = 61 + 11 = 72 kg/m'

q mati = 72 + 10%. 72 = 79,2 kg/m' , pakai q mati = 80 kg/m'

$$Mx1 = \frac{1}{8}.\ q.\ \cos\alpha.\ L^2$$
$$= \frac{1}{8}.\ 80.\ \cos 35.\ 6^2 = 294{,}89 \text{ kgm}$$
$$My1 = \frac{1}{8}.\ q.\ \sin\alpha.\ (\frac{L}{3})^2$$
$$= \frac{1}{8}.\ 80.\ \sin 35.\ 2^2 = 22{,}94 \text{ kgm}$$



- **Beban hidup**

- Beban q merata = (40 - 0,8. α)

$= (40 - 0{,}8.\ 35) = 12$ kg/m^2 < 20 kg/m^2

q = 12. 1,22 = 14,64 kg/m' , pakai q = 15 kg/m'

$$Mx2 = \frac{1}{8}.\ 15.\ \cos 35.\ 6^2 = 55{,}29 \text{ kgm}$$
$$My2 = \frac{1}{8}.\ 15.\ \sin 35.\ 2^2 = 4{,}3 \text{ kgm}$$

- Beban terpusat P = 100 kg

$$Mx2 = \frac{1}{4}.\ P.\ \cos\alpha.\ L$$

$$= \frac{1}{4}.\ 100.\ \cos 35.\ 6 = 122{,}87\ kgm \qquad \text{(menentukan)}$$

$$My2 = \frac{1}{4}.\ P.\ \sin\alpha.\ (\frac{L}{3})$$

$$= \frac{1}{4}.\ 100.\ \sin 35.\ 2 = 28{,}68\ kgm \qquad \text{(menentukan)}$$

- **Beban angin**

q angin = 30 kg/m^2

Koefisien angin tekan = (0,02. α - 0,4)

q angin tekan = (0,02. 35 - 0,4). 30. 1,22

= 10,98 kg/m' , pakai q angin tekan = 11 kg/m'

$$Mx3 = \frac{1}{8}.\ 11.\ \cos 35.\ 6^2 = 40{,}55\ kgm$$

$$My3 = \frac{1}{8}.\ 11.\ \sin 35.\ 2^2 = 3{,}15\ kgm$$

Koefisien angin hisap = -0,4. q

q angin hisap = -0,4. 30. 1,22

= -14,64 kg/m' , pakai q angin hisap = -15 kg/m'

$$Mx3 = -\frac{1}{8}.\ 15.\ \cos 35.\ 6^2 = -55{,}29\ kgm$$

$$My3 = -\frac{1}{8}.\ 15.\ \sin 35.\ 2^2 = -4{,}3\ kgm$$

☐ **Kombinasi beban**

- **Beban tetap**

Mx = Mx1 + Mx2

= 294,89 + 122,87 = 417,77 kgm

My = My1 + My2

= 22,94 + 28,68 = 51,62 kgm

$$\sigma = \frac{Mx}{Wx} + \frac{My}{0{,}5.Wy}$$
$$= \frac{41777}{65{,}2} + \frac{5162}{0{,}5.\ 19{,}8} = 1162{,}18\ kg/cm^2 \quad < 1600\ kg/cm^2 \quad (OK)$$

- **Beban sementara**

$Mx = Mx1 + Mx3$

$= 294{,}89 + 40{,}55 = 335{,}44$ kgm

$My = My1 + My3$

$= 22{,}94 + 3{,}15 = 26{,}1$ kgm

$$\sigma = \frac{Mx}{Wx} + \frac{My}{0{,}5.Wy}$$
$$= \frac{33544}{65{,}2} + \frac{2610}{0{,}5.\ 19{,}8} = 778{,}1\ kg/cm^2 \quad < 1{,}3.\ 1600\ (= 2080\ kg/cm^2) \quad (OK)$$

☐ **Cek tegangan profil**

$$\frac{h}{tb} = \frac{15}{0{,}45} = 33{,}33 \quad < 75 \quad (OK)$$
$$\frac{L}{h} = \frac{200}{15} = 13{,}33$$
$$1{,}25.\ \frac{b}{ts} = 1{,}25.\ \frac{7{,}5}{0{,}45} = 20{,}83 \quad > 13{,}33 \quad \text{(tidak memenuhi)}$$

<u>Hitung dengan syarat profil berubah bentuk :</u>

$$A' = \frac{1}{6}.\ A\ badan + A\ flens$$
$$= \frac{1}{6}\ (h - 2.\ ts).\ tb + ts.\ b + (c - ts).\ ts$$
$$= \frac{1}{6}\ (15 - 2.\ 0{,}45).\ 0{,}45 + 0{,}45.\ 7{,}5 + (2 - 0{,}45).\ 0{,}45$$
$$= 5{,}13\ cm^2$$

$$Iy' = \Sigma\ \frac{1}{12}.\ b.\ h^3 + A.\ e^2$$
$$= \frac{1}{12}.\ ts.\ b^3 + ts.\ b.\ (ey - 0{,}5.\ B)^2 + \frac{1}{12}.\ \frac{1}{6}.\ (h - 2.\ ts).\ tb^3 + \frac{1}{6}.\ (h - 2.\ ts).\ tb.\ (cy - 0{,}5.\ tb)^2 + \frac{1}{12}.\ (c - ts).\ ts^3 + (c - ts).\ ts.\ (ey - 0{,}5.\ ts)^2$$

$= \frac{1}{12}.\ 0{,}45.\ 7{,}5^3 + 0{,}45.\ 7{,}5.\ (5 - 0{,}5.\ 7{,}5)^2 + \frac{1}{12}.\frac{1}{6}.\ (15 - 2.\ 0{,}45).\ 0{,}45^3 + \frac{1}{6}.\ (15 - 2.\ 0{,}45).\ 0{,}45.\ (2{,}5 - 0{,}5.\ 0{,}45)^2 + \frac{1}{12}.\ (2 - 0{,}45).\ 0{,}45^2 + (2 - 0{,}45).\ 0{,}45.\ (5 - 0{,}5.\ 0{,}45)^2 = 69{,}87\ \text{cm}^4$

$iy' = \sqrt{\frac{Iy'}{A'}}$

$= \sqrt{\frac{69{,}87}{5{,}13}} = 3{,}69\ \text{cm}$

$\lambda = \frac{Lk}{iy'}$

$= \frac{200}{3{,}69} = 54{,}2$, w = 1,276 (tabel 3 PPBBI)

$\bar{\sigma}\ \text{kip} = \frac{\bar{\sigma}}{w}$

$= \frac{1600}{1{,}276} = 1253{,}92\ \text{kg/cm}^2 > 1162{,}18\ \text{kg/cm}^2$ (OK)

☐ **Cek lendutan**

$\bar{f} = \frac{L}{180} = \frac{600}{180} = 3{,}33\ \text{cm}$

$f\ \text{terjadi} = \sqrt{fx^2 + fy^2}$

$fx = \frac{5}{384}.\frac{q.\cos\alpha.\ L^4}{E.\ Ix} + \frac{1}{48}.\frac{p.\cos\alpha.\ L^3}{E.\ Ix}$

$= \frac{5}{384}.\frac{(0{,}8+0{,}11).\ \cos 35.\ 600^4}{2{,}1.\ 10^6.\ 489} + \frac{1}{48}.\frac{100.\ \cos 35.\ 600^3}{2{,}1.\ 10^6.\ 489}$

$= 1{,}22 + 0{,}36 = 1{,}58\ \text{cm}$

$fy = \frac{5}{384}.\frac{q.\sin\alpha.\ L^4}{E.\ Iy} + \frac{1}{48}.\frac{p.\sin\alpha.\ L^3}{E.\ Iy}$

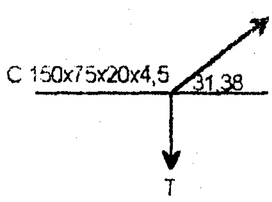
$= \frac{5}{384}\frac{(0{,}8+0{,}11).\ \sin 35.\ 200^4}{2{,}1.\ 10^6.\ 99{,}2} + \frac{1}{48}\frac{100.\ \sin 35.\ 200^3}{2{,}1.\ 10^6.\ 99{,}2}$

$= 0{,}05 + 0{,}05 = 0{,}1\ \text{cm}$

$f\ \text{terjadi} = \sqrt{1{,}58^2 + 0{,}1^2} = 1{,}59\ \text{cm} < 3{,}33\ \text{cm}$ (OK)

☐ Perhitungan penggantung gording

Penggantung gording dipasang pada jarak 200 cm



α = arc tan$\frac{122}{200}$ = 31,38^0

Gaya tarik T = $(\frac{q.\frac{L}{3}}{2} + P).\sin\alpha$

$= (\frac{80.2}{2} + 100).\sin 35 = 103,24$ kg

n (jumlah gording yang digantung) = 3

Penggantung miring T' (satu batang) = $\frac{T.n}{\sin\alpha}$

$= \frac{103,24.3}{\sin 31,38} = 594,84$ kg

A perlu = $\frac{T}{0,75.\sigma} = \frac{594,84}{0,75.1600} = 0,5$ cm^2

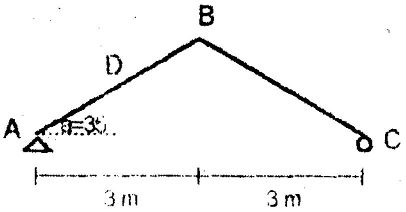
Ø penggantung perlu = $\sqrt{\frac{4.A}{\pi}} + 0,3$

$= \sqrt{\frac{4.0,5}{\pi}} + 0,3 = 1,1$ cm

Ø min = $\frac{L}{500} = \frac{235}{500} = 0,5$ cm , pakai Ø 12 mm

2.2.2. Perencanaan balok kuda-kuda tengah A1

☐ Desain dan perencanaan



Perletakan A = sendi, B = jepit, dan C = rol

Bentang kuda-kuda = 6 m

Panjang balok = $\frac{3}{\cos 35} = 3,66$ m

Coba profil Light Beam 10x4x17

A = 32,1 cm^2 q = 25,3 kg/m'

h = 25,7 cm b = 10,2 cm r = 0,762 cm

tb = 0,61 cm ts = 0,836 cm

Ix = 3405 cm^4 Iy = 143,6 cm^4

Wx = 265,5 cm^3 Wy = 28,19 cm^3

☐ **Beban yang bekerja**

- **Beban vertikal**

  - Beban gording = q. L

  - Beban P

  - Beban angin = q angin. L. cosα

- **Beban horisontal**

  - Beban angin = q angin. L. sinα

1. Beban tetap

Pv = q. L + P = 80. 6 + 100 = 580 kg

2. Beban sementara

P1v = q. L + q angin tekan. L. cosα = 80. 6 + 11. 6. cos35 = 534,06 kg
P2v = q. L + q angin hisap. L. cosα = 80. 6 - 15. 6. cos35 = 406,28 kg
P1h = q angin tekan. L. sinα = 11. 6. sin35 = 37,86 kg
P2h = q angin hisap. L. sinα = 15. 6. sin35 = 51,62 kg

Dimana : P1v = beban gording arah vertikal di pihak angin tekan

P1h = beban gording arah horisontal di pihak angin tekan

P2v = beban gording arah vertikal di pihak angin hisap

P2h = beban gording arah horisontal di pihak angin hisap

☐ **Analisa struktur**

1. Beban tetap

Rav = 4. Pv + q. Lbatang

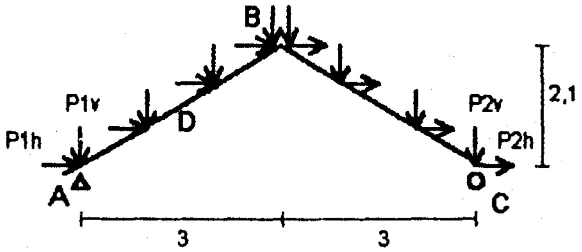
= 4. 580 + 25,3. 3,66 = 2413 kg

$$Mb = Rav.\ l - Pv.\ l - Pv.\ \frac{2}{3}\ l - Pv.\ \frac{1}{3} l - q.\ Lbatang.\ \frac{l}{2}$$

$$= 2413.\ 3 - 580.\ 3 - 580.\ \frac{2}{3}.\ 3 - 580.\ \frac{1}{3}.\ 3 - 25{,}3.\ 3{,}66.\ \frac{3}{2} = 3620 \text{ kgm}$$

2. Beban sementara

Atap kiri angin tekan, dan atap kanan angin hisap



sket Beban Angin Tekan dan Hisap di Kuda-Kuda A1

$\Sigma Mc = 0$

$Rav.\ L - P1v.\ L - P1v.\ \frac{5}{6}L + P1h.\ \frac{1}{3}t - P1v.\ \frac{4}{6}L + P1h.\ \frac{2}{3}t - P1v.\ \frac{3}{6}L + P1h.\ t - P2v.\frac{3}{6}L$
$+ P2h.\ t - P2v.\ \frac{2}{6}L + P2h.\ \frac{2}{3}t - P2v.\ \frac{1}{6}L + P2h.\ \frac{1}{3}t - q.\ (2.\ Lbatang).\ \frac{L}{2} = 0$

$Rav.\ 6 - 534{,}06.\ 6 - 534{,}06.\ \frac{5}{6}.6 + 37{,}86.\ \frac{1}{3}.2{,}1 - 534{,}06.\ \frac{4}{6}.6 + 37{,}86.\ \frac{2}{3}.2{,}1 - 534{,}06.$
$\frac{3}{6}.6 + 37{,}86.\ 2{,}1 - 406{,}28.\ \frac{3}{6}.6 + 51{,}62.\ 2{,}1 - 406{,}28.\ \frac{2}{6}.6 + 51{,}62.\ \frac{2}{3}.2{,}1 - 406{,}28.\ \frac{1}{6}.6$
$+ 51{,}62.\ \frac{1}{3}.2{,}1 - 25{,}3.\ (2.\ 3{,}66).\ \frac{6}{2} = 0$

Rav = 2438,43 kg

$\Sigma Rah = 0$

Rah = 4. P1h + 4. P2h = 4. 37,86 + 4. 51,62 = 357,91 kg

$\Sigma Ma = 0$

$Rbv.\ L - P2v.\ L - P2v.\ \frac{5}{6}L - P2h.\ \frac{1}{3}t - P2v.\ \frac{4}{6}L - P2h.\ \frac{2}{3}t - P2v.\ \frac{3}{6}L - P2h.\ t - P1v.\ \frac{3}{6}L$
$- P1h.\ t - P1v.\ \frac{2}{6}L - P1h.\ \frac{2}{3}t - P1v.\ \frac{1}{6}L - P1h.\ \frac{1}{3}t - q.\ (2.\ Lbatang).\ \frac{L}{2} = 0$

$Rbv.\ 6 - 406{,}28.\ 6 - 406{,}28.\ \frac{5}{6}.6 - 51{,}62.\ \frac{1}{3}.2{,}1 - 406{,}28.\ \frac{4}{6}.6 - 51{,}62.\ \frac{2}{3}.2{,}1 - 406{,}28.$
$\frac{3}{6}.6 - 51{,}62.\ 2{,}1 - 534{,}06.\ \frac{3}{6}.6 - 37{,}86.\ 2{,}1 - 534{,}06.\ \frac{2}{6}.6 - 37{,}86.\ \frac{2}{3}.2{,}1 - 534{,}06.\ \frac{1}{6}.6$
$- 37{,}86.\ \frac{1}{3}.2{,}1 - 25{,}3.\ (2.\ 3{,}66).\ \frac{6}{2} = 0$

Rbv = 2308,13 kg

- **Cek reaksi**

$\Sigma R\ tot = 0$

$Rav + Rbv - 4.\ P1v - 4.\ P2v - q.\ (2.\ Lbatang) = 0$

$2438{,}43 + 2308{,}13 - 4.\ 534{,}06 - 4.\ 406{,}28 - 25{,}3.\ (2.\ 3{,}66) = 0$ (OK)

$$Mb = Rbv.l + P2h.t - P2v.l + P2h.\frac{2}{3}t - P2v.\frac{2}{3}l + P2h.\frac{1}{3}t - P2v.\frac{1}{3}l - q.\ Lbatang.\ \frac{l}{2}$$

$$= 2308{,}13\ .3 + 51{,}62.\ 2{,}1 - 406{,}28.\ 3 + 51{,}62.\ \frac{2}{3}.2{,}1 - 406{,}28.\ \frac{2}{3}.3 + 51{,}62.\ \frac{1}{3}.2{,}1 -$$

$$406{,}28.\ \frac{1}{3}.3 - 25{,}3.\ 3{,}66.\ \frac{3}{2} = 3964{,}63\ kgm$$

☐ **Cek tegangan profil**

$\frac{h}{tb} < 75$

$\frac{25{,}7}{0{,}61} = 42{,}13 < 75$ (OK)

$\frac{L}{h} = 0$ (tanpa pengaku lateral)

Hitung dengan syarat profil berubah bentuk :

$\lambda = \frac{L}{iy'} = 0$, w = 1 (tabel 3 PPBBI)

$\bar{\sigma}$ kip = 1600 kg/cm^2

σ sisi terluar :

1. krn b. tetap $= \frac{Mx}{Wx} = \frac{3620.\ 100}{265{,}5} = 1364{,}4$ kg/cm^2 < 1600 kg/cm^2 (OK)
2. krn b. sementara $= \frac{3964{,}63.\ 100}{265{,}5} = 1493{,}27$ kg/cm^2 < (1,3. 1600) kg/cm^2 (OK)

☐ **Perhitungan sambungan**

Sambungan di B direncanakan dengan baut 8 Ø 19 mm, tampang satu.

$A = \frac{1}{4}\pi.\ 1{,}9^2 = 2{,}83\ cm^2$

$\bar{\sigma}$ tarik baut $= 0{,}7.\ \bar{\sigma}$

$= 0{,}7.\ 1600 = 1120$ kg/cm^2

$$Ti = \frac{M.\ di}{\sum di^2} \qquad \text{(gaya tarik yang diterima oleh baut Ti)}$$

$$\text{T1 satu baut} = \frac{396463.\ 32,4}{2\ (32,4^2 + 25,4^2 + 18,4^2)} = 3158,48 \text{ kg}$$

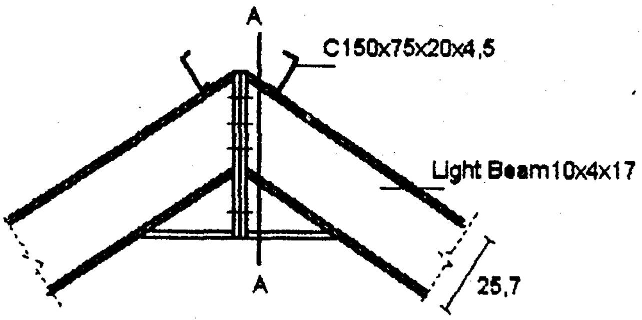
$$\sigma \text{ tarik T1} = \frac{T1}{A} = \frac{3158,48}{2,83} = 1114,55 \text{ kg/cm}^2 < 1120 \text{ kg/cm}^2 \qquad \text{(OK)}$$

$$\text{T2 satu baut} = \frac{396463.\ 25,4}{2\ (32,4^2 + 25,4^2 + 18,4^2)} = 2476,09 \text{ kg}$$

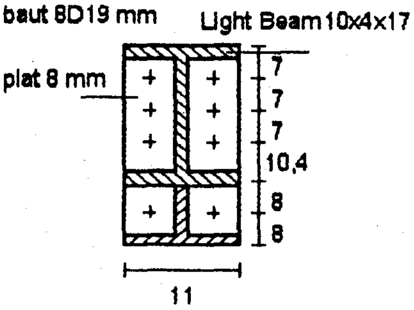
$$\sigma \text{ tarik T2} = \frac{2476,09}{2,83} = 873,76 \text{ kg/cm}^2$$

$$\text{T3 satu baut} = \frac{396463.\ 18,4}{2\ (32,4^2 + 25,4^2 + 18,4^2)} = 1793,71 \text{ kg}$$

$$\sigma \text{ tarik T3} = \frac{1793,71}{2,83} = 632,96 \text{ kg/cm}^2$$



sket Detail Sambungan B



sket Potongan A-A

☐ **Cek di sambungan B**

Cek geser baut :

$$\text{Ra resultan} = \sqrt{Rah^2 + Rav^2}$$
$$= \sqrt{357,91^2 + 2438,43^2} = 2464,56 \text{ kg}$$

$$\text{P resultan} = \sqrt{P1h^2 + P1v^2}$$
$$= \sqrt{37,86^2 + 534,06^2} = 635,19 \text{ kg}$$

D (gaya lintang) di B = Ra reslt - 4. P reslt kiri - q. Lbatang. cosα

= 2464,56 - 4. 635,19 - 25,3. 3,66. cos35 = -152,06 kg

D geser pada sambungan B = 152,06. cos35 = 124,56 kg

$\bar{\tau}$ baut $= 0{,}6.\ \bar{\sigma} = 0{,}6.\ 1600 = 960$ kg/cm^2

τ satu baut $= \dfrac{\text{D geser}}{\text{n. A}}$

$= \dfrac{124{,}56}{8.\ 2{,}83} = 5{,}5$ kg/cm^2 $\quad < 960$ kg/cm^2 $\qquad$ (OK)

Cek tegangan kombinasi :

Tegangan max pada baut T1 (krn beban sementara) :

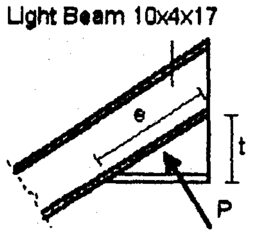
$$\sigma 1 = \sqrt{\sigma^2 + 1{,}56.\ \tau^2}$$

$$= \sqrt{1114{,}55^2 + 1{,}56.\ 5{,}5^2} = 1114{,}58 \text{ kg/cm}^2 < (1{,}3.\ 1600) \text{ kg/cm}^2 \quad \text{(OK)}$$

Cek tekuk badan :

Voute dianggap sebagai perletakan

Pada perletakan (voute) seolah-olah ada gaya P sebagai pengganti M.



sket Letak Gaya Perletakan P

Panjang perletakan e $= \dfrac{\text{t tinggi voute}}{\sin \alpha}$

$= \dfrac{16}{\sin 35} = 27{,}9$ cm

$P = \dfrac{M}{\frac{1}{2}.\ e} = \dfrac{396463}{\frac{1}{2}.\ 27{,}9} = 28425{,}2$ kg

$P < \text{tb}.\ (c' + d').\ \bar{\sigma}$ $\qquad$ (PPBBI Bab 6.4.1)

$28425{,}2 < 0{,}61.\ (27{,}9 + 1{,}598).\ 1600$

$28425{,}2 < 28790{,}1$ $\qquad$ (OK)

☐ **Syarat tebal plat**

$$\frac{bp}{tp} = \frac{24{,}03}{0{,}61} = 39{,}4 \quad < 60 \quad (OK)$$

Dari cek dan syarat diatas berarti tidak ada bahaya lipat, balok tidak perlu pengaku samping.

☐ **Perhitungan perletakan**

Ukuran plat :

A plat landasan = $\frac{Rv\ max}{\overline{\sigma c'}}$

mutu beton balok fc' = 30 MPa, atau $\sigma c' = 300\ kg/cm^2$

$\overline{\sigma c'} = \frac{\sigma c'}{\gamma p.\ \gamma m.\ \gamma s}$ (PBI 71 bab 10.4)

Angka-angka keamanan berdasar PBI 71 tabel 10.1 :

$\gamma p = 1{,}2$ (untuk gaya aksial tekan pembebanan tetap)

$\gamma m = \frac{1{,}4}{\phi} = 1{,}4$, dengan $\phi = 1$

$\gamma s = 1{,}5$

$\overline{\sigma c'} = \frac{300}{1{,}2.\ 1{,}4.\ 1{,}5} = 119\ kg/cm^2$

A perlu plat = $\frac{2438{,}43}{119} = 20{,}5\ cm^2$, pakai plat ukuran 26 x 15 cm

A terpasang = 26. 15 = 390 cm^2

Tebal plat landasan :

Plat ditumpu diatas tiga perletakan

σ plat = $\frac{Rv\ max}{A\ terpasang}$

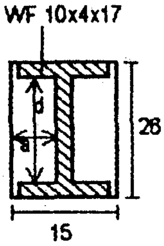
$= \frac{2438{,}43}{26.\ 15} = 6{,}3\ kg/cm^2$

q plat per 1 cm' = 6,3 kg/cm'

d (panjang sisi bebas plat) = 24,03 cm

$$a = \frac{b\ \text{plat} - \text{tb}}{2} = \frac{15 - 0{,}61}{2} = 7{,}2\ \text{cm}$$

$$\text{Rasio sisi plat } \frac{a}{d} = \frac{7{,}2}{24{,}03} = 0{,}3$$



$\alpha = 0{,}06$ (Konstruksi Baja Gudang tabel 8-11, Ir. Marwan)

$M = \alpha.\ q.\ d^2 = 0{,}06.\ 6{,}3.\ 24{,}03^2 = 219{,}5$ kgcm

$$\bar{\sigma}\ \text{plat} = \frac{M}{W\ \text{plat}}$$

$$t\ \text{plat} = \sqrt{\frac{6.\ M}{b.\ \bar{\sigma}\ \text{plat}}}$$

$$t\ \text{per 1 cm lebar} = \sqrt{\frac{6.\ 219{,}5}{1600}} = 0{,}91\ \text{cm}$$, pakai tebal plat 1 cm

Angker / baut jangkar :

Angker / baut jangkar dipasang untuk :

1. Menahan gaya geser horisontal akibat Rah,
2. Pemindahan gaya geser horisontal akibat gempa ke kolom/portal.

Rah = 357,91 kg

$$A\ \text{perlu} = \frac{\text{Rah}}{n.\ 0{,}6.\ \bar{\sigma}}$$, n (jumlah angker) = 2

$$A\ \text{perlu} = \frac{357{,}91}{2.\ 0{,}6.\ 1600} = 0{,}2\ \text{cm}^2$$

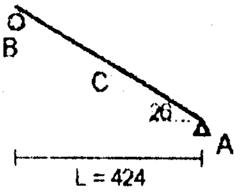
$$\varnothing\ \text{perlu} = \sqrt{\frac{0{,}2.\ 4}{\pi}} = 0{,}5\ \text{cm}$$

Pada Buku Pedoman Perenc. Str Beton Bertulang 1983 bab 6.12.2, ∅ min = 10 mm

Ld (panjang angker) = 20. ∅ = 20 cm (pakai Ld = 25 cm)

.3. Perencanaan balok kuda-kuda tepi A2

Desain dan Perencanaan



Perletakan A = sendi, dan B = rol

$\alpha = \text{arc tan}\,\dfrac{2,1}{4,24} = 26,36^0$, pakai $\alpha = 26^0$

$\text{Lbalok} = \dfrac{4,24}{\cos 26} = 4,73\ \text{m}$

Coba profil Light Beam 6x4x8,5

$A = 16,1\ \text{cm}^2$ $q = 12,65\ \text{kg/m}'$

$h = 14,8\ \text{cm}$ $b = 10\ \text{cm}$ $r = 0,635\ \text{cm}$

$tb = 0,432\ \text{cm}$ $ts = 0,493\ \text{cm}$

$Ix = 616\ \text{cm}^4$ $Iy = 78,66\ \text{cm}^4$

$Wx = 83,1\ \text{cm}^3$ $Wy = 15,73\ \text{cm}^3$

Beban yang bekerja

- **Beban vertikal**
  - Beban gording = q. Lbeban
  - Beban P
  - Beban angin = q angin. Lbeban. $\cos\alpha$
- **Beban horisontal**
  - Beban angin = q angin. Lbeban. $\sin\alpha$

dimana : Lbeban = panjang gording yang membebani balok

$= \dfrac{600}{2} + \dfrac{850}{4} = 512,5\ \text{cm}$, pakai Lbeban = 520 cm

1. Beban tetap

Pv = q. Lbeban + P = 80. 5,2 + 100 = 516 kg

2. Beban sementara

P1v = q. Lbeban + q angin tekan. Lbeban. cos35

= 80. 5,2 + 11. 5,2. cos35 = 462,86 kg

P1h = q angin tekan. Lbeban. sin35 = 11. 5,2. sin35 = 32,81 kg

P2v = q. Lbeban + q angin hisap. Lbeban. cos35

= 80. 5,2 - 15. 5,2. cos35 = 352,11 kg

P2h = q angin hisap. Lbeban. sin35 = 15. 5,2. sin35 = 44,74 kg

Analisa struktur

1. Beban tetap

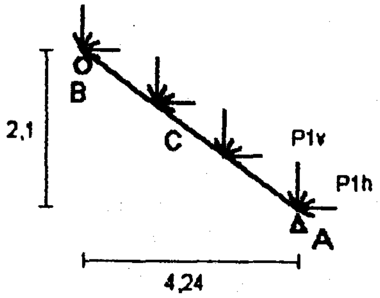
$$Rav = Rbv = 2.\ Pv + \frac{1}{2}.\ q.\ Lbatang = 2.\ 516 + \frac{1}{2}.\ 12,65.\ 4,73 = 1062\ kg$$

$$Mc = Rav.\ \frac{L}{2} - Pv.\ \frac{L}{2} - Pv.\ (\frac{1}{2} - \frac{1}{3}).\ L - q.\ \frac{Lbatang}{2}.\frac{L}{4}$$

$$= 1062.\ \frac{4,24}{2} - 516.\ \frac{4,24}{2} - 516.\ (\frac{1}{2} - \frac{1}{3}).\ 4,24 - 12,65.\ \frac{4,73}{2}.\frac{4,24}{4} = 762\ kgm$$

2. Beban sementara

2.1. Atap terkena angin tekan



sket Beban AnginTekan di Balok A2

$\Sigma Ma = 0$

Rbv. L - P1v. L - P1h. t - P1v. $\frac{2}{3}$L - P1h. $\frac{2}{3}$t - P1v. $\frac{1}{3}$L - P1h. $\frac{1}{3}$t - q. Lbatang. $\frac{L}{2}$= 0

Rbv. 4,24 - 462,86. 4,24 - 32,81. 2,1 - 462,86. $\frac{2}{3}$.4,24 - 32,81. $\frac{2}{3}$.2,1 - 462,86. $\frac{1}{3}$.4,24 - 32,81. $\frac{1}{3}$.2,1 - 12,65. 4,73. $\frac{4{,}24}{2}$ = 0

Rbv = 1186,8 kg

$\Sigma Rah = 0$

Rah = 4. P1h = 4. 32,81 = 131,23 kg

$\Sigma Mb = 0$

Rav. L + Rah. t - P1v. L - P1h. t - P1v. $\frac{2}{3}$.L - P1h. $\frac{2}{3}$.t - P1v. $\frac{1}{3}$.L - P1h. $\frac{1}{3}$.t - q. Lbatang. $\frac{L}{2}$ = 0

Rav. 4,24 + 131,23. 2,1 - 462,86. 4,24 - 32,81. 2,1 - 462,86. $\frac{2}{3}$.4,24 - 32,81. $\frac{2}{3}$.2,1 - 462,86. $\frac{1}{3}$.4,24 - 32,81. $\frac{1}{3}$.2,1 - 12,65. 4,73. $\frac{4{,}24}{2}$ = 0

Rav = 1121,8 kg

- **Cek reaksi**

  ΣR tot = 0

  Rav + Rbv - 4. P1v - q. Lbatang = 0

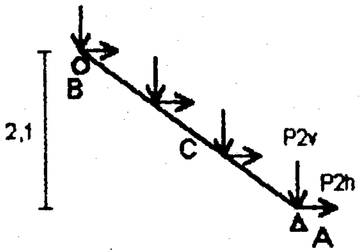
  1121,8 + 1186,8 - 4. 462,86 - 12,65. 4,73 = 0 (OK)

  Mc (di tengah bentang) :

  Mc = Rbv. $\frac{1}{2}$.L - P1v. $\frac{1}{2}$.L - P1h. $\frac{1}{2}$.t - P1v. $(\frac{1}{2}-\frac{1}{3})$.L - P1h. $(\frac{1}{2}-\frac{1}{3})$.t - q. $\frac{\text{Lbatang}}{2}$.

  = 1186,8. $\frac{1}{2}$.4,24 - 462,86. $\frac{1}{2}$.4,24 - 32,81. $\frac{1}{2}$.2,1 - 462,86. $(\frac{1}{2}-\frac{1}{3})$.4,24 - 32,81. $(\frac{1}{2}-\frac{1}{3})$. 2,1 - 12,65. $\frac{4{,}73}{2}$.$\frac{4{,}24}{4}$ = 848,3 kgm

2.2. Atap terkena angin hisap



sket Beban Angin Hisap di Balok A2

$\Sigma Ma = 0$

Rbv. L - P2v. L + P2h. t - P2v. $\frac{2}{3}$L + P2h. $\frac{2}{3}$t - P2v. $\frac{1}{3}$L + P2h. $\frac{1}{3}$t - q. Lbatang. $\frac{L}{2}$ = 0

Rbv. 4,24 - 352,11. 4,24 + 44,74. 2,1 - 352,11. $\frac{2}{3}$.4,24 + 44,74. $\frac{2}{3}$.2,1 - 352,11. $\frac{1}{3}$.

4,24 + 47,44. $\frac{1}{3}$.2,1 - 12,65. 4,73. $\frac{4,24}{2}$ = 0

Rbv = 888,75 kg

$\Sigma Rah = 0$

Rah = 4. P2h = 4. 44,74 = 178,96 kg

$\Sigma Mb = 0$

Rav. L - Rah. t - P2v. L + P2h. t - P2v. $\frac{2}{3}$.L + P2h. $\frac{2}{3}$.t - P2v. $\frac{1}{3}$.L + P2h. $\frac{1}{3}$.t - q. Lbatang. $\frac{L}{2}$ = 0

Rav. 4,24 - 178,96. 2,1 - 352,11. 4,24 + 44,74. 2,1 - 352,11. $\frac{2}{3}$.4,24 + 44,74. $\frac{2}{3}$.2,1 -

352,11. $\frac{1}{3}$.4,24 + 44,74. $\frac{1}{3}$.2,1 - 12,65. 4,73. $\frac{4,24}{2}$ = 0

Rav = 977,38 kg

- **Cek reaksi**

  ΣR tot = 0

  Rav + Rbv - 4. P2v - q. Lbatang = 0

  977,38 + 888,75 - 4. 352,11 - 12,65. 4,73 = 0

  $$Mc = Rbv. \frac{1}{2}.L - P2v. \frac{1}{2}.L + P2h. \frac{1}{2}.t - P2v. (\frac{1}{2} - \frac{1}{3}).L + P2h. (\frac{1}{2} - \frac{1}{3}).t - q. \frac{Lbatang}{2} \frac{L}{4}$$

  $$= 888,75. \frac{1}{2}.4,24 - 352,11. \frac{1}{2}.4,24 + 44,74. \frac{1}{2}.2,1 - 352,11. (\frac{1}{2} - \frac{1}{3}).4,24 + 44,74. (\frac{1}{2} - \frac{1}{3}).2,1 - 12,65. \frac{4,73}{2}.\frac{4,24}{4} = 637,86 \text{ kgm}$$

  Dari analisa struktur diatas reaksi yang menentukan :

Rav = 1121,8 kg	Rbv = 1186,8 kg
Rah = 178,96 kg	Mc = 848,3 kgm

☐ **Cek tegangan profil**

$\frac{h}{tb} < 75$

$\frac{14,8}{0,432} = 34,6 \quad < 75$ (OK)

$\frac{L}{h} = 0$ (tanpa pengaku lateral)

<u>Hitung dengan syarat profil berubah bentuk :</u>

$\lambda = \frac{L}{iy'} = 0$, w = 1

$\bar{\sigma}$ kip = 1600 kg/cm^2

σ sisi terluar :

1. krn b. tetap = $\frac{Mx}{Wx} = \frac{762.\ 100}{83,1} = 917$ kg/cm^2 < 1600 kg/cm^2 (OK)
2. krn b. sementara = $\frac{848,3.\ 100}{83,1} = 1020,8$ kg/cm^2 < (1,3. 1600) kg/cm^2 (OK)

☐ **Syarat tebal plat**

$$\frac{bp}{tp} = \frac{13{,}81}{0{,}43} = 32{,}13 \quad < 60 \quad (OK)$$

Dari cek dan syarat diatas berarti tidak ada bahaya lipat, balok tidak perlu pengaku samping

☐ **Perhitungan perletakan**

Ukuran plat :

$$A \text{ plat landasan} = \frac{R \text{ vert max}}{\overline{\sigma c'}}$$

$$\overline{\sigma c'} = \frac{\sigma c'}{\gamma p.\ \gamma m.\ \gamma s} = \frac{300}{1{,}2.\ 1{,}4.\ 1{,}5} = 119 \text{ kg/cm}^2$$

$$A \text{ perlu plat} = \frac{1186{,}8}{99} = 12 \text{ cm}^2 \qquad \text{, pakai plat ukuran } 15 \times 15 \text{ cm}$$

A terpasang = 15. 15 = 225 cm^2

Tebal plat landasan :

Plat ditumpu diatas tiga perletakan

$$\sigma \text{ plat} = \frac{R \text{ vert max}}{A \text{ terpasang}} = \frac{1186{,}8}{15.\ 15} = 5{,}3 \text{ kg/cm}^2$$

q plat per 1 cm' = 5,3 kg/cm'

d (panjang sisi bebas plat) = 13,81 cm

$$a = \frac{b \text{ plat} - tb}{2} = \frac{15 - 0{,}432}{2} = 7{,}2 \text{ cm}$$

$$\text{Rasio sisi plat } \frac{a}{d} = \frac{7{,}2}{13{,}81} = 0{,}5 \qquad , \alpha = 0{,}06$$

$$M = \alpha.\ q.\ d^2 = 0{,}06.\ 5{,}3.\ 13{,}81^2 = 60{,}65 \text{ kgcm}$$

$$\overline{\sigma} \text{ plat} = \frac{M}{W \text{ plat}}$$

$$t \text{ per 1 cm lebar} = \sqrt{\frac{6.\ 60{,}65}{1600}} = 0{,}48 \text{ cm} \qquad \text{, pakai tebal plat 5 mm}$$

Angker :

Angker hanya untuk menahan geser horisontal akibat Rah

Rah max = 178,96 kg

$$A\ perlu = \frac{Rah}{n.\ 0{,}6.\ \bar{\sigma}} \qquad ,\ n\ (\text{jumlah angker}) = 2$$

$$A\ perlu = \frac{178{,}96}{2.\ 0{,}6.\ 1600} = 0{,}1\ cm^2$$

$$\varnothing\ perlu = \sqrt{\frac{0{,}1.\ 4}{\pi}} = 0{,}4\ cm \quad ,\ \text{pakai}\ \varnothing\ \text{min} = 10\ mm$$

2.3. PERHITUNGAN ATAP B, C, D

2.3.1. Perhitungan gording B, C, D

Dapat dilihat pada tabel 2.3.a.

2.3.2. Perhitungan kuda-kuda tengah B

Dapat dilihat pada tabel 2.3.b.

2.3.3. Perhitungan kuda-kuda tepi C, D

Dapat dilihat pada tabel 2.3.c.

Gording	**Pilih profil**	**L. gording (cm)**	**L. pengg. gording (cm)**	**Bbn. tetap (kgm)**		**Teg. (kg/cm2)**		**Lendutan (cm)**		**Pengg. gording**	
				Mx	**My**	**terjadi**	**ijin kip**	**terjadi**	**ijin**	**T' (kg)**	**D (mm)**
B	C 150x75x20x4,5	500	165	307.18	39.28	867.86	1350.21	0.80	2.78	548.57	12
C	C 150x75x20x4,5	350		172.02	120.45	1480.51	1600	0.77	1.94		
D	C 150x75x20x4,5	350		153.21	107.28	1318.58	1600	0.68	1.94		

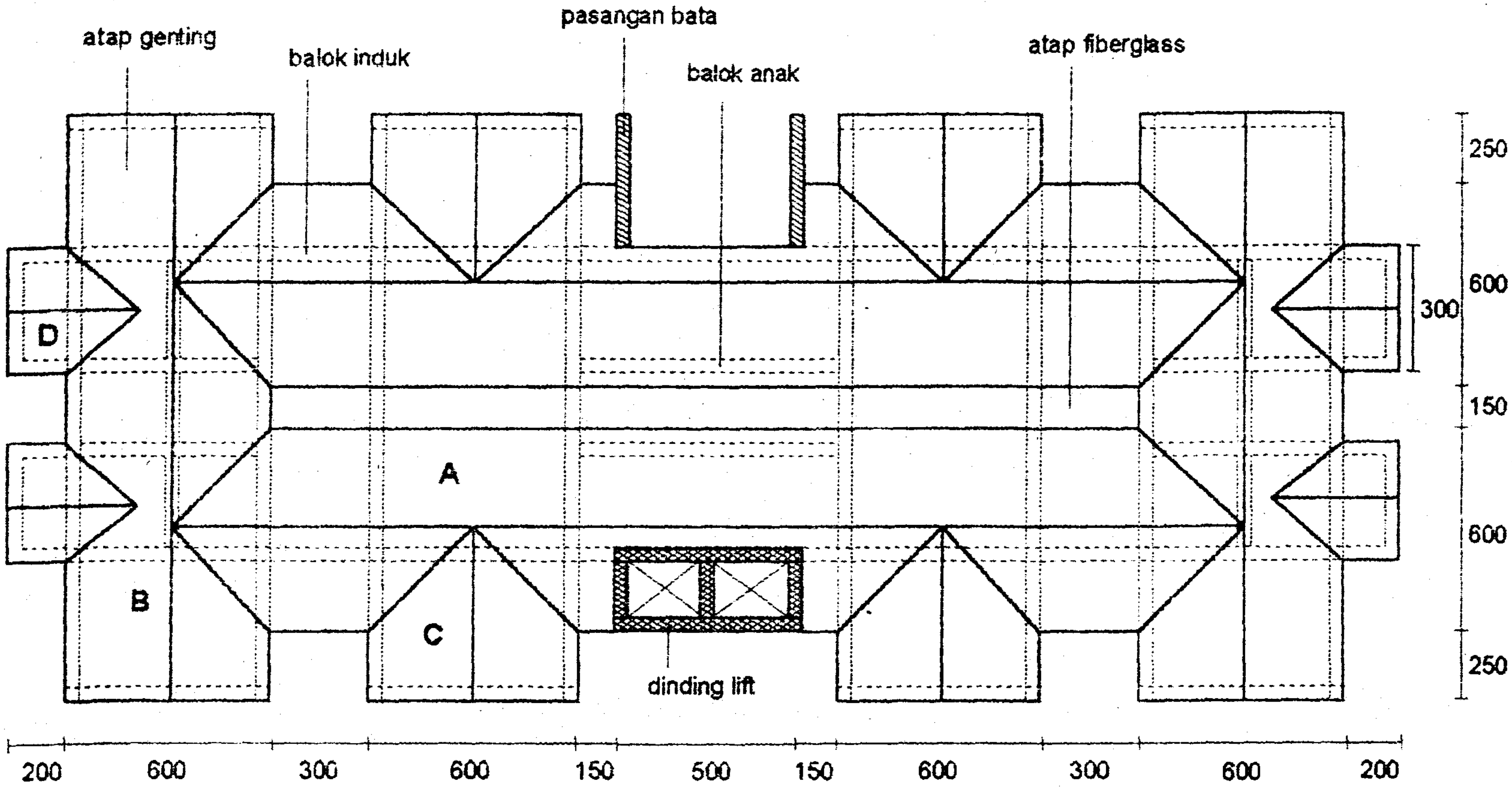
Tabel 2.3.a.

Kuda-kuda	Profil	L. balok (cm)	R max perlt. (kg)			M max (kgm)	Teg. (kg/cm2)		Cek tekuk badan di B		Baut (mm)	Teg.baut(kg/cm2)		Landasan (cm)	Angker(cm)	
			Rav	Rah	Rcv		terjadi	ijin kip	P	tb(c'+d')1600		tr max	tr ijin		D	Ld
tengah B	WF 10x4x15	366	1989.71	277.38	1888.73	3222.48	1424.62	1600	24644.52	25786.38	6D19	1034.36	1120	26x15x1	0.6	20
tengah C1	WF 10x4x15	366	1616.76	208.78	1540.75	2604.22	1151.29	1600	19916.21	25786.38	6D19	1046.58	1120	26x15x1	0.6	20

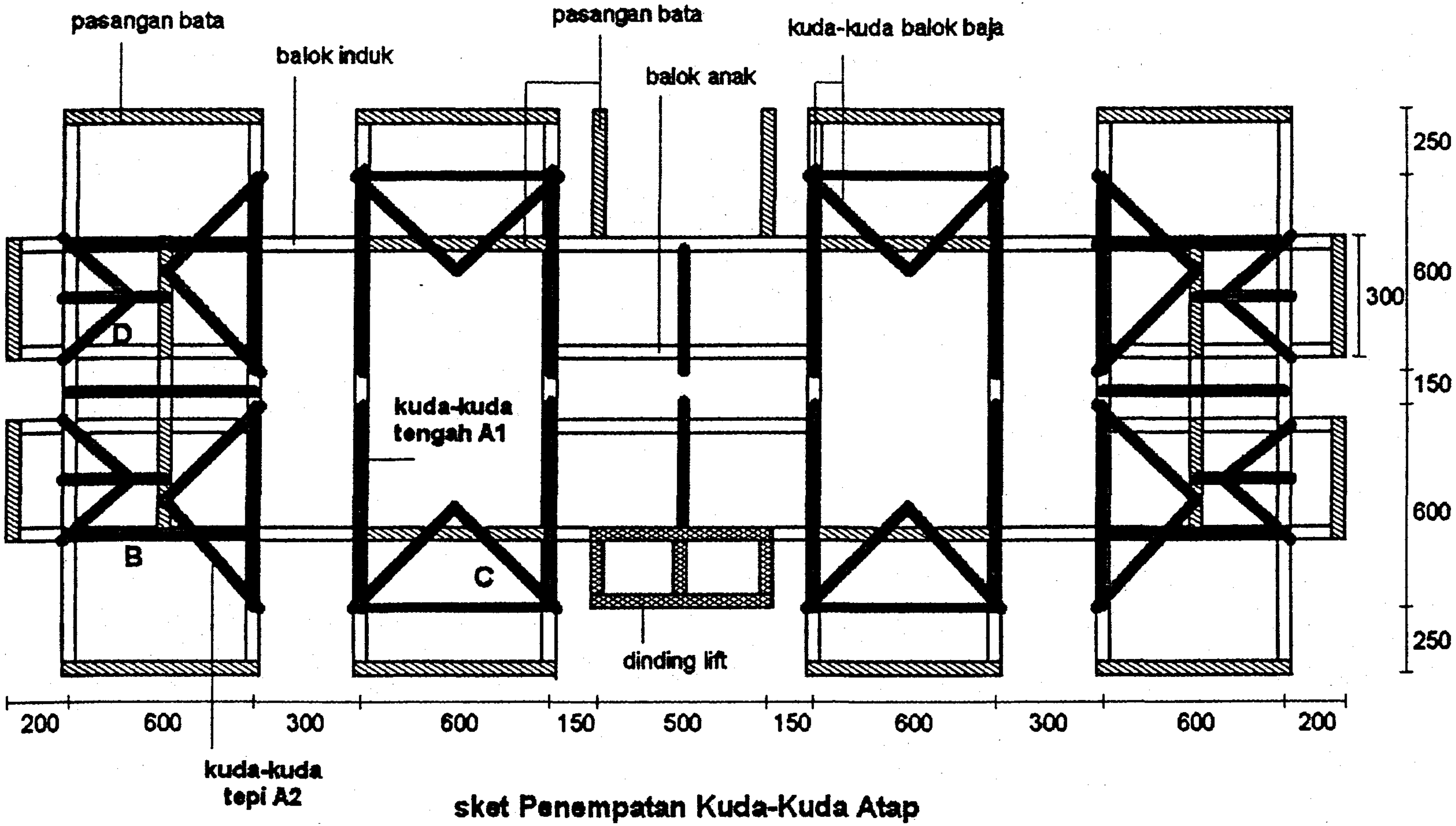
Tabel 2.3.b.

Kuda-kuda	Profil	L. balok (cm)	R max perlt. (kg)			M max (kgm)	Teg. (kg/cm2)		Landasan (cm)	Angker	
			Rav	Rah	Rbv		terjadi	ijin kip		D (mm)	Ld (cm)
tepi C2	WF 100x100x17,2	473	840.91	120.45	884.66	638.84	835.09	1600	15x15x5	6	20
tepi D	WF 100x50x9,3	185	418.01	47.32	448.13	113.11	301.62	1600	15x15x5	6	20

Tabel 2.3.c.



sket Tampak Atas Atap



sket Penempatan Kuda-Kuda Atap

BAB III

DESAIN PENDAHULUAN

3.1. DESKRIPSI

Dalam mendesain stuktur, terlebih dulu dilakukan desain pendahuluan elemen struktur. Desain pendahuluan ini dimaksudkan untuk mendapatkan dimensi awal, yang akan berguna sebagai :

☐ Tumpuan dalam perhitungan plat,

☐ Input data dimensi elemen balok pada saat analisa struktur,

☐ Sebagai kontrol dimensi balok dan dimensi elemen struktur yang lain, agar dapat diketahui apakah elemen tersebut telah mempunyai kekakuan dan kemampuan yang cukup saat menerima beban maksimum yang direncanakan.

3.2. PERHITUNGAN DAN ANALISA

☐ Dimensi awal

Dimensi awal balok ditentukan berdasar perumusan pada SKSNI tabel 3.2.5.(a).

☐ Gaya dalam

Analisa gaya dalam struktur utama dengan cara pendekatan pada PBI 71 bab 13.2. Analisa ini untuk mendapatkan dimensi awal balok yang akan berguna sebagai input data dan kontrol dimensi elemen struktur pada saat analisa struktur.

3.3. PEMBEBANAN

☐ Beban plat

Beban yang berasal dan bekerja pada plat adalah beban luasan segitiga (untuk sumbu pendek plat), dan beban luasan trapesium (untuk sumbu panjang plat). Beban luasan tersebut membebani balok sebagai beban q uniform ekivalen per satuan panjang balok.

Perhitungan beban luasan plat menjadi beban q merata per satuan panjang balok dengan menggunakan perumusan pada referensi Reinforced Concrete Design, Everard and Tanner sebagai berikut :

- q uniform ekivalen dari beban luasan trapesium (bentang panjang/long span) :

$$q = \frac{w.\ S}{3} . \frac{(3 - m^2)}{2} \qquad (N/m')$$

- q uniform ekivalen dari beban luasan segitiga (bentang pendek/short span) :

$$q = \frac{w.\ S}{3} \qquad (N/m')$$

dimana :

m = rasio antara bentang pendek dibagi bentang panjang pada plat dua arah

$= \frac{S}{L}$

S = panjang bentang pendek antara pusat tumpuan pada plat dua arah (m)

w = total beban uniform (N/m^2)

☐ **Analisa gaya beban**

Gaya dalam yang berasal dari struktur sekunder dan balok anak bekerja membebani balok induk berupa beban P terpusat, dan atau beban q terbagi rata.

3.4. LANGKAH DESAIN PENDAHULUAN

Berikut adalah langkah-langkah dalam menentukan dimensi awal balok :

- Ditentukan beban yang bekerja diatas balok. Beban tersebut antara lain :

  Beban mati :

  - Berat sendiri balok - dimensi balok telah ditentukan dengan analisa pada SKSNI tabel 3.2.5.(a),
  - Berat sendiri plat lantai - direncanakan t = 10 cm,
  - Berat elemen dan panel diatas plat, yaitu spesi, tegel, dll, menurut PPI 83.

  Beban hidup :

  - Beban orang

- Dilakukan analisa untuk didapatkan gaya dalam yang terjadi. Gaya dalam (momen balok) tersebut dicari dengan menggunakan perumusan pada PBI 71 bab 13.2. Analisa dengan memperhatikan sifat, dan keadaan tumpuan balok menurut yang kita rencanakan. Antara lain :

  a. Balok menumpu pada dua tumpuan, dan terjepit elastis pada dua tumpuan

  b.Balok menumpu pada tiga tumpuan, dan terjepit elastis pada tumpuan ujung, dll.

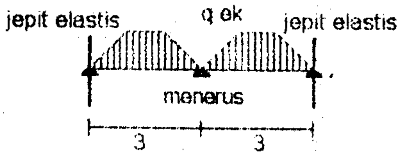
- Setelah didapatkan momen balok, kemudian dicek dengan rasio tulangan balok. Momen dan dimensi balok yang telah kita dapatkan harus mempunyai rasio tulangan (ρ perlu) berkisar antara ρ min dan ρ max. Demikian seterusnya dimensi balok kita rencanakan sehingga ρ perlu balok memenuhi.

3.5. DATA PERENCANAAN

- Mutu beton fc' 30 MPa,
- Mutu baja tulangan fy 320 MPa,
- Tebal selimut balok d' = 40 mm.

3.6. DIMENSI BALOK DI PORTAL A

3.6.1. Balok anak portal A (L = 3 m)



sket Beban pada Balok Anak (L = 3 m)

☐ **Pendahuluan dimensi balok**

Balok bentang L m terletak pada dua tumpuan :

$$h = \frac{L}{16} \cdot (0{,}4 + \frac{fy}{700}) \qquad \text{(SKSNI Tabel 3.2.5.a)}$$

$$= \frac{300}{16} \cdot (0{,}4 + \frac{320}{700}) = 16{,}1 \text{ cm} \qquad \text{, pakai } h = 25 \text{ cm}$$

$$b \approx \frac{2}{3} \cdot h$$

$$\approx \frac{2}{3} \cdot 25 = 16{,}7 \text{ cm} \qquad \text{, pakai } b = 20 \text{ cm}$$

☐ **Beban yang bekerja**

Berdasar PPIUG 83, didapat beban yang bekerja dari plat lantai :

1. Beban luasan trapesium plat lantai

Beban mati :

- Berat sendiri plat = 0,12. 2400 = 288 kg/m^2
- Langit-langit/plafon = 11 kg/m^2
- Penggantung langit = 7 kg/m^2
- Penutup lantai ubin tebal 2 cm = 2. 24 = 48 kg/m^2
- Finishing lantai = 2. 21 = 42 kg/m^2
- Dinding tembok = 450 kg/m^2

--------------- +

q mati = 808 kg/m^2

Beban hidup :

- Beban orang di lantai dan balkon, q hidup = 300 kg/m^2

w = 1,2. q mati + 1,6. q hidup

= 1,2. 808 + 1,6. 300 = 1450 kg/m^2

q ekivalen plat :

$$m = \frac{S}{L} = \frac{2,5}{3} = 0,83$$

$$\text{q ek satu sisi} = \frac{w.\ S}{3} . \frac{(3 - m^2)}{2}$$

$$= \frac{1450.\ 2,5}{3} . \frac{(3 - 0,83^2)}{2} = 1392,6\ \text{kg/m'}$$

2. Beban merata

- q bs (berat sendiri balok) = 150 kg/m'

q total = 2. q ek + 1,2. q bs

= 2. 1392,6 + 1,2. 150 = 2965,2 kg/m'

☐ **Momen balok**

Berdasar PBI 71 bab 13.2, dapat dicari momen balok dengan cara pendekatan :

- Balok terletak pada dua tumpuan, dan terjepit elastis di tumpuan

$$M\ \text{tumpuan} = -\frac{1}{16}.\ q.\ l^2 = -\frac{1}{16}.\ 2965{,}2.\ 3^2 = -1667{,}9\ \text{kgm}$$
$$M\ \text{lapangan} = \frac{1}{11}.\ q.\ l^2 = \frac{1}{11}.\ 2965{,}2.\ 3^2 = 2426{,}1\ \text{kgm}$$

☐ **Syarat tulangan**

$fc' = 30$ MPa , $\beta 1 = 0{,}85$ (SKSNI 3.3.2.7)

$$\rho\,\text{balance} = \frac{0{,}85.\ \beta 1.\ fc'}{fy} . \frac{600}{600 + fy} \quad \text{(SKSNI 3.1.4.3)}$$
$$= \frac{0{,}85.\ 0{,}85.\ 30}{320} . \frac{600}{600 + 320} = 0{,}0442$$

ρ max = 0,75. ρ balance = 0,75 . 0,0442 = 0,0331

Untuk mengontrol lendutan disyaratkan : ρ ada $\leq$ 0,5. ρ max

: ρ ada $\leq$ 0,0166

$$\rho\ \text{min} = \frac{1{,}4}{fy} = \frac{1{,}4}{320} = 0{,}00438$$

Syarat tulangan = 0,00438 $\leq \rho$ ada $\leq$ 0,0166

☐ **Cek ρ tulangan**

- Cek di tumpuan

M tump = -1667,9 kgm

$$Rn = \frac{Mu}{\Phi.\ b.\ d^2} = \frac{1667{,}9.\ 10000}{0{,}8.\ 200.\ (300 - 40)^2} = 2\ MPa$$

$$m = \frac{fy}{0{,}85.\ fc'} = \frac{320}{0{,}85.\ 30} = 12{,}55$$

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

$$= \frac{1}{12{,}55}\left(1 - \sqrt{1 - \frac{2.\ 12{,}55.\ 2}{320}}\right) = 0{,}007\ (OK)$$

- Cek di lapangan

M lap = 2426,1 kgm

$$Rn = \frac{2426{,}1.10000}{0{,}8.\ 200.\ (300 - 40)^2} = 3{,}79\ MPa$$

$$\rho\ perlu = \frac{1}{12{,}55}\left(1 - \sqrt{1 - \frac{2.\ 12{,}55.\ 3{,}79}{320}}\right) = 0{,}0098 \qquad (OK)$$

3.6.2. Balok anak portal A (L = 5 m)

☐ **Beban yang bekerja**

1. Beban luasan segitiga plat lantai

Beban mati = 808 kg/m^2

Beban hidup = 300 kg/m^2

$w = 1{,}2.\ q\ \text{mati} + 1{,}6.\ q\ \text{hidup} = 1{,}2.\ 808 + 1{,}6.\ 300 = 1450\ \text{kg/m}^2$

q ek plat :

$$q\ \text{ek satu sisi} = \frac{1450.\ 2{,}5}{3} = 1208\ \text{kg/m'}$$

2. Berat sendiri

Balok anak 30/40 (L = 5 m) :

$q\ \text{bs (berat sendiri balok)} = 2500.\ 0{,}55.\ 0{,}4 = 550\ \text{kg/m'}$

$q\ \text{total} = 2.\ q\ \text{ek} + 1{,}2.\ q\ \text{bs} = 2.\ 1208 + 1{,}2.\ 550 = 2776\ \text{kg/m'}$

3. Beban terpusat akibat tumpuan balok anak (L = 3 m)

Beban mati :

$q\ \text{mati} = 808\ \text{kg/m}^2$

Beban hidup :

$q\ \text{hidup} = 300\ \text{kg/m}^2$

$w = q\ \text{mati} + q\ \text{hidup} = 808 + 300 = 1108\ \text{kg/m}^2$

$$q\ \text{ek satu sisi} = \frac{1108.\ 2{,}5}{3}.\frac{(3 - 0{,}83^2)}{2} = 1064{,}4\ \text{kg/m'}$$

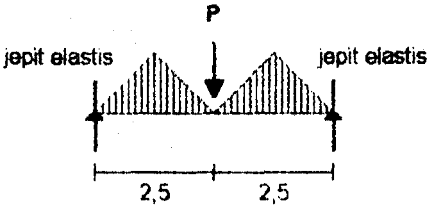
Berat sendiri balok anak 20/25 (L = 3 m) :

$q\ \text{bs} = 125\ \text{kg/m'}$

$q\ \text{total} = 2.\ q\ \text{ek} + q\ \text{bs} = 2.\ 1064{,}4 + 125 = 2253{,}8\ \text{kg/m'}$

$P = q\ \text{total}.\ \text{Lbeban}$

$= 2253{,}8.\ 3 = 6761\ \text{kg}$



sket Beban pada Balok Anak (L = 5 m)

☐ **Momen balok**

Berdasar PBI 71 bab 13.2, dapat dicari momen balok dengan cara pendekatan :

- **Balok terletak pada dua tumpuan, dan terjepit elastis di kedua tumpuan**

$$M\ q\ \text{tumpuan} = -\frac{1}{16} \cdot q.\ l^2$$
$$= -\frac{1}{16} \cdot 2776.\ 5^2 = -4338\ \text{kgm}$$
$$M\ q\ \text{lapangan} = \frac{1}{11} \cdot q.\ l^2$$
$$= \frac{1}{11} \cdot 2776.\ 5^2 = 6309\ \text{kgm}$$

- **Momen balok karena beban terpusat**

$$Mo = \frac{1}{4} \cdot P.\ L = \frac{1}{4} \cdot 6761.\ 5 = 8452\ \text{kgm}$$

dimana Mo = momen max dengan anggapan balok terletak bebas di dua tumpuan

$$M\ P\ \text{tumpuan} = -\frac{1}{2} \cdot Mo$$
$$= -\frac{1}{2} \cdot 8452 = -4226\ \text{kgm}$$
$$M\ P\ \text{lapangan} = \frac{4}{5} \cdot Mo$$
$$= \frac{4}{5} \cdot 8452 = 6761\ \text{kgm}$$

ΣM tump = M q tump + M P tump = -4338 - 4226 = -8564 kgm
ΣM lap = M q lap + M P lap = 6309 + 6761 = 13070 kgm

☐ **Cek ρ tulangan**

- Cek di tumpuan

M tump = -8564 kgm

$$Rn = \frac{8564.\ 10000}{0{,}8.\ 300.\ (400-40)^2} = 2{,}1 \text{ MPa}$$

$$\rho \text{ perlu} = \frac{1}{12{,}55}\left(1-\sqrt{1-\frac{2.\ 12{,}55.\ 2{,}1}{320}}\right) = 0{,}007 \text{(OK)}$$

- **Cek di lapangan**

M lap = 13070 kgm

$$Rn = \frac{13070.\ 10000}{0{,}8.\ 300.\ (400-40)^2} = 3{,}3 \text{ MPa}$$

$$\rho \text{ perlu} = \frac{1}{12{,}55}\left(1-\sqrt{1-\frac{2.\ 12{,}55.\ 3{,}3}{320}}\right) = 0{,}011 \qquad \text{(OK)}$$

3.6.3. Balok induk portal A (L = 5 m)

$h = \frac{500}{16}\ (0{,}4 + \frac{320}{700}) = 26{,}8$ cm , pakai h = 55 cm

$b = \frac{2}{3}.\ 55 = 36{,}6$ cm , pakai b = 40 cm

☐ **Beban yang bekerja**

1. Beban luasan trapesium atau segitiga plat

q mati = 808 kg/m^2

q hidup = 300 kg/m^2

w = 1,2. q mati + 1,6. q hidup = 1,2. 808 + 1,6. 300 = 1450 kg/m^2

$$q \text{ ek plat satu sisi} = \frac{1450.\ 2{,}5}{3} = 1208 \text{ kg/m'}$$

2. Berat sendiri

q bs balok induk 40/55 (L = 5 m)= 550 kg/m'

q total = 2. q ek + 1,2. q bs = 2. 1208 + 1,2. 550 = 3026,6 kg/m'

3. Beban terpusat akibat tumpuan balok konsol (L = 2 m)

w = 808 + 300 = 1108 kg/m^2

q ek satu sisi = $\frac{1108.\ 2}{3}$ = 738,7 kg/m'

q bs balok konsol 20/25 (L = 2 m) = 0,25. 0,2. 2500 = 125 kg/m'

q total = 2. 738,7 + 125 = 1605 kg/m'

4. Beban terpusat akibat tumpuan balok anak (L = 3 m)

w = 808 + 300 = 1108 kg/m^2

q ek plat satu sisi = $\frac{1108.\ 2,5}{3}.\frac{(3 - 0,83^2)}{2}$ = 1064,4 kg/m'

q total = 2. q ek + q bs = 2. 1064,4 + 125 = 2235 kg/m'

q total dari point 3 dan 4 menjadi beban terpusat :

ΣP = Σ(q total. Lbeban)

= (1605. 2) + (2235. 1,5) = 6519,7 kg

☐ **Momen balok**

- **Balok terletak pada dua tumpuan, dan terjepit elastis di tumpuan**

M q tumpuan = $-\frac{1}{16}$. q. l^2 = $-\frac{1}{16}$. 3026,6. 5^2 = -4729 kgm

M q lapangan = $\frac{1}{11}$. q. l^2 = $\frac{1}{11}$. 3026,6. 5^2 = 6878,4 kgm

- **Balok dibebani beban terpusat**

$$Mo = \frac{1}{4} . 6519,7. 5 = 8150 \text{ kgm}$$

$$M\,P \text{ tumpuan } = -\frac{1}{2} . Mo = -\frac{1}{2} . 8150 = -4074,8 \text{ kgm}$$

$$M\,P \text{ lapangan } = \frac{4}{5} . Mo = \frac{4}{5} . 8150 = 6520 \text{ kgm}$$

ΣM tump = -4729 - 4074,8 = 8803,8 kgm

ΣM lapangan = 6878,4 + 6520 = 13398,4 kgm

☐ **Cek ρ tulangan**

- Cek di tumpuan

M tump = -8803,8 kgm

$$Rn = \frac{88038000}{0,8. 400. (550 - 40)^2} = 1,14 \text{ MPa}$$

$$\rho \text{ perlu} = \frac{1}{12,55}\left(1 - \sqrt{1 - \frac{2. 12,55. 1,14}{320}}\right) = 0,00366 \text{ , pakai } \rho \min$$

- Cek di lapangan

M lap = 13398,4 kgm

$$Rn = \frac{133984000}{0,8. 400. (550 - 40)^2} = 1,7 \text{ MPa}$$

$$\rho \text{ perlu} = \frac{1}{12,55}\left(1 - \sqrt{1 - \frac{2. 12,55. 1,7}{320}}\right) = 0,0056 \qquad \text{(OK)}$$

3.6.4. Balok induk portal A (L = 6 m)

$h = \frac{600}{16} (0,4 + \frac{320}{700}) = 32,1$ cm , pakai h = 55 cm

$b = \frac{2}{3} . 55 = 36,7$ cm , pakai b = 40 cm

☐ **Beban yang bekerja**

1. Beban luasan trapesium atau segitiga plat lantai

q mati = 808 kg/m^2

q hidup = 300 kg/m^2

w = 1,2. 808 + 1,6. 300 = 1450 kg/m^2

q ek satu sisi = $\frac{1450. 3}{3}$ = 1450 kg/m'

q bs balok induk (L = 6 m) = 2500. 0,4. 0,55 = 550 kg/m'

q total = 2. 1450 + 1,2. 550 = 3510,5 kg/m'

2. Beban terpusat akibat tumpuan balok anak (L = 5 m)

w = 808 + 300 = 1108 kg/m^2

q ek satu sisi = $\frac{1108. 2,5}{3}$ = 923 kg/m'

q bs balok anak 40/30 (L = 5 m) = 300 kg/m'

q total = 2. 923 + 300 = 2186 kg/m'

3. Beban terpusat akibat tumpuan balok anak plat B (L = 3 m)

q bs balok anak plat B = 2500. 0,25. 0,2 = 125 kg/m'

w = 808 + 300 = 1108 kg/m^2

q satu sisi = $\frac{1108. 3}{3}$ = 1108 kg/m'

q total = 2. q + q bs = 2. 1108 + 125 = 2322 kg/m'

4. Beban terpusat dari balok anak (L = 3 m)

$P = \frac{1}{2}$. P balok anak

$= \frac{1}{2} . 6705{,}1 = 3352{,}6$ kg

dimana P balok anak = P akibat tumpuan pada point 3.6.2

q total dari point 2 dan 3 menjadi beban terpusat :

$\Sigma P = \Sigma(\text{q total. Lbeban}) + P$

$= (2186.\ 2{,}5) + (2322.\ 3) + 3352{,}6 = 12296{,}4$ kg

☐ **Momen balok**

- **Balok yang terletak pada dua tumpuan, dan terjepit elastis pada tumpuan**

  M q tumpuan $= -\frac{1}{16} .\ q.\ l^2 = -\frac{1}{16} .\ 3510{,}5.\ 6^2 = -7896{,}8$ kgm

  M q lapangan $= \frac{1}{11} .\ q.\ l^2 = \frac{1}{11} .\ 3510{,}5.\ 6^2 = 11486{,}3$ kgm

- **Momen balok karena beban terpusat**

  $Mo = \frac{1}{4} .\ 12296{,}4.\ 6 = 18444{,}5$ kgm

  M tumpuan $= -\frac{1}{2} .\ 18444{,}5 = -9222{,}3$ kgm

  M lapangan $= \frac{4}{5} .\ 18444{,}5 = 14755{,}6$ kgm

ΣM tump = M q tump + M P tump = -7896,8 - 9222,3 = -17119,1 kgm

ΣM lap = M q lap + M P lap = 11486,3 + 14755,6 = 26241,9 kgm

☐ **Cek ρ tulangan**

- Cek di tumpuan

  M tump = -17119,1 kgm

$$Rn = \frac{171191000}{0{,}8.\ 400.\ (550 - 40)^2} = 2{,}2 \text{ MPa}$$

$$\rho \text{ perlu} = \frac{1}{12{,}55}\left(1 - \sqrt{1 - \frac{2.\ 12{,}55.\ 2{,}2}{320}}\right) = 0{,}0073 \qquad \text{(OK)}$$

- **Cek di lapangan**

M lap = 26241,9 kgm

$$Rn = \frac{262419000}{0{,}8.\ 400.\ (550 - 40)^2} = 3{,}4 \text{ MPa}$$

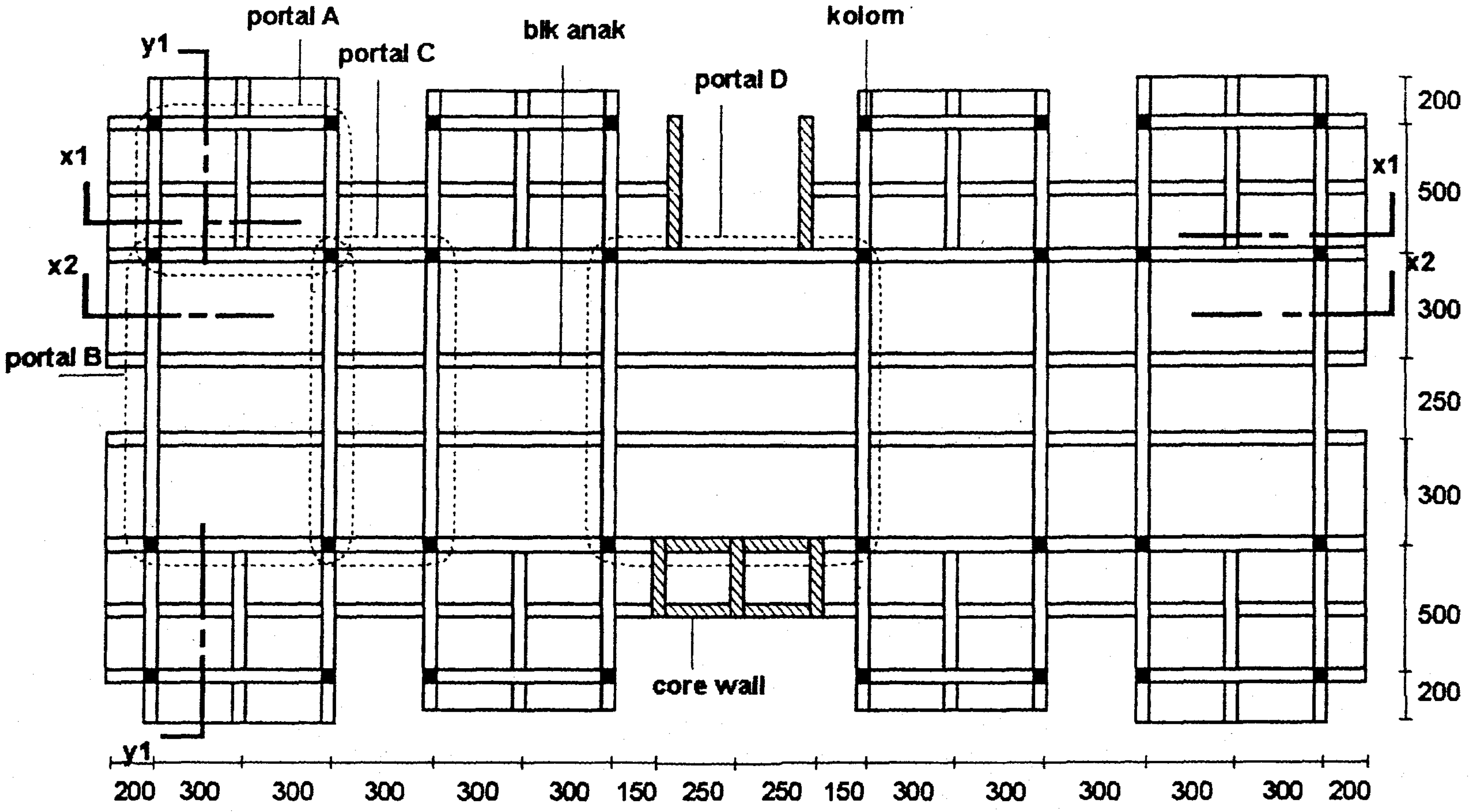
$$\rho \text{ perlu} = \frac{1}{12{,}55}\left(1 - \sqrt{1 - \frac{2.\ 12{,}55.\ 3{,}4}{320}}\right) = 0{,}0114 \qquad \text{(OK)}$$

3.7. DIMENSI BALOK DI PORTAL B, C, D

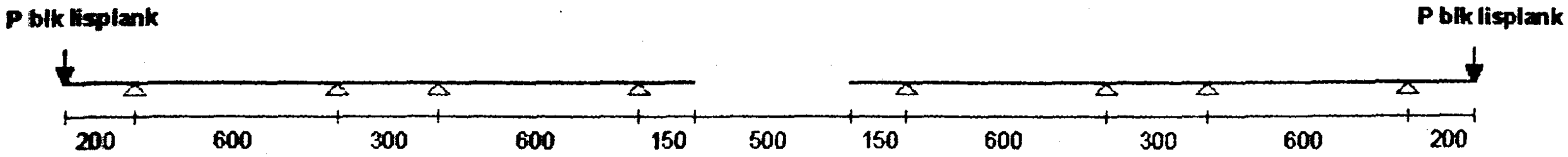
Perhitungan dimensi balok di portal B, C, dan D lihat tabel 3.7

Portal-Balok		L	b	h	q	PBI 71	Mu max q (Nm)		P max	Mu max P (Nm)		Mu tot (Nm)		ro perlu	
		(cm)	(cm)	(cm)	(N/m')	kasus bab	Tump.	Lap.	(N)	Tump.	Lap.	Tump.	Lap.	Tump.	Lap.
B	anak	600	30	50	41652	13.2.3.a	93717.00	136315.64	37573.33	28180.00	45088	121897.00	181403.64	9.58E-03	1.48E-02
B	induk	600	30	60	43302	13.2.3.a	97429.50	141715.64	76807.36	57605.52	92168.83	155035.02	233884.47	6.72E-03	1.04E-02
B	induk	850	40	80	47502	13.2.3.a	214501.22	312001.77	86341.67	129512.50	207220	344013.72	519221.77	6.05E-03	9.32E-03
C	konsol	150	25	30	30606	jepit penuh	34431.75	8607.94	20565.56	30848.33	15424.17	65280.08	24032.10	9.48E-03	4.59E-03
C	konsol	200	25	30	33638	jepit penuh	67276.00	16819.00	20565.56	41131.11	20565.56	108407.11	37384.56	1.29E-02	6.18E-03
C	anak	150	25	25	25758	13.2.3.b	5795.55	5795.55				5795.55	5795.55	2.61E-03	2.61E-03
C	anak	300	25	30	36670	13.2.3.a	20626.88	30002.73				20626.88	30002.73	6.20E-03	9.20E-03
C	lisplank	300	25	25	28958.44	13.2.3.c	32578.25	26062.60				32578.25	26062.60	1.60E-02	1.25E-02
C	lisplank	250	25	25	28365.52	13.2.3.e	17728.45	17728.45				17728.45	17728.45	8.28E-03	8.28E-03
C	induk	300	30	50	41652	13.2.3.a	23429.25	34078.91				23429.25	34078.91	1.75E-03	2.56E-03
D	anak	800	30	60	47281.5	13.2.3.a	189126.00	275092.36	37573.33	37573.33	60117.33	226699.33	335209.70	1.00E-02	1.54E-02
D	induk	800	30	60	47281.5	13.2.3.a	189126.00	275092.36	21990.00	21990.00	35184	211116.00	310276.36	9.31E-03	1.41E-02
D	induk	850	40	80	47502	13.2.3.a	214501.22	312001.77	168583.33	252875.00	404600	467376.22	716601.77	8.34E-03	1.32E-02

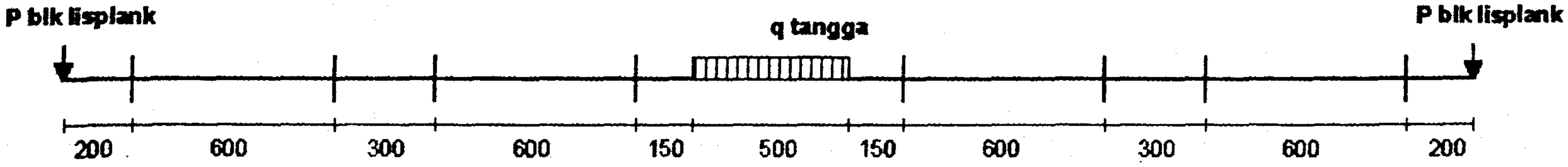
Tabel 3.7



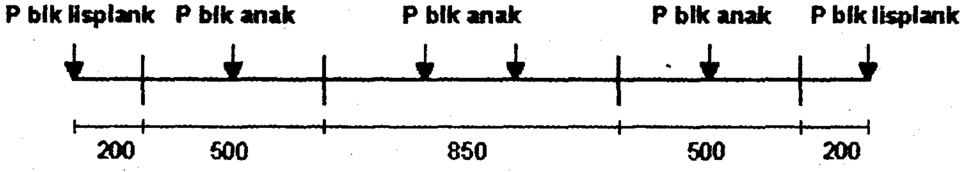
sket Denah Balok



pot. x1 - x1



pot. x2 - x2



pot. y1 - y1

ket :

△ = jepit elastis

┼──┼ = jepit

BAB IV

PERENCANAAN PLAT

4.1. DESAIN DAN PERENCANAAN

☐ **Perencanaan**

- Plat dan balok direncanakan sebagai satu kesatuan monolit,
- Tumpuan plat pada balok direncanakan sebagai jepit elastis, sehingga plat relatif dapat berotasi pada tumpuan saat menerima beban ekstrim,
- Plat direncanakan sebagai elemen *plate bending*, yaitu elemen yang hanya menerima beban dalam arah tegak lurus sumbu utama elemen.

☐ **Asumsi**

- Plat dianggap bersifat kaku di dua arah sumbu utama plat. Saat terjadi beban ekstrim plat dianggap bergerak lateral secara bersama atau bersifat *rigid body motion*, sehingga setiap titik dalam plat tidak terjadi relatif deformasi terhadap titik yang lain.

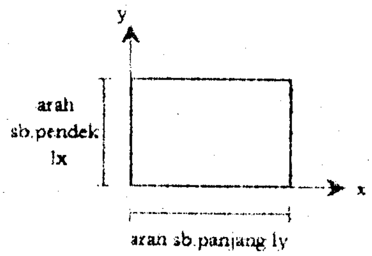
4.2. PEMBEBANAN

Beban yang bekerja pada plat terbagi dua macam yaitu :

- Beban luasan merata (N/m^2), yaitu beban akibat beban orang, berat sendiri plat, berat spesi, dll,
- Beban garis merata (N/m'), yaitu beban akibat berat dinding dan panel.

4.3. ANALISA DAN PERHITUNGAN

- Perhitungan gaya dalam momen plat akibat beban terbagi rata per luasan plat dengan menggunakan koefisien momen seperti yang terdapat dalam PBI 71 bab 13.3 tabel 13.3.2.,
- Perhitungan momen plat akibat beban garis terbagi rata dengan menggunakan referensi Analysis of Rectangulor Plates, Bares, tabel 1.110.b,
- Plat dianggap menerima beban garis merata pada kedua arah sumbu utama plat (sumbu x dan sumbu y),

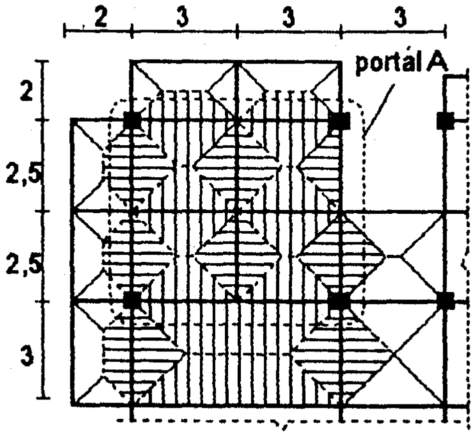


sket Sumbu Plat

- Momen total pada plat yaitu momen yang didapat akibat beban luasan plat ditambah dengan momen akibat beban garis. Momen tersebut diambil harga yang terbesar antara tumpuan dan lapangan plat. Hal ini agar lebih menyederhanakan perhitungan.

4.4. PERENCANAAN PLAT DI PORTAL A

4.4.1. Perhitungan tebal plat



sket Pembebanan Plat A di Balok Portal A

Plat menumpu diatas balok :

- Balok anak 20/25 (L = 3 m)
- Balok induk 40/55 (L = 5 m)
- Balok anak 30/40 (L = 5 m)
- Balok induk 40/55 (L = 6 m)

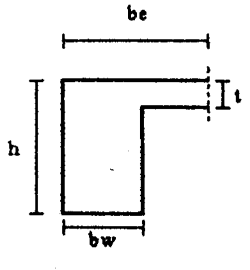
$$ln = 300 - (\frac{40}{2} + \frac{30}{2}) = 265 \text{ cm}$$

$$sn = 250 - (\frac{40}{2} + \frac{20}{2}) = 220 \text{ cm}$$

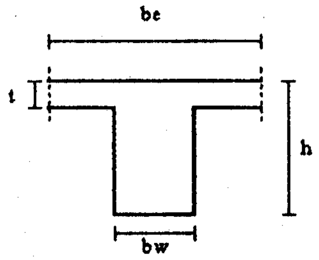
$$\beta = \frac{ln}{sn} = \frac{265}{220} = 1,2 \quad < 2$$ (tulangan dua arah)

Plat menerus di keempat sisi :

$$\beta s = \frac{300.\ 2 + 250.\ 2}{300.\ 2 + 250.\ 2} = 1$$



sket Plat di Balok Tepi



sket Plat di Balok Tengah

- **Plat di balok anak tengah 20/25 (L = 3 m)**

$$be1 = bw + 2.\ (h - t)$$

$$= 20 + 2.\ (25 - 12) = 46 \text{ cm}$$ (terkecil)

$$be2 = bw + 8.\ t$$

$$= 20 + 8.\ 12 = 116 \text{ cm}$$

$$K = \frac{1 + \left(\frac{be}{bw} - 1\right).\left(\frac{t}{h}\right).\left[4 - 6.\left(\frac{t}{h}\right) + 4.\left(\frac{t}{h}\right)^2 + \left(\frac{be}{bw} - 1\right)\left(\frac{t}{h}\right)^3\right]}{1 + \left(\frac{be}{bw} - 1\right).\left(\frac{t}{h}\right)}$$

$$K = \frac{1 + \left(\frac{46}{20} - 1\right).\left(\frac{12}{25}\right).\left[4 - 6.\left(\frac{12}{25}\right) + 4.\left(\frac{12}{25}\right)^2 + \left(\frac{46}{20} - 1\right).\left(\frac{12}{25}\right)^3\right]}{1 + \left(\frac{46}{20} - 1\right).\left(\frac{12}{25}\right)} = 1,5$$

$$Ib = K.\ bw.\ \frac{h^3}{12}$$

$$= 1{,}5.\ 20.\ \frac{25^3}{12} = 39088{,}5\ cm^4$$ (momen inersia balok)

$$Is = bs.\ \frac{t^3}{12}$$

$$= 250.\ \frac{12^3}{12} = 20833{,}3\ cm^4$$ (momen inersia plat)

$$\alpha 1 = \frac{Ib}{Is}$$

$$= \frac{39088{,}5}{20833{,}3} = 1{,}88$$

- **Plat di balok induk tengah 40/55 (L = 5 m)**

$be1 = 40 + 2.\ (55 - 12) = 126$ cm (terkecil)

$be2 = 40 + 8.\ 12 = 136$ cm

$K = 1{,}55$

$$Ib = 1{,}55.\ 40.\ \frac{55^3}{12} = 858250\ cm^4$$

$$Is = 250.\ \frac{12^3}{12} = 20833{,}3\ cm^4$$

$$\alpha 2 = \frac{858250}{20833{,}3} = 41{,}2$$

- **Plat di balok anak tengah 30/40 (L = 5 m)**

$be1 = 90$ cm (terkecil)

$be2 = 110$ cm

$K = 1{,}6$

$Ib = 255000\ cm^4$

$Is = 25000\ cm^4$

$\alpha 3 = 10{,}2$

- **Plat di balok induk tengah 40/55 (L = 6 m)**

be1 = 130 cm

be2 = 120 cm (terkecil)

K = 1,5

Ib = 858250 cm^4

Is = 22916,7 cm^4

$\alpha 4 = 37{,}5$

$$\alpha m = \frac{\alpha 1 + \alpha 2 + \alpha 3 + \alpha 4}{4}$$
$$= \frac{1{,}88 + 41{,}2 + 10{,}2 + 37{,}5}{4} = 22{,}7$$

☐ **Cek tebal plat**

Tebal plat lantai direncanakan 12 cm.

Cek tebal plat berdasar SKSNI bab 3.2.5.3.3 :

$$h\ min1 = \frac{\ln.\left(0{,}8 + \frac{fy}{1500}\right)}{36 + 5.\ \beta.\left[\alpha m - 0{,}12.\left(1 + \frac{1}{\beta}\right)\right]}$$
$$= \frac{2650.\left(0{,}8 + \frac{320}{1500}\right)}{36 + 5.\ 1{,}2.\left[22{,}7 - 0{,}12.\left(1 + \frac{1}{1{,}2}\right)\right]} = 15{,}7\ mm \quad (OK)$$

$$h\ min2 = \frac{\ln.\left(0{,}8 + \frac{fy}{1500}\right)}{36 + 9.\ \beta}$$
$$= \frac{2650.\left(0{,}8 + \frac{320}{1500}\right)}{36 + 9.\ 1{,}2} = 57{,}3\ mm \quad (OK)$$

h min3 = 90 mm , untuk $\alpha m \geq 2$ (OK)

4.4.2. Penulangan plat

☐ **Beban yang bekerja**

- **Beban mati :**

  - Berat sendiri plat = 0,12. 2400 = 288 kg/m^2
  - Langit-langit/plafon = 11 kg/m^2
  - Penggantung langit = 7 kg/m^2
  - Penutup lantai ubin tebal 2 cm = 2. 24 = 48 kg/m^2
  - Finishing lantai = 2. 21 = 42 kg/m^2

  --------------- +

  q mati = 468 kg/m^2

- **Beban hidup :**

  - Beban di lantai dan balkon q hidup = 300 kg/m^2

qu = 1,2. q mati + 1,6. q hidup

= 1,2. 468 + 1,6. 300 = 1041,6 kg/m^2 = 10416 N/m^2

☐ **Momen plat**

- **Momen akibat beban luasan plat**

Berdasar PBI 71 tabel 13.3.2 untuk kondisi plat terjepit elastis pada keempat sisi :

$$\frac{ly}{lx} = \frac{265}{220} = 1{,}2$$

Mlx = -Mtx = 0,001. q. lx^2 . X

= 0,001. 10416. 2,2^2. 46 = 2319 Nm

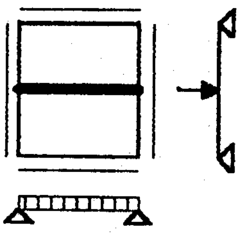
$Mly = -Mty = 0{,}001.\ q.\ lx^2 .\ X$

$= 0{,}001.\ 10416.\ 2{,}2^2.\ 38 = 1916$ Nm

- **Momen akibat beban garis merata**

Berat pasangan bata satu batu/beban garis n 5 kg/m'

q = 1,2. 1642,5. 10 = 19710 N/m'



sket Beban Garis pada Plat

Analisa momen dengan menggunakan tabel 1.110.b Bares :

$\gamma = \frac{a}{b} = \frac{265}{220} = 1{,}2$

Mx1 di lapangan = 0,098. q. a = 0,098. 19710. 2,65 = 5118,7 Nm

Mx5 di tumpuan = 0,008. q. a = 0,008. 19710. 2,65 = 419 Nm

My1 di lapangan = 0,084. q. b = 0,084. 19710. 2,2 = 3642,4 Nm

My5 di tumpuan = 0,021. q. b = 0,021. 19710. 2,2 = 911 Nm

Momen total plat diambil momen terbesar (lapangan) :

ΣMlx (momen arah sumbu pendek) = Mlx + Mx1

= 2319 + 5119 = 7438 Nm

ΣMly (momen arah sumbu panjang) = Mly + My1

= 1916 + 3643 = 5559 Nm

☐ **Syarat tulangan**

$$\rho \text{ balance} = \frac{0{,}85.\ \beta 1.\ fc'}{fy} \cdot \frac{600}{600 + fy} \qquad \text{(SKSNI 3.1.4.3)}$$

$$= \frac{0{,}85.\ 0{,}85.\ 30}{320} \cdot \frac{600}{600 + 320} = 0{,}0442$$

$\rho\,\text{max} = 0{,}75.\ \rho$ balance = 0,75. 0,0442 = 0,0331

Untuk mengontrol lendutan disyaratkan : ρ ada $\leq 0{,}5.\ \rho\,\text{max}$
: ρ ada $\leq$ 0,0166

$$\rho\,\text{min} = \frac{1{,}4}{fy} = \frac{1{,}4}{320} = 0{,}00438$$

Syarat tulangan = 0,00438 $\leq \rho$ ada $\leq$ 0,0166

- **Penulangan karena Mlx (sumbu pendek)**

Pakai tul. ∅ 10 mm, d' = 2 cm

Mlx = 7438 Nm

$$Rn = \frac{Mu}{\Phi.\ b.\ Dx^2} = \frac{7438.\ 1000}{0{,}8.\ 1000.\ (120 - 20 - 0{,}5.\ 10)^2} = 1 \text{ MPa}$$

$$m = \frac{fy}{0{,}85.\ fc'} = \frac{320}{0{,}85.\ 30} = 12{,}55$$

$$\rho \text{ perlu} = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.\ m.\ Rn}{fy}}\right)$$

$$= \frac{1}{12{,}55}\left(1 - \sqrt{1 - \frac{2.\ 12{,}55.\ 1}{320}}\right) = 0{,}0032, \text{ pakai } \rho\,\text{min}$$

As perlu = ρ perlu. b. Dx

= 0,00438. 1000. (120 - 20 - 0,5. 10) = 416,1 mm^2

Pakai tulangan D10 - 150 As = 471 mm^2 - tul. dipasang dibawah

- **Penulangan karena Mly (sumbu panjang)**

Mly = 5559 Nm

$$Rn = \frac{Mu}{\Phi.\ b.\ Dy^2} = \frac{5559.\ 1000}{0{,}8.\ 1000.\ (120 - 30 - 0{,}5.\ 10)^2} = 1 \text{ MPa}$$

$$\rho \text{ perlu} = \frac{1}{12{,}55}\left(1 - \sqrt{1 - \frac{2.\ 12{,}55.\ 1}{320}}\right) = 0{,}0032, \text{ pakai } \rho \min$$

As perlu = ρ perlu. b. Dy

$$= 0{,}00438.\ 1000.\ (120 - 30 - 0{,}5.\ 10) = 372{,}3 \text{ mm}^2$$

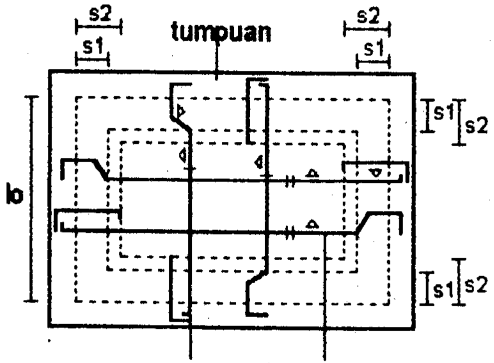
Pakai tulangan D10 - 200, As = 393 mm^2

☐ Pemasangan tulangan

- Tulangan karena Mlx dipasang di bawah atau lapis 1,

- Tulangan karena Mly dipasang di atas atau lapis 2.

Lihat sket/gambar :



sket Cara Penulangan Plat

- **Panjang penyaluran**

$S1 = 0{,}2.\ (lo + 2.\ \frac{1}{2}.\ 0{,}05)$

$= 0{,}2.\ (250 + 0{,}05) = 50$ cm

$S2 = 0{,}25.\ (lo + 2.\ \frac{1}{2}.\ 0{,}05)$

$= 0{,}25.\ (250 + 0{,}05) = 62{,}5$ cm , pakai 65 cm

dimana : S1 = panjang penyaluran untuk tulangan menerus,

S2 = panjang penyaluran untuk tulangan tidak menerus/terputus,

lo = panjang sumbu pendek.

4.5. PERENCANAAN PLAT B, C, D

4.5.1. Perhitungan tebal plat B, C, D dapat dilihat pada tabel 4.5.a.

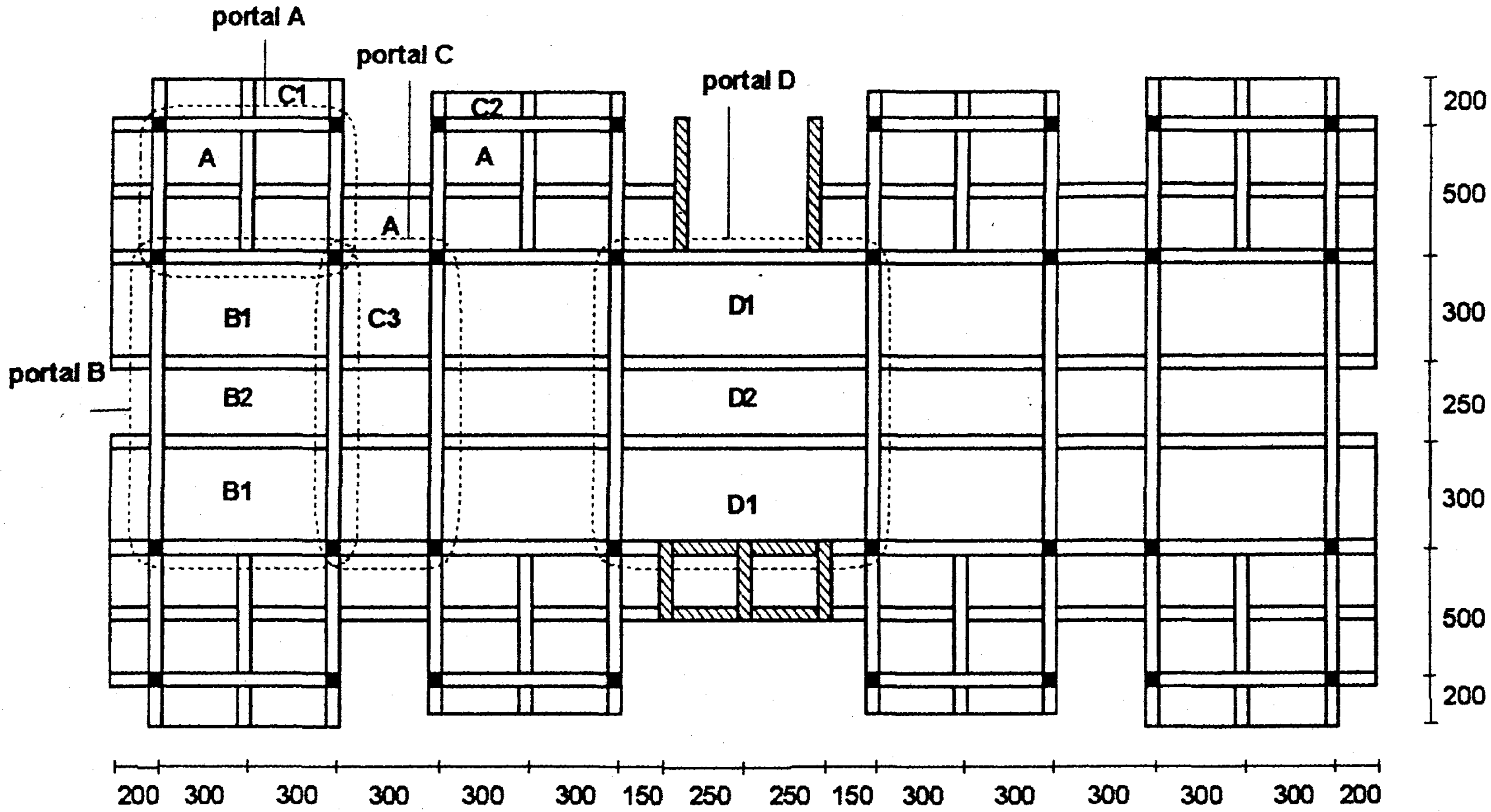
4.5.2. Penulangan plat B, C, D dapat dilihat pada tabel 4.5.b.

	(cm)	(cm)		(cm)	(cm)		(cm4)	(cm4)		1	2	3	plat (cm)
B1	600	300	induk 30/60 (L = 6m)	126	275	1.61	891686.52	39600	39.26	14.24	112.59	90	12
			anak 30/50 (L = 6 m)	126	275	1.61	891686.52	39600					
			induk 40/80 (L = 8,5 m)	151	400	1.46	3415882.02	57600					
			induk 40/80 (L = 8,5 m)	151	450	1.46	3415882.02	64800					
B2	600	250	anak 30/50 (L = 6 m)	126	275	1.61	891686.52	39600	41.46	11.44	105.56	90	12
			anak 30/50 (L = 6 m)	126	275	1.61	891686.52	39600					
			induk 40/80 (L = 8,5 m)	103	300	1.25	2942358.09	43200					
			induk 40/80 (L = 8,5 m)	151	450	1.46	3415882.02	64800					
C1	300	200	induk 30/60 (L = 6m)	126	225	1.61	891686.52	32400	11.41	25.32	61.41	90	12
			konsol 25/30 (L = 2 m)	58	150	1.35	215482.00	21600					
			konsol 25/30 (L = 2 m)	86	300	1.58	252494.77	43200					
			lisplank 25/25 (L = 3 m)	33	100	1.26	32937.29	14400					
C2	300	150	lisplank 25/25 (L = 3 m)	33	75	1.26	32937.29	10800	12.57	19.02	56.30	90	12
			konsol 25/30 (L = 1,5 m)	58	150	1.35	215482.00	21600					
			konsol 25/30 (L = 1,5 m)	86	300	1.58	252494.77	43200					
			induk 30/60 (L = 6 m)	126	200	1.63	904043.04	28800					
C3	300	300	induk 30/50 (L = 3m)	86	275	1.58	252955.88	39600	42.58	12.27	67.56	90	12
			anak 25/30 (L = 3m)	46	275	1.49	38831.69	39600					
			induk 40/80 (L = 8,5 m)	151	300	1.50	3519625.57	43200					
			induk 40/80 (L = 8,5 m)	151	300	1.50	3519625.57	43200					
D1	800	300	induk 30/60 (L = 8 m)	80	150	1.36	754404.76	42187.5	16.81	31.43	135.11	90	15
			induk 40/80 (L = 8,5 m)	175	700	1.59	3729690.86	196875					
			induk 40/80 (L = 8,5 m)	175	700	1.59	3729690.86	196875					
			anak 30/60 (L = 8 m)	120	275	1.60	887671.57	77343.75					
D2	800	250	anak 30/60 (L = 8 m)	120	275	1.60	887671.57	77343.75	15.21	29.28	125.10	90	15
			anak 30/60 (L = 8 m)	120	275	1.60	887671.57	77343.75					
			induk 40/80 (L = 8,5 m)	175	700	1.59	3729690.86	196875					
			induk 40/80 (L = 8,5 m)	175	700	1.59	3729690.86	196875					

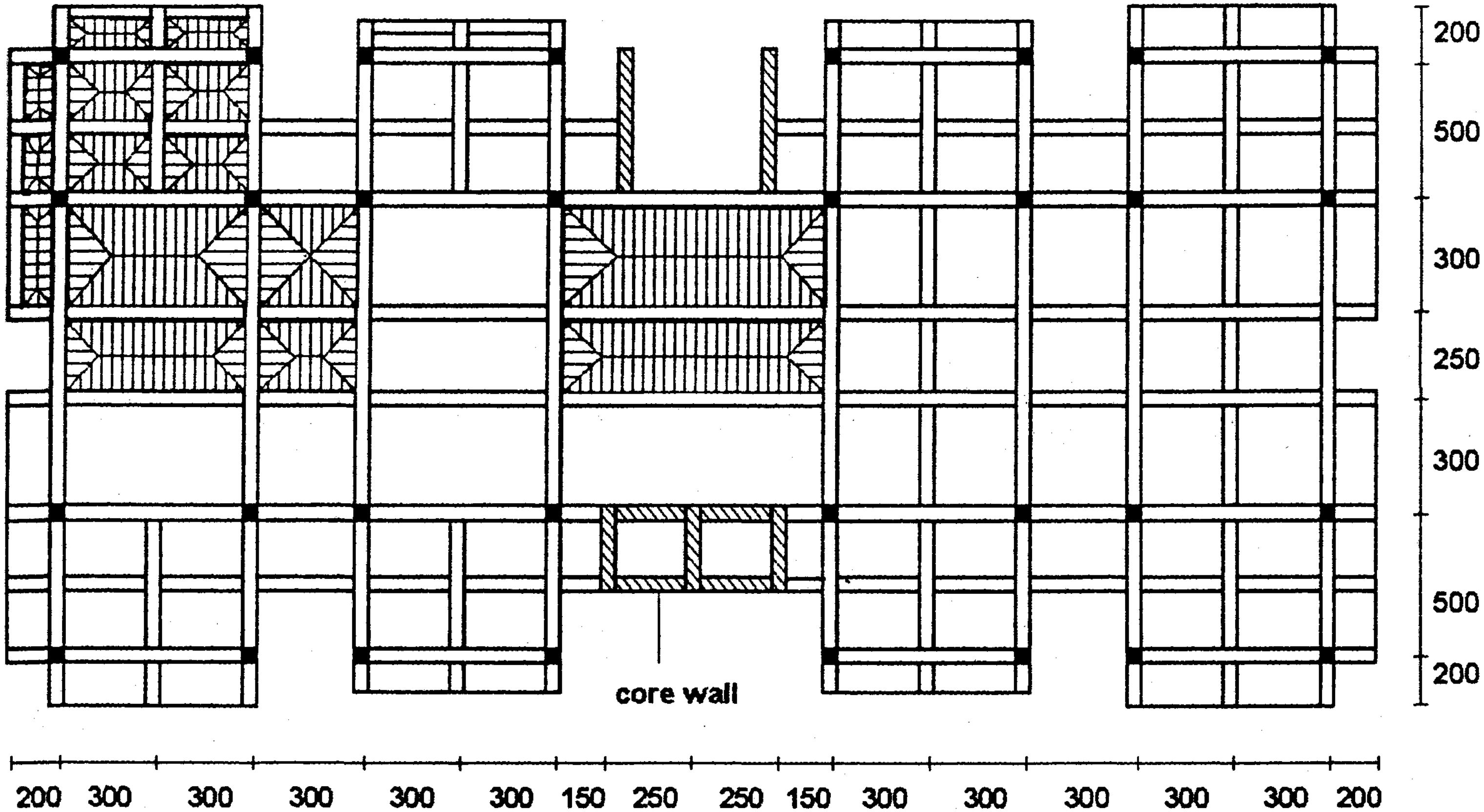
Tabel 4.5.a.

Plat	ln/sn	Mlx=-Mtx (Nm)	Mx1 (Nm)	Ro perlu	As perlu (mm2)	Pakai As (mm2)		Mly=-Mty (Nm)	My1 (Nm)	Ro perlu	As perlu (mm2)	Pakai As (mm2)		Penyaluran (cm)	
														S1	S2
B1	2	5812.13	7213.86	5.85E-03	556.03	628	D10-120	3281.04	5735.61	5.03E-03	427.88	471	D10-150	60	75
B2	2.4	4101.30	7213.86	5.06E-03	480.51	550	D10-140	2213.40	4779.68	4.38E-03	372.30	393	D10-200	50	65
C1	1.5	2333.18		4.38E-03	416.10	471	D10-150	1541.57		4.38E-03	372.30	393	D10-200	40	50
C2	2	1453.03		4.38E-03	416.10	471	D10-150	820.26		4.38E-03	372.30	393	D10-200	30	40
C3	1	3374.78		4.38E-03	416.10	471	D10-150	3374.78		4.38E-03	372.30	393	D10-200	60	75
D1	2.67	5905.87	9618.48	4.38E-03	547.50	550	D10-140	plat satu arah		2.00E-03	300.00	302	D8-150	60	75
D2	3.2	4101.30	9618.48	4.38E-03	547.50	550	D10-140	plat satu arah		2.00E-03	300.00	302	D8-150	50	65

Tabel 4.5.b.



sket Nomenklatur Plat



sket Analisa Beban pada Plat

BAB V

PERENCANAAN TANGGA

5.1. DESAIN DAN PERENCANAAN

- Tangga direncanakan sebagai unsur sekunder,
- Tumpuan tangga pada struktur utama bersifat membebani struktur utama (pada balok induk). Beban berupa beban terbagi rata (kN/m'),
- Perhitungan gaya dalam/momen di plat tangga dan bordes dengan menggunakan analisa program SAP 90,
- Pada plat bordes terdapat dilatasi. Dilatasi ini berfungsi agar antara struktur tangga yang satu (tangga naik) dengan yang lain (tangga turun) tidak saling mempengaruhi saat menerima beban ekstrim.

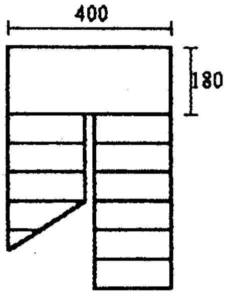
☐ **Tumpuan tangga**

Tumpuan plat menurut Buku Pedoman Perenc Struktur ..... 1983 bab 6.14.2 yaitu :

- Plat tangga menumpu pada balok induk sebagai tumpuan sendi,
- Plat bordes menumpu pada balok bordes sebagai tumpuan rol.

Perencanaan tumpuan ini agar apabila terjadi gempa atau beban lateral, pergoyangan tangga tidak terlalu berpengaruh terhadap struktur utama.

5.2. DATA PERENCANAAN



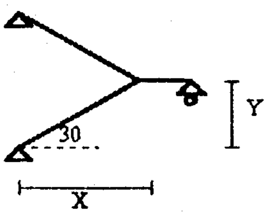
sket Tampak Atas Tangga

- Dari desain arsitektur telah ditentukan :
  - Lebar total tangga = 4 m
  - Panjang total tangga = 5 m
- Tebal plat direncanakan = 15 cm
- Tebal selimut d' = 2 cm
- Lebar tangga direncanakan = 180 cm
- Lebar bordes direncanakan = 180 cm

$$x = 500 - 180 = 320 \text{ cm}$$

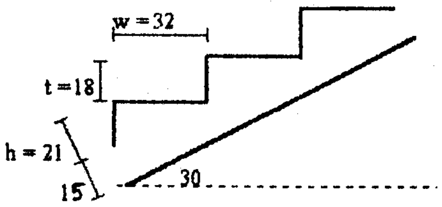
$$y = \frac{365}{2} = 182{,}5 \text{ cm}$$

$$\alpha = \text{arc tan}\frac{182{,}5}{320} = 30^{\circ}$$



sket Tampak Samping Tangga

- Jumlah anak tangga direncanakan = 10 buah
- Tinggi injakan $t = \frac{182{,}5}{10} = 18$ cm
- Lebar injakan $w = \frac{320}{10} = 32$ cm
- h anak tangga $= \frac{18}{\cos 30} = 21$ cm
- Untuk mempermudah perhitungan beban akibat anak tangga, h anak tangga dianggap ≈ $\frac{h}{2}$



sket plat tangga

5.3. PEMBEBANAN

Beban yang bekerja pada tangga adalah beban akibat beban hidup dan beban mati. Arah kerja beban adalah vertikal karena gaya gravitasi.

Berdasar PPIUG 83, didapat beban yang bekerja pada tangga :

1. Beban mati :

- Berat sendiri plat = 0,15. 2500 = 375 kg/m^2
- Berat anak tangga = $\frac{0,21}{2}$. 2500 = 262,5 kg/m^2
- Penutup lantai ubin tebal 2 cm = 2. 24 = 48 kg/m^2
- Finishing lantai = 2. 21 = 42 kg/m^2

--------------- +

q mati = 727,5 kg/m^2

2. Beban hidup :

- Beban hidup q = 300 kg/m^2

5.4. ANALISA STRUKTUR

- Plat tangga dan bordes dianggap sebagai frame dua dimensi dengan lebar per 1m' lebar plat, dan tebal 15 cm,
- Perhitungan beban yang bekerja pada plat adalah beban per 1m' lebar plat (kg/m'). Sehingga output gaya dalam yang dihasilkan juga dalam satuan gaya per 1m' lebar plat (kg/m'),
- Tumpuan plat tangga adalah sendi, dan plat bordes adalah rol.

5.5. PENULANGAN PLAT

$$\rho\ b = \frac{0{,}85.\ 0{,}85.\ 30}{320} . \frac{600}{600 + 320} = 0{,}0442$$
ρ max = 0,75. 0,0442 = 0,0331

Untuk mengontrol lendutan disyaratkan : ρ ada $\leq$ 0,5. ρ max
: ρ ada $\leq$ 0,0166

$$\rho\ \min = \frac{1{,}4}{320} = 0{,}00438$$
Syarat tulangan = 0,00438 $\leq \rho$ ada $\leq$ 0,0166

$$ly = \sqrt{320^2 + 182{,}5^2} = 368\text{ cm}$$

lx = 180 cm

$$\beta = \frac{ly}{lx} = \frac{368}{180} = 2 \qquad \geq 2 \qquad \text{(tulangan satu arah)}$$

- **Arah sumbu ly**

Berdasar analisa gaya dalam dengan program SAP 90 didapat :

Mu max = 3976,82 kgm

$$Rn = \frac{Mu}{\Phi.\ b.\ Dy^2} = \frac{39768{,}2.\ 1000}{0{,}8.\ 1000.\ (150 - 20 - 0{,}5.\ 16)^2} = 3{,}3\text{ MPa}$$

$$\rho\text{ perlu} = \frac{1}{12{,}55}.(1 - \sqrt{1 - \frac{2.\ 12{,}55.\ 3{,}3}{320}}) = 0{,}011 \qquad \text{(OK)}$$

As perlu = ρ perlu. b. Dy

= 0,011. 1000. (130 - 0,5. 16) = 1342 mm^2

Pakai tul. $\varnothing$ 16 - 140 mm, As = 1407 mm^2 - tulangan dipasang dibawah/lapis satu.

- **Arah sumbu lx**

Plat termasuk plat satu arah, jadi dipasang tulangan bagi/praktis.

ρ perlu = 0,002 (SKSNI bab 3.16.12)
As perlu = ρ perlu. A bruto

= 0,002. 1000. 150 = 300 mm^2

Pakai tul. D 10 - 250 mm, As = 314 mm^2 - tulangan lapis dua.

BAB VI

PERENCANAAN BALOK ANAK

6.1. DESAIN DAN PERENCANAAN

- Balok anak direncanakan sebagai unsur sekunder,
- Balok anak direncanakan hanya menerima beban akibat beban mati dan beban hidup. Arah kerja beban yaitu vertikal akibat gaya gravitasi,
- Gaya dalam/reaksi yang terjadi pada balok anak bersifat membebani struktur utama. Beban ini berupa beban terpusat, dan beban momen,
- Perencanaan balok anak berdasarkan pada persyaratan desain kekuatan batas atau *ultimate strength* pada SKSNI,
- Perencanaan balok anak meliputi penulangan lentur dan penulangan geser.

☐ **Mutu bahan**

Mutu beton fc' 30 MPa

Mutu baja tulangan fy 320 MPa

$Es = 2.\ 10^5$ MPa

6.2. ANALISA STRUKTUR

Untuk mencari gaya dalam yang terjadi pada balok anak dipakai program Etabs. *Running* analisa struktur untuk balok anak (sekunder) dilakukan secara bersama dengan struktur utama dalam satu lantai.

Asumsi perletakan pada ujung kolom bawah dan atas adalah jepit.

☐ **Dimensi balok**

Dimensi balok anak didapatkan dari analisa struktur balok anak. Analisa struktur ini dilakukan dengan beberapa kali *running*. Dari beberapa running tersebut kemudian dicari dimensi balok yang optimum, dan cukup memenuhi syarat penulangan elemen.

☐ **Beban**

- Beban merata (kN/m') dan terpusat (untuk balok anak atap, karena tumpuan kuda-kuda atap),
- Sifat beban adalah statis (akibat gaya gravitasi).

☐ **Perhitungan beban**

6.2.1. Di balok anak di portal A, L = 6 m

Beban mati :

Berat plat (pakai plat tertebal) = 0,15. 2400 = 360 kg/m^2

Penggantung langit + plafon = 18 kg/m^2

Finishing + tegel = 90 kg/m^2

Berat dinding tembok = 450 kg/m^2

-------------- +

q mati = 918 kg/m^2

$$\text{q mati ek} = \frac{w.\ S}{3} . \frac{(3 - m^2)}{2} \qquad \text{(balok } \textit{long span}\text{)}$$

$$= \frac{918.\ 2{,}5}{3} . \frac{(3 - 0{,}83^2)}{2} = 882\ \text{kg/m'}$$

q mati dua sisi = 2. 882 = 1764 kg/m' = 17,64 kN/m'

q hidup = 300 kg/m^2

$$\text{q hidup ek} = \frac{300.2{,}5}{3} . \frac{(3 - 0{,}83^2)}{2} = 288\ \text{kg/m'}$$

q hidup dua sisi = 2. 288 = 576 kg/m' = 5,76 kN/m'

6.2.2. Balok anak lain

Beban yang bekerja pada balok anak yang lain (lantai dan atap) dapat dilihat pada tabel 6.2.

6.3. PENULANGAN BALOK ANAK

Mencari d' yaitu jarak serat terluar tarik beton ke tulangan lentur tarik :

∅ sengkang direncanakan = 10 mm

decking selimut balok direncanakan = 40 mm

Untuk perencanaan pakai d' = 40 + 10 = 50 mm

- **Penulangan lentur balok di tumpuan.**

Perhitungan dengan cara penampang balok segiempat.

- **Penulangan lentur balok di lapangan**

Dicari posisi garis netral diagram tegangan (*block stress*) balok setelah diberi penulangan. Letak garis netral terbagi dua :

- x (garis netral tegangan balok) ≤ t (tebal plat lantai)

  Perhitungan balok dianggap "balok biasa" berpenampang persegi atau T palsu,
- x (garis netral tegangan balok) > t (tebal plat lantai)

  Perhitungan dengan persyaratan balok T.

Lebar balok di lapangan dengan menggunakan bE (b efektif). Untuk mencari bE balok digunakan syarat pada SKSNI pasal 3.1.10

☐ **Penulangan lentur**

Syarat tulangan : $0{,}00438 \leq \rho$ ada $\leq 0{,}0166$

(telah dihitung pada bab III Desain Pendahuluan)

☐ **Penulangan geser**

- Penulangan geser lentur , syarat-syarat penulangan sbb :

  Syarat jarak sengkang dan kategori geser :

  1. $Vu \leq 0{,}5.\ \Phi.\ Vc$ tidak perlu tulangan geser, pakai praktis
  2. $0{,}5.\ \Phi.\ Vc < Vu \leq \Phi.\ Vc$ perlu tul. geser minimum

     syarat : $Av = \frac{bw.\ S}{3.\ fy}$ (SKSNI 3.4.14)

     $S \leq \frac{d}{2} \leq 600$ mm (SKSNI 3.4.5.4)
  3. $\Phi.\ Vc < Vu \leq [\Phi.\ Vc + \min \Phi.\ Vs]$

     syarat seperti point 2 diatas
  4. $[\Phi.\ Vc + \min \Phi.\ Vs] < Vu \leq [\Phi.\ Vc + \Phi.\ \frac{1}{3}.\ \sqrt{fc'}.bw.\ d]$

     syarat : $\Phi.\ Vs = Vu - \Phi.\ Vc$

     pakai $Vs = \frac{Av.\ fy.\ d}{S}$ (SKSNI 3.4.17)

     $S \leq \frac{d}{2} \leq 600$ mm
  5. $[\Phi.\ Vc + \Phi.\sqrt{fc'}.bw.\ d.\frac{1}{3}] < Vu \leq [\Phi.\ Vc + \Phi.\sqrt{fc'}.bw.\ d.\ \frac{2}{3}]$

     syarat seperti point 4 diatas

     $S \leq \frac{d}{4} \leq 300$ mm

  dimana : $Vs\ min = \left(\frac{1}{3}Mpa\right).\ bw.\ d$

- Cek terhadap beban geser torsi berdasar SKSNI pasal 3.4.6

6.3.1. Penulangan balok anak portal A 25/40 (L = 6m)

- **Di tumpuan balok**

  Berdasar output pada file scndflor.frm, didapat gaya dalam balok :

  Mu = -92,6 kNm

  $$Mn\ perlu = \frac{Mu}{\Phi} = \frac{92{,}6}{0{,}8} = 115{,}8\ kNm = 115800\ Nm$$

  $$Rn = \frac{Mn}{b.\ d^2} = \frac{115{,}8.\ 1000000}{250.\ (400 - 50)^2} = 3\ MPa$$

$$\rho \text{ perlu} = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.\,m.\,Rn}{fy}}\right)$$

$$= \frac{1}{12{,}55}\left(1 - \sqrt{1 - \frac{2.\,12{,}55.\,3}{320}}\right) = 0{,}012 \qquad \text{(OK)}$$

As perlu = ρ perlu. b. d

= 0,012. 250 (400 - 50) = 1124 mm^2

(Pakai tul. 4 D 19 mm, As = 1134 mm^2)

$$\delta = \frac{\rho'}{\rho} = \frac{\text{As tekan}}{\text{As tarik}} = 0{,}4$$

As' perlu = 0,4. As

= 0,4. 1124 = 449 mm^2

(Pakai tul. 2 D 19 mm, As' = 567 mm^2)

<u>Cek kelelehan tul. tekan :</u>

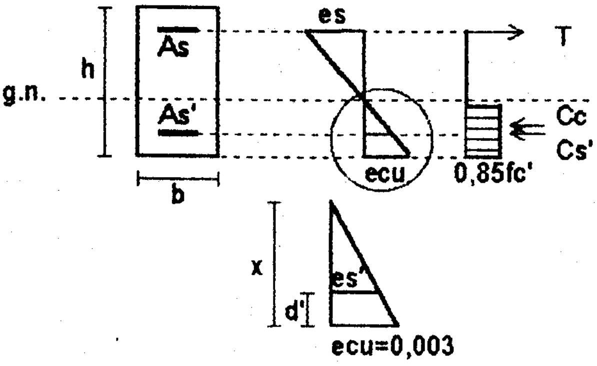
fy = 320 MPa = 320 N/mm^2

Es = 2. 10^6 kg/cm^2 = 2. 10^5 MPa

d' = 50 mm

εcu pada serat terluar = 0,003 (SKSNI 3.3.2)

Anggap tul. tekan belum leleh :



sket Diagram blok tegangan

$$\frac{\varepsilon cu}{\varepsilon s'} = \frac{x}{x\text{-}d'} \qquad , Es = \frac{fs'}{\varepsilon s'}$$

$$\frac{0{,}003}{\varepsilon s'} = \frac{x}{x\text{-}50}$$

$$0{,}003.\,(x - 50) = x.\,\varepsilon s' \qquad , \varepsilon s' = \frac{0{,}003.x - 0{,}15}{x}$$

$T = Cc + Cs$

$As.\ fy\ = 0{,}85.\ fc'.\ (x.\ \beta).\ b + (fs' - 0{,}85.\ fc').\ As'$

$1134.\ 320 = 0{,}85.30.\ (x.\ 0{,}85).\ 250 + (2.\ 10^5.\left(\frac{0{,}003.\ x - 0{,}15}{x}\right) - 0{,}85.30).\ 567$

Pers. diatas dikali x menjadi pers. kuadrat :

$5418{,}75.\ x^2 - 22680.\ x - 17010000 = 0$

Dengan rumus ABC didapat :

$x = 59{,}6$ mm

$a = x.\ \beta$ (SKSNI bab 3.3.2.7)

$= 59{,}6.\ 0{,}85 = 50{,}7$ mm

$\varepsilon s' = \frac{0{,}003.\ 59{,}6 - 0{,}15}{59{,}6} = 0{,}00048$

$fs' = \varepsilon s'.\ Es$

$= 0{,}00048.\ 200000 = 96{,}6$ MPa < 320 MPa (tul. tekan belum leleh)

$Cs = (fs' - 0{,}85.\ fc').\ As' = (96{,}6 - 0{,}85.\ 30).\ 567 = 40338{,}8$ N

$Cc = 0{,}85.\ fc'.\ a.\ b = 0{,}85.\ 30.\ 50{,}7.\ 250 = 322957{,}5$ N

Perhitungan Mn balok :

Mn terpasang $= Cc.\ (d - \frac{a}{2}) + Cs.\ (d - d')$

$= 322957{,}5.\ (350 - \frac{50{,}7}{2}) + 40338{,}8.\ (350 - 50)$

$= 116802$ Nm $>$ Mn perlu (OK)

- **Di lapangan balok**

Mu = 46,01 kNm

Mn perlu $= \frac{46{,}01}{0{,}8} = 57{,}51$ kNm $= 57510$ Nm

$Rn = \frac{57510.\ 1000}{250.\ (400 - 50)^2} = 1{,}8$ MPa

ρ perlu $= \frac{1}{12{,}55}\left(1 - \sqrt{1 - \frac{2.\ 12{,}55.\ 1{,}8}{320}}\right) = 0{,}0058$ (OK)

As perlu $= 0{,}0058.\ 250\ (400 - 50) = 534\ mm^2$

(Pakai tul. 2 D 19 mm, As = 567 mm^2)

As' $= 0{,}4.\ 534 = 214\ mm^2$ (Pakai tul. 2 D 19 mm, As' = 567 mm^2)

Lebar efektif penampang balok T : (SKSNI 3.1.10.2)

1. $bE < \frac{1}{4}. L$

$< \frac{1}{4}. 600 = 150$ cm (menentukan)

2. $bE < 16.t + bw$

$< 16. 12 + 25 = 217$ cm

3. $bE < 2. \frac{1}{2}. sn + bw$

$< 2. \frac{1}{2}. 220 + 25 = 245$ cm

Cek kelelehan tul. tekan :

Dengan cara yang sama seperti pada balok di tumpuan, anggap tul. tekan belum leleh

$$\frac{0,003}{\varepsilon s'} = \frac{x}{x - 50}$$

$T = Cc + Cs$

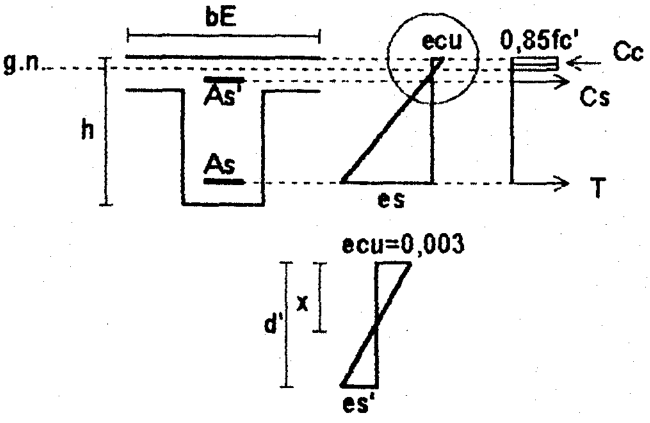
$As. fy = 0,85. fc'. a. bE + As'. (fs' - 0,85. fc')$

$567. 320 = 0,85. 30. (x. 0,85). 1500 + 567. (2. 10^5. (\frac{0,003.x - 0,15}{x}) - 0,85. 30)$

didapat x = 26,7 mm < d' (50 mm)

(garis netral berada diatas tulangan tekan)

cek lagi :



sket Diagram blok tegangan

BAB VI

PERENCANAAN BALOK ANAK

6.1. DESAIN DAN PERENCANAAN

- Balok anak direncanakan sebagai unsur sekunder,
- Balok anak direncanakan hanya menerima beban akibat beban mati dan beban hidup. Arah kerja beban yaitu vertikal akibat gaya gravitasi,
- Gaya dalam/reaksi yang terjadi pada balok anak bersifat membebani struktur utama. Beban ini berupa beban terpusat, dan beban momen,
- Perencanaan balok anak berdasarkan pada persyaratan desain kekuatan batas atau *ultimate strength* pada SKSNI,
- Perencanaan balok anak meliputi penulangan lentur dan penulangan geser.

☐ **Mutu bahan**

Mutu beton fc' 30 MPa

Mutu baja tulangan fy 320 MPa

Es = 2. 10^5 MPa

6.3. PENULANGAN BALOK ANAK

Mencari d' yaitu jarak serat terluar tarik beton ke tulangan lentur tarik :

∅ sengkang direncanakan = 10 mm
decking selimut balok direncanakan = 40 mm

Untuk perencanaan pakai d' = 40 + 10 = 50 mm

- **Penulangan lentur balok di tumpuan.**

Perhitungan dengan cara penampang balok segiempat.

- **Penulangan lentur balok di lapangan**

Dicari posisi garis netral diagram tegangan (*block stress*) balok setelah diberi penulangan. Letak garis netral terbagi dua :

- x (garis netral tegangan balok) ≤ t (tebal plat lantai)
  Perhitungan balok dianggap "balok biasa" berpenampang persegi atau T palsu,
- x (garis netral tegangan balok) > t (tebal plat lantai)
  Perhitungan dengan persyaratan balok T.

Lebar balok di lapangan dengan menggunakan bE (b efektif). Untuk mencari bE balok digunakan syarat pada SKSNI pasal 3.1.10

☐ **Penulangan lentur**

Syarat tulangan : 0,00438 ≤ ρ ada ≤ 0,0166
(telah dihitung pada bab III Desain Pendahuluan)

$$\rho \text{ perlu} = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2.\,m.\,Rn}{fy}}\right)$$

$$= \frac{1}{12{,}55}\left(1 - \sqrt{1 - \frac{2.\,12{,}55.\,3}{320}}\right) = 0{,}012 \qquad \text{(OK)}$$

As perlu = ρ perlu. b. d

= 0,012. 250 (400 - 50) = 1124 mm^2

(Pakai tul. 4 D 19 mm, As = 1134 mm^2)

$$\delta = \frac{\rho'}{\rho} = \frac{\text{As tekan}}{\text{As tarik}} = 0{,}4$$

As' perlu = 0,4. As

= 0,4. 1124 = 449 mm^2

(Pakai tul. 2 D 19 mm, As' = 567 mm^2)

<u>Cek kelelehan tul. tekan :</u>

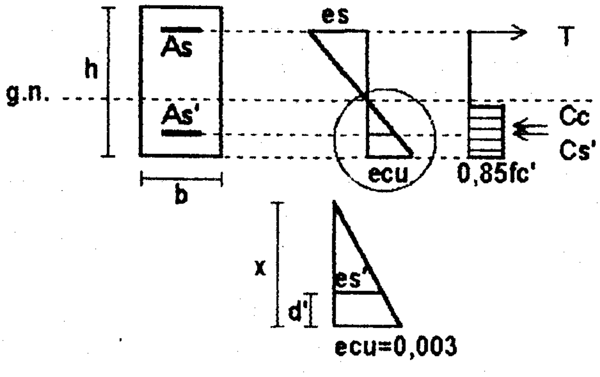
fy = 320 MPa = 320 N/mm^2

Es = 2. 10^6 kg/cm^2 = 2. 10^5 MPa

d' = 50 mm

ε cu pada serat terluar = 0,003 (SKSNI 3.3.2)

Anggap tul. tekan belum leleh :



sket Diagram blok tegangan

$$\frac{\varepsilon cu}{\varepsilon s'} = \frac{x}{x\text{-}d'} \qquad , Es = \frac{fs'}{\varepsilon s'}$$

$$\frac{0{,}003}{\varepsilon s'} = \frac{x}{x\text{-}50}$$

$$0{,}003.\,(x - 50) = x.\,\varepsilon s' \qquad , \varepsilon s' = \frac{0{,}003.x - 0{,}15}{x}$$

$T = Cc + Cs$

$As.\ fy\ = 0{,}85.\ fc'.\ (x.\ \beta).\ b + (fs' - 0{,}85.\ fc').\ As'$

$1134.\ 320 = 0{,}85.30.\ (x.\ 0{,}85).\ 250 + (2.\ 10^5.\left(\frac{0{,}003.\ x - 0{,}15}{x}\right) - 0{,}85.30).\ 567$

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$x = 59{,}6$ mm

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$\varepsilon s' = \dfrac{0{,}003.\ 59{,}6 - 0{,}15}{59{,}6} = 0{,}00048$

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$= 0{,}00048.\ 200000 = 96{,}6$ MPa < 320 MPa (tul. tekan belum leleh)

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Perhitungan Mn balok :

Mn terpasang $= Cc.\ (d - \frac{a}{2}) + Cs.\ (d - d')$

$= 322957{,}5.\ (350 - \frac{50{,}7}{2}) + 40338{,}8.\ (350 - 50)$

$= 116802$ Nm $>$ Mn perlu (OK)

- **Di lapangan balok**

Mu = 46,01 kNm

Mn perlu $= \dfrac{46{,}01}{0{,}8} = 57{,}51$ kNm $= 57510$ Nm

$Rn = \dfrac{57510.\ 1000}{250.\ (400 - 50)^2} = 1{,}8$ MPa

ρ perlu $= \dfrac{1}{12{,}55}\left(1 - \sqrt{1 - \dfrac{2.\ 12{,}55.\ 1{,}8}{320}}\right) = 0{,}0058$ (OK)

As perlu $= 0{,}0058.\ 250\ (400 - 50) = 534\ mm^2$

(Pakai tul. 2 D 19 mm, As = 567 mm^2)

$As' = 0{,}4.\ 534 = 214\ mm^2$ (Pakai tul. 2 D 19 mm, As' = 567 mm^2)

Lebar efektif penampang balok T : (SKSNI 3.1.10.2)

1. $bE < \frac{1}{4}.\ L$

   $< \frac{1}{4}.\ 600 = 150$ cm (menentukan)

2. $bE < 16.t + bw$

   $< 16.\ 12 + 25 = 217$ cm

3. $bE < 2.\ \frac{1}{2}.\ sn + bw$

   $< 2.\ \frac{1}{2}.\ 220 + 25 = 245$ cm

Cek kelelehan tul. tekan :

Dengan cara yang sama seperti pada balok di tumpuan, anggap tul. tekan belum leleh

$$\frac{0,003}{\varepsilon s'} = \frac{x}{x - 50}$$

$T = Cc + Cs$

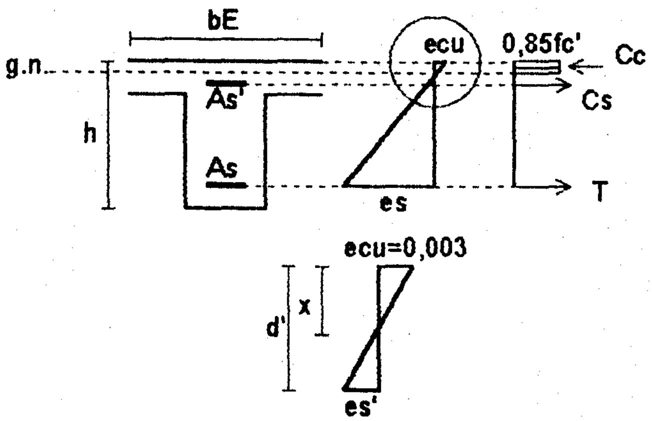
$As.\ fy = 0,85.\ fc'.\ a.\ bE + As'.\ (fs' - 0,85.\ fc')$

$567.\ 320 = 0,85.\ 30.\ (x.\ 0,85).\ 1500 + 567.\ (2.\ 10^5.\ (\frac{0,003.x - 0,15}{x}) - 0,85.\ 30)$

didapat x = 26,7 mm < d' (50 mm)

(garis netral berada diatas tulangan tekan)

cek lagi :



sket Diagram blok tegangan

$$\frac{\varepsilon cu}{\varepsilon s'} = \frac{x}{d' - x}$$
$$\frac{0{,}003}{\varepsilon s'} = \frac{x}{50 - x}$$

T + Cs = Cc

As. fy + As'. fs' = 0,85. fc'. (x. β). bE

$$567.\ 320 + 567.\ 2.\ 10^5.\ \left(\frac{0{,}15 - 0{,}003.\ x}{x}\right) = 0{,}85.\ 30.\ (x.\ 0{,}85).\ 1500$$

Pers. diatas adalah pers. kuadrat.

Dengan rumus ABC, didapat x = 20,6 mm

a = 20,6. 0,85 = 17,5 mm

$$\varepsilon s' = \left(\frac{0{,}15 - 0{,}003.20{,}6}{20{,}6}\right) = 0{,}0043$$

fs' = 200000. 0,0043 = 859,1 MPa > 320 MPa (tul. leleh, pakai fy)

Perhitungan Mn balok :

Mn terpasang = Cc. $(d - \frac{a}{2})$ - Cs. (d - d')

$= 0{,}85.\ 30.\ 17{,}5.\ 1500.\ (350 - \frac{17{,}5}{2}) - 567.\ 320.\ (350 - 50)$

= 173687 Nm > Mn perlu (OK)

☐ **Kontrol retak**

Berdasar SKSNI 3.3.6, pada balok dengan fy tulangan tarik melebihi 300 MPa, harus dikontrol terjadinya retak.

$Z = fs^3 \sqrt{dc.\ A}$

dimana : dc = jarak titik berat tul. ke serat tarik terluar beton

$A = \frac{2.\ dc.\ bw}{jml\ tul.}$

Z untuk di dalam ruangan < 30 MN/m

Z untuk di luar ruangan < 25 MN/m

Cek di tumpuan :

n tul. atas = 4

$dc = 40 + 10 + \frac{1}{2}.\ 19 = 59{,}5$ mm

fs = 60%. fy = 0,6. 320 = 192 MPa

$A = \frac{2.\ 59{,}5.\ 250}{4} = 7437{,}5\ \text{mm}^2$

$Z = 192^3\sqrt{59{,}5.7437{,}5}$

$= 14631$ Nmm = 14,6 MN/m < 30 MN/m (OK)

Cek di lapangan :

n tul. bawah = 2

$A = \frac{2.\ 59{,}5.\ 250}{2} = 14875\ \text{mm}^2$

Z = 18,4 MN/m < 30 MN/m (OK)

☐ **Pemutusan tulangan**

➢ Pemutusan tul tarik momen negatif di tumpuan :

$x1 = \frac{1}{4}.\ L = \frac{1}{4}.\ 600 = 150$ cm (dari muka tumpuan)

☐ **Panjang penyaluran**

Panjang penyaluran min. tulangan lentur berdasarkan SKSNI pasal 3.5.

Panjang penyaluran tulangan tarik dan tekan ini juga disesuaikan dengan kondisi tumpuan, apakah tulangan tersebut diputus atau diteruskan/dilewatkan untuk penulangan pada balok yang bersebelahan.

Contoh perhitungan :

Pada tulangan deform tarik :

Untuk batang D19, $= 0{,}02.\ \text{Ab}.\ \text{fy}/\sqrt{\text{fc}'}$

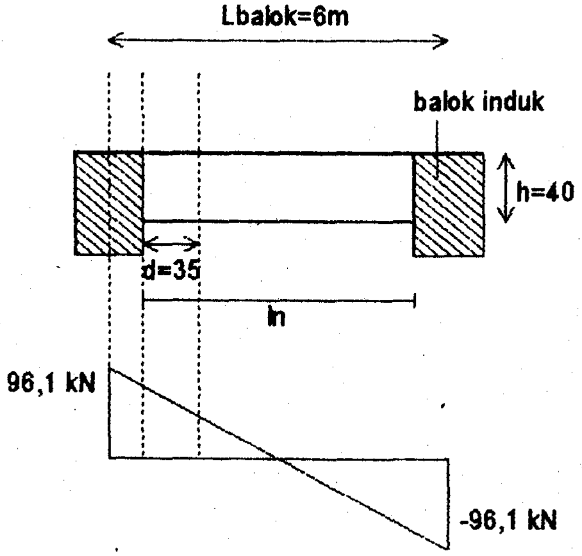
$= 0{,}02.\ 284.\ 320/\sqrt{30} = 332$ mm,

☐ **Penulangan geser**

- **Di tumpuan**

  Dari output analisa balok anak didapat :

  Vu perlu = 96,1 kN (Vu as ke as)



sket Diagram geser balok

Perencanaan geser berdasar Vu dari muka tumpuan :

ln (bentang bersih balok) = L - b tump

= 600 - 40 = 560 cm

$$\frac{\frac{1}{2} \cdot \ln}{\frac{1}{2} \cdot L} = \frac{\text{Vu muka tump}}{\text{Vu (as ke as)}}$$

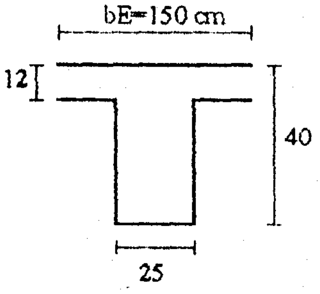
$$\text{Vu muka tump} = \frac{560.\ 96{,}1}{600} .\ 1000 = 89693 \text{ N}$$

Tu perlu = 0,67 kNm (hasil analisa struktur)

Cek batas torsi tanpa tulangan :

$$Tu = \frac{1}{20} . \Phi . \left[\sqrt{fc'} . \Sigma x^2 . y \right]$$

pilih terkecil :



$\Sigma x^2 . y = 25^2 . 40 + 2. (12^2 . 62{,}5) = 43000 \text{ cm}^3$ (menentukan)

$= 25^2 . (40 - 12) + 12^2 . 150 = 46100 \text{ cm}^3$

$Tu = \frac{1}{20} . 0{,}6. [(\sqrt{30}). 39100. 1000] = 7065{,}6 \text{ Nm}' > Tu$ (torsi diabaikan)

Kekuatan geser beton : (SKSNI 3.4.3.1)

$$Vc = \left(\frac{\sqrt{fc'}}{6} \right) . bw. d$$

$$= \left(\frac{\sqrt{30}}{6} \right) . 250. (400 - 50) = 79876 \text{ N}$$

$Vs \text{ perlu} = Vn \text{ perlu} - Vc = \frac{89693}{0{,}6} - 79876 = 69612 \text{ N}$

$Vs = \frac{Av.fy.d}{S}$ (SKSNI 3.4.5.6)

Kategori desain geser :

$$\Phi. Vc + \min \Phi. Vs < Vu \leq \Phi. Vc + \Phi . \frac{\sqrt{fc'}}{3} . bw. d$$

$$(0{,}6. 79876 + 0{,}6. \frac{1}{3}. 250. 350) < 89693 \leq (0{,}6. 79876 + 0{,}6. \frac{\sqrt{30}}{3}. 250. 350)$$

$65426 < 89693 < 143777 \text{ N}$ (OK)

Dicoba sengkang D 8 mm, Av 2 tul. = 101 mm^2

$$S\ perlu = \frac{Av.fy.d}{Vs} = \frac{101.\ 320.\ (400 - 50)}{69612} = 162{,}5\ mm$$

Syarat jarak :

- $S = \frac{d}{2}$
  $= \frac{350}{2} = 175\ mm$
- $S = 600\ mm$

(pakai sengkang D 8 - 150 mm).

- **Di lapangan balok**

Sengkang dari tumpuan dipasang sebanyak 8 sengkang.

Jarak dari tumpuan (muka kolom) = 150. 7 = 1050 mm

Vu di lapangan direncanakan pada jarak x = 105 cm dari muka tumpuan :

$$\frac{\frac{1}{2}.\ ln - x}{\frac{1}{2}.\ L} = \frac{Vu\ di\ x}{Vu}$$

$$Vu\ di\ x = \frac{\frac{1}{2}.\ 560 - 105}{\frac{1}{2}.\ 600}.\ 96{,}1.\ 1000 = 56058\ N$$

$$Vs\ perlu = \frac{56058}{0{,}6} - 79876 = 13554\ N$$

Kategori geser :

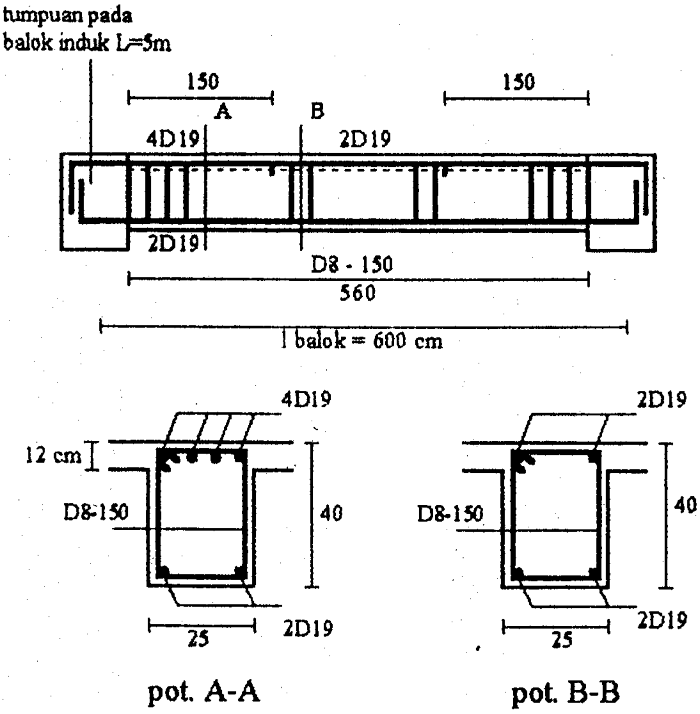
$\Phi.\ Vc < Vu \leq (\Phi.\ Vc + \Phi.\ \frac{1}{3}.\ bW.\ d)$

$47925{,}7 < 56058 < 65425{,}7$

Coba sengkang D 8, Av 2 tul. = 101 mm^2. Syarat jarak harus memenuhi :

- $S = \frac{Av.fy.\ d}{Vs}$
  $= \frac{101.\ 320.\ 350}{13554} = 471\ mm$
- $S = \frac{d}{2} = 175\ mm$
- $S = \frac{Av.\ 3.\ fy}{bW} = \frac{101.3.320}{250} = 387{,}8\ mm$

(Dari syarat diatas, pakai sengkang D 8 - 150 mm)



sket Penulangan lentur dan geser balok anak
25/40 (L = 6m)

6.3.2. Perencanaan balok anak yang lain

- Perencanaan lentur dapat dilihat pada tabel 6.3.2.a
- Perencanaan geser dapat dilihat pada tabel 6.3.2.b

No	Portal	Balok	level	L	b	h	m=	span (kN/m')		pakai q	span (kN/m')		pakai q	P
		anak			(cm)		S/L	short	long	hidup (kN/m')	short	long	mati (kN/m')	(kN)
1	A	anak	lantai	600	25	40	0.83		2.88	5.76		8.82	17.64	
2	A	anak	lantai	500	25	35	0.83	2.50		5.00	7.65		15.30	
3	B	anak	lantai	600	30	50	0.50		4.13	8.25		12.62	25.25	
4	C	konsol	lantai	150	25	35	0.50	1.50		2.00	4.59		6.12	
5	C	konsol	lantai	200	25	35	0.67	2.00		2.67	6.12		7.16	
6	C	anak	lantai	150	25	30	0.60	1.50		1.50	4.59		4.59	
7	C	anak	lantai	300	25	30	0.83	2.50		5.00	7.65		15.30	
8	C	lisplank	lantai	300	25	30	0.67		2.56	2.56		7.82	7.82	
9	C	lisplank	lantai	250	25	30	0.80		2.36	2.36		7.22	7.22	
10	D	anak	lantai	800	30	60	0.38		4.29	8.58		13.12	26.25	
11	B	anak	atap	600	25	40								
12	B	anak	atap	250	25	30								
13	B	anak	atap	300	25	30							8.50	
14	C	konsol	atap	200	25	35								
15	C	lisplank	atap	300	25	30							8.50	
16	D	anak	atap	800	30	50								8

Tabel 6.2. Beban pada balok anak

No blk.	Portal	Balok	level tipikal	L	b	h	Mu tump. (kNm)	ro perlu	As (mm2)		As' (mm2)		Mn di tump. (Nm)		ket
				(cm)					perlu	pakai	perlu	pakai	terpasang	perlu	
1	A	anak	lantai	600	25	40	-92.6	1.28E-02	1124.10	1134	449.64	567	116802.47	115800	
2	A	anak	lantai	500	25	35	-76.51	1.46E-02	1096.89	1134	438.76	567	98791.44	95637.5	
3	B	anak	lantai	600	30	50	-116.25	7.86E-03	1061.49	1134	424.60	567	154744.44	145312.5	
4	C	konsol	lantai	150	25	35	-72.8	1.38E-02	1038.08	1134	415.23	567	98791.44	91000	as bl. anak
5	C	konsol	lantai	200	25	35	-87.24	1.69E-02	1271.12	1418	508.45	567	121228.58	109050	as bl. anak
6	C	konsol	lantai	150	25	35	-72.8	1.38E-02	1038.08	1140	415.23	760	99238.70	91000	as bl. induk
7	C	konsol	lantai	200	25	35	-87.24	1.69E-02	1271.12	1521	508.45	760	129493.98	109050	as bl. induk
8	C	anak	lantai	150	25	30	-14.29	4.38E-03	273.44	567	109.38	567	43812.03	17862.5	
9	C	anak	lantai	300	25	35	-36.5	6.61E-03	495.83	567	198.33	567	52911.59	45625	
10	C	lisplank	lantai	300	25	30	-16.11	4.38E-03	273.44	402	109.38	402	32633.49	20137.5	
11	C	lisplank	lantai	250	25	30	-6.63	4.38E-03	273.44	402	109.38	402	32633.49	8287.5	
12	D	anak	lantai	800	30	60	-234.24	1.08E-02	1784.78	1985	713.91	851	326389.39	292800	
13	B	anak	atap	600	25	40	-29.77	4.38E-03	382.81	567	153.13	567	61834.29	37212.5	
14	B	anak	atap	250	25	30	-2.59	4.38E-03	273.44	402	109.38	402	32633.49	3237.5	
15	B	anak	atap	300	25	30	-13.12	4.38E-03	273.44	402	109.38	402	32633.49	16400	
16	C	konsol	atap	200	25	35	-36.7	6.65E-03	498.67	567	199.47	567	52763.73	45875	
17	C	lisplank	atap	300	25	30	-5.04	4.38E-03	273.44	402	109.38	402	32633.49	6300	
18	D	anak	atap	800	30	50	-20.95	4.38E-03	590.63	851	236.25	567	118095.59	26187.5	

Tabel 6.3.2.a. Perencanaan lentur

No blk.	Mu lap. (kNm)	ro perlu	As (mm2)		As' (mm2)		bE (mm)	Mn di lap. (Nm)		retak Z (MN/m)		cek lendutan
			perlu	pakai	perlu	pakai		terpasang	perlu	di tump.	di lap.	
1	46.01	5.71E-03	533.95	567	213.58	567	1500	173686.97	57512.5	14.63	18.43	ok
2	39.73	7.23E-03	541.89	567	216.75	567	1250	130170.97	49662.5	14.63	18.43	ok
3	111.14	7.50E-03	1012.40	1134	404.96	567	1500	259696.98	138925	15.55	15.55	ok
4	-29.89	5.37E-03	402.77	567	161.11	567		52911.59	37362.5	14.63	18.43	ok
5	-37.34	6.77E-03	507.77	567	203.11	567		52911.59	46675	13.58	18.43	ok
6	-29.89	5.37E-03	402.77	760	161.11	760		68361.27	37362.5	16.10	18.43	ok
7	-37.34	6.77E-03	507.77	760	203.11	760		68361.27	46675	14.63	18.43	ok
8	-3.57	4.38E-03	273.44	567	109.38	567		43812.03	4462.5	18.43	18.43	ok
9	-2.45	4.38E-03	328.13	567	131.25	567		20711.75	3062.5	18.43	18.43	ok
10	6.92	4.38E-03	273.44	402	109.38	402	750	67829.97	8650	18.43	18.43	ok
11	9.66	4.38E-03	273.44	402	109.38	402	625	58434.67	12075	18.43	18.43	ok
12	169.1	7.65E-03	1261.52	1418	504.61	567	2000	405538.15	211375	12.90	14.43	ok
13	19.14	4.38E-03	382.81	567	153.13	567		61834.29	23925	18.43	18.43	ok
14	7.07	4.38E-03	273.44	402	109.38	402		32633.49	8837.5	18.43	18.43	ok
15	6.49	4.38E-03	273.44	402	109.38	402		32633.49	8112.5	18.43	18.43	ok
16	-18.15	4.38E-03	328.13	567	131.25	567		52763.73	22687.5	18.43	18.43	ok
17	10.76	4.38E-03	273.44	402	109.38	402		32633.49	13450	18.43	18.43	ok
18	32.81	4.38E-03	590.63	851	236.25	567		118095.59	41012.5	17.11	17.11	ok

Tabel 6.3.2.a. (lanjutan - 1)

No blk.	Portal	Balok anak	level tipikal	L (cm)	Ln (cm)	Tu perlu (kNm)	x2. y (mm3)	Tu batas (kNm)	Tc (kNm)	Vu perlu (kN)		Vc (N)	Vs perlu (N)
										c to c	m. tump.		
1	A	anak	lantai	600	560	0.67	4.30E+07	7.07	15.55	96.1	89.69333333	79876.21	69612.68
2	A	anak	lantai	500	460	0.29	3.63E+07	5.96	12.72	82.6	75.992	68465.32	58188.01
3	B	anak	lantai	600	560	0.21	6.23E+07	10.23	20.21	147.53	137.6946667	123237.58	106253.54
4	C	konsol	lantai	150	130	0.04	2.37E+07	3.89	5.68	60.85	52.73666667	68465.32	19429.12
5	C	konsol	lantai	200	180	0.04	2.55E+07	4.19	5.64	66.43	59.787	68465.32	31179.68
6	C	anak	lantai	150	130	0.02	2.06E+07	3.38	4.50	19.06	16.51866667	57054.43	-29523.32
7	C	anak	lantai	300	260	0.18	2.91E+07	4.78	10.26	43.86	38.012	68465.32	-5111.99
8	C	lisplank	lantai	300	275	2.37	1.88E+07	3.08	6.85	27.75	25.4375	57054.43	-14658.60
9	C	lisplank	lantai	250	225	1.45	1.82E+07	2.98	6.63	25.82	23.238	57054.43	-18324.43
10	D	anak	lantai	800	760		7.85E+07	12.90		201.65	191.5675	150623.70	168655.46
11	B	anak	atap	600	570	1.07	4.30E+07	7.07	15.68	26.58	25.251	79876.21	-37791.21
12	B	anak	atap	250	220		2.42E+07	3.97		15.45	13.596	57054.43	-34394.43
13	B	anak	atap	300	270	0.1	2.60E+07	4.26	8.88	22.34	20.106	57054.43	-23544.43
14	C	konsol	atap	200	180		2.55E+07	4.19		19.81	17.829	68465.32	-38750.32
15	C	lisplank	atap	300	270		2.60E+07	4.26		23.37	21.033	57054.43	-21999.43
16	D	anak	atap	800	760		6.95E+07	11.42		22.08	20.976	123237.58	-88277.58

Tabel 6.3.2.b. Perencanaan geser

No blk.	Kategori desain geser (N)				Syarat jarak (mm)			D tul (mm)	S (mm)		pasang di x (cm)	Vu perlu di x (N)	Vs perlu (N)	D tul (mm)	S (mm)	
	0,5.phi.Vc	phi.vc	syarat 3	syarat 4	d/2	600	S ger min.		perlu	pasang					perlu	pasang
1	23962.86	47925.72	65425.72	143777.17	175	600	387.84	8	162.50	150	105	56058.33	13554.35	8	834.57	150
2	20539.60	41079.19	56079.19	123237.58	150	600	387.84	8	166.63	100	100	42952.00	3121.35	8	3106.35	150
3	36971.27	73942.55	100942.55	221827.64	225	600	323.20	8	136.88	100	100	88518.00	24292.42	8	598.71	200
4	20539.60	41079.19	56079.19	123237.58	150	600	387.84	8	499.04	100	80	30425.00	-17756.99	8		150
5	20539.60	41079.19	56079.19	123237.58	150	600	387.84	8	310.97	100	100	33215.00	-13106.99	8		150
6	17116.33	34232.66	46732.66	102697.98	125	600	387.84	8		200	150					
7	20539.60	41079.19	56079.19	123237.58	150	600	387.84	8		100	80	14620.00	-44098.65	8		200
8	17116.33	34232.66	46732.66	102697.98	125	600	387.84	8		100	50	16187.50	-30075.27	8		200
9	17116.33	34232.66	46732.66	102697.98	125	600	387.84	8		100	50	12910.00	-35537.77	8		200
10	45187.11	90374.22	123374.22	271122.67	275	600	323.20	8	105.40	100	100	141155.00	84634.63	8	210.03	200
11	23962.86	47925.72	65425.72	143777.17	175	600	387.84	8		150	105	15948.00	-53296.21	8		200
12	17116.33	34232.66	46732.66	102697.98	125	600	387.84	8		200	250					
13	17116.33	34232.66	46732.66	102697.98	125	600	387.84	8		100	50	12659.33	-35955.54	8		200
14	20539.60	41079.19	56079.19	123237.58	150	600	387.84	8		200	200					
15	17116.33	34232.66	46732.66	102697.98	125	600	387.84	8		100	50	13243.00	-34982.77	8		200
16	36971.27	73942.55	100942.55	221827.64	225	600	323.20	8		200	800					

Tabel 6.3.2.b Perencanaan geser

$$\frac{\varepsilon cu}{\varepsilon s'} = \frac{x}{d' - x}$$

$$\frac{0{,}003}{\varepsilon s'} = \frac{x}{50 - x}$$

$T + Cs = Cc$

$As.\ fy\ + As'.\ fs' = 0{,}85.\ fc'.\ (x.\ \beta).\ bE$

$$567.\ 320 + 567.\ 2.\ 10^5.\ \left(\frac{0{,}15-0{,}003.\ x}{x}\right) = 0{,}85.\ 30.\ (x.\ 0{,}85).\ 1500$$

Pers. diatas adalah pers. kuadrat.

Dengan rumus ABC, didapat $x = 20{,}6$ mm

$a = 20{,}6.\ 0{,}85 = 17{,}5$ mm

$$\varepsilon s' = \left(\frac{0{,}15-0{,}003.20{,}6}{20{,}6}\right) = 0{,}0043$$

$fs' = 200000.\ 0{,}0043 = 859{,}1$ MPa > 320 MPa (tul. leleh, pakai fy)

Perhitungan Mn balok :

$$Mn \text{ terpasang} = Cc.\ (d - \frac{a}{2}) - Cs.\ (d - d')$$

$$= 0{,}85.\ 30.\ 17{,}5.\ 1500.\ (350 - \frac{17{,}5}{2}) - 567.\ 320.\ (350 - 50)$$

= 173687 Nm > Mn perlu (OK)

☐ **Kontrol retak**

Berdasar SKSNI 3.3.6, pada balok dengan fy tulangan tarik melebihi 300 MPa, harus dikontrol terjadinya retak.

$Z = fs^3 \sqrt{dc.\ A}$

dimana : dc = jarak titik berat tul. ke serat tarik terluar beton

$$A = \frac{2.\ dc.\ bw}{jml\ tul.}$$

Z untuk di dalam ruangan < 30 MN/m

Z untuk di luar ruangan < 25 MN/m

Cek di tumpuan :

n tul. atas = 4

$dc = 40 + 10 + \frac{1}{2}.\ 19 = 59{,}5$ mm

fs = 60%. fy = 0,6. 320 = 192 MPa

$$A = \frac{2.\ 59{,}5.\ 250}{4} = 7437{,}5\ \text{mm}^2$$

$$Z = 192^3\sqrt{59{,}5.7437{,}5}$$

$= 14631$ Nmm = 14,6 MN/m < 30 MN/m (OK)

Cek di lapangan :

n tul. bawah = 2

$$A = \frac{2.\ 59{,}5.\ 250}{2} = 14875\ \text{mm}^2$$

Z = 18,4 MN/m < 30 MN/m (OK)

☐ **Pemutusan tulangan**

- Pemutusan tul tarik momen negatif di tumpuan :

$x1 = \frac{1}{4}.\ L = \frac{1}{4}.\ 600 = 150$ cm (dari muka tumpuan)

☐ **Panjang penyaluran**

Panjang penyaluran min. tulangan lentur berdasarkan SKSNI pasal 3.5.

Panjang penyaluran tulangan tarik dan tekan ini juga disesuaikan dengan kondisi tumpuan, apakah tulangan tersebut diputus atau diteruskan/dilewatkan untuk penulangan pada balok yang bersebelahan.

Contoh perhitungan :

Pada tulangan deform tarik :

Untuk batang D19, $= 0{,}02.\ \text{Ab}.\ \text{fy}/\sqrt{\text{fc'}}$

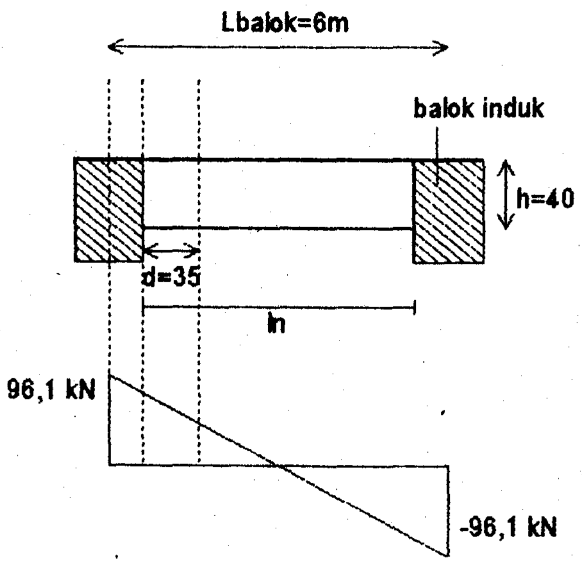
$= 0{,}02.\ 284.\ 320/\sqrt{30} = 332$ mm,

☐ **Penulangan geser**

- **Di tumpuan**

  Dari output analisa balok anak didapat :

  Vu perlu = 96,1 kN (Vu as ke as)



sket Diagram geser balok

Perencanaan geser berdasar Vu dari muka tumpuan :

ln (bentang bersih balok) = L - b tump

= 600 - 40 = 560 cm

$$\frac{\frac{1}{2}.\ \mathrm{ln}}{\frac{1}{2}.\ L} = \frac{\text{Vu muka tump}}{\text{Vu (as ke as)}}$$

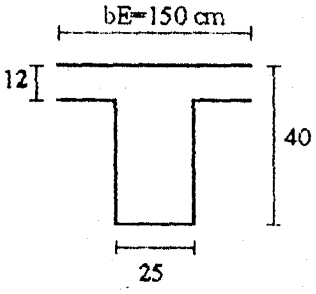
$$\text{Vu muka tump} = \frac{560.\ 96{,}1}{600}.\ 1000 = 89693\ \text{N}$$

Tu perlu = 0,67 kNm (hasil analisa struktur)

Cek batas torsi tanpa tulangan :

$$Tu = \frac{1}{20} . \Phi . \left[\sqrt{fc'} . \Sigma x^2 . y \right]$$

pilih terkecil :



$\Sigma x^2 . y = 25^2 . 40 + 2. (12^2 . 62,5) = 43000 \text{ cm}^3$ (menentukan)

$= 25^2 . (40 - 12) + 12^2 . 150 = 46100 \text{ cm}^3$

$Tu = \frac{1}{20} . 0,6. [(\sqrt{30}). 39100. 1000] = 7065,6 \text{ Nm} > Tu$ (torsi diabaikan)

Kekuatan geser beton : (SKSNI 3.4.3.1)

$$Vc = \left(\frac{\sqrt{fc'}}{6} \right) . bw. d$$

$$= \left(\frac{\sqrt{30}}{6} \right) . 250. (400 - 50) = 79876 \text{ N}$$

$Vs \text{ perlu} = Vn \text{ perlu} - Vc = \frac{89693}{0,6} - 79876 = 69612 \text{ N}$

$Vs = \frac{Av.fy.d}{S}$ (SKSNI 3.4.5.6)

Kategori desain geser :

$$\Phi. Vc + \min \Phi. Vs < Vu \leq \Phi. Vc + \Phi . \frac{\sqrt{fc'}}{3} . bw. d$$

$$(0,6. 79876 + 0,6. \frac{1}{3}. 250. 350) < 89693 \leq (0,6. 79876 + 0,6. \frac{\sqrt{30}}{3}. 250. 350)$$

$65426 < 89693 < 143777 \text{ N}$ (OK)

Dicoba sengkang D 8 mm, Av 2 tul. = 101 mm^2

$$S\ perlu = \frac{Av.fy.d}{Vs} = \frac{101.\ 320.\ (400 - 50)}{69612} = 162{,}5\ mm$$

<u>Syarat jarak :</u>

- $S = \frac{d}{2}$ $= \frac{350}{2} = 175\ mm$
- $S = 600\ mm$

(pakai sengkang D 8 - 150 mm).

- **Di lapangan balok**

Sengkang dari tumpuan dipasang sebanyak 8 sengkang.

Jarak dari tumpuan (muka kolom) = 150. 7 = 1050 mm

Vu di lapangan direncanakan pada jarak x = 105 cm dari muka tumpuan :

$$\frac{\frac{1}{2}.\ ln - x}{\frac{1}{2}.\ L} = \frac{Vu\ di\ x}{Vu}$$

$$Vu\ di\ x = \frac{\frac{1}{2}.\ 560 - 105}{\frac{1}{2}.\ 600}.\ 96{,}1.\ 1000 = 56058\ N$$

$$Vs\ perlu = \frac{56058}{0{,}6} - 79876 = 13554\ N$$

<u>Kategori geser :</u>

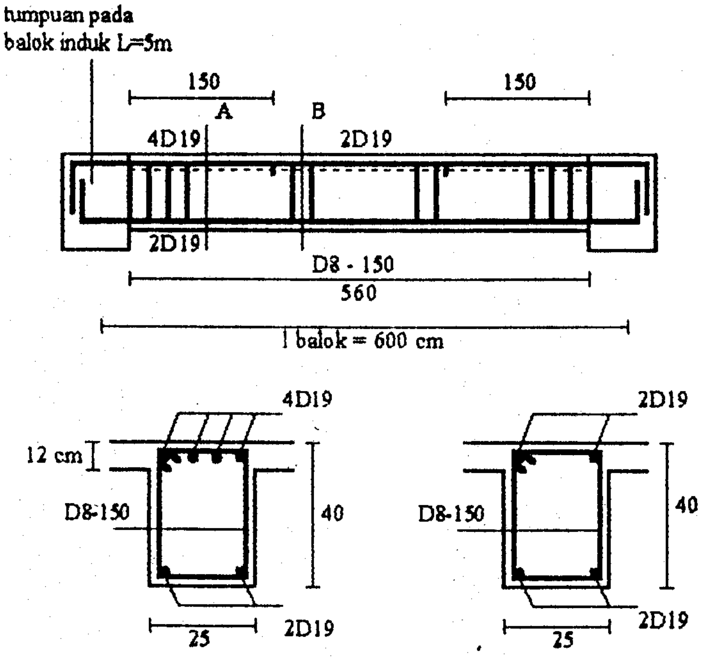
$\Phi.\ Vc < Vu \leq (\Phi.\ Vc + \Phi.\ \frac{1}{3}.\ bW.\ d)$

$47925{,}7 < 56058 < 65425{,}7$

Coba sengkang D 8, Av 2 tul. = 101 mm^2. Syarat jarak harus memenuhi :

- $S = \frac{Av.fy.\ d}{Vs}$ $= \frac{101.\ 320.\ 350}{13554} = 471\ mm$
- $S = \frac{d}{2} = 175\ mm$
- $S = \frac{Av.\ 3.\ fy}{bW} = \frac{101.3.320}{250} = 387{,}8\ mm$

(Dari syarat diatas, pakai sengkang D 8 - 150 mm)



pot. A-A

pot. B-B

sket Penulangan lentur dan geser balok anak
25/40 (L = 6m)

6.3.2. Perencanaan balok anak yang lain

- Perencanaan lentur dapat dilihat pada tabel 6.3.2.a
- Perencanaan geser dapat dilihat pada tabel 6.3.2.b

No	Portal	Balok	level	L	b	h	m=	span (kN/m')		pakai q	span (kN/m')		pakai q	P
		anak			(cm)		S/L	short	long	hidup (kN/m')	short	long	mati (kN/m')	(kN)
1	A	anak	lantai	600	25	40	0.83		2.88	5.76		8.82	17.64	
2	A	anak	lantai	500	25	35	0.83	2.50		5.00	7.65		15.30	
3	B	anak	lantai	600	30	50	0.50		4.13	8.25		12.62	25.25	
4	C	konsol	lantai	150	25	35	0.50	1.50		2.00	4.59		6.12	
5	C	konsol	lantai	200	25	35	0.67	2.00		2.67	6.12		7.16	
6	C	anak	lantai	150	25	30	0.60	1.50		1.50	4.59		4.59	
7	C	anak	lantai	300	25	30	0.83	2.50		5.00	7.65		15.30	
8	C	lisplank	lantai	300	25	30	0.67		2.56	2.56		7.82	7.82	
9	C	lisplank	lantai	250	25	30	0.80		2.36	2.36		7.22	7.22	
10	D	anak	lantai	800	30	60	0.38		4.29	8.58		13.12	26.25	
11	B	anak	atap	600	25	40								
12	B	anak	atap	250	25	30								
13	B	anak	atap	300	25	30							8.50	
14	C	konsol	atap	200	25	35								
15	C	lisplank	atap	300	25	30							8.50	
16	D	anak	atap	800	30	50								8

Tabel 6.2. Beban pada balok anak

No blk.	Portal	Balok	level tipikal	L	b	h	Mu tump. (kNm)	ro perlu	As (mm2)		As' (mm2)		Mn di tump. (Nm)		ket
				(cm)					perlu	pakai	perlu	pakai	terpasang	perlu	
1	A	anak	lantai	600	25	40	-92.6	1.28E-02	1124.10	1134	449.64	567	116802.47	115800	
2	A	anak	lantai	500	25	35	-76.51	1.46E-02	1096.89	1134	438.76	567	98791.44	95637.5	
3	B	anak	lantai	600	30	50	-116.25	7.86E-03	1061.49	1134	424.60	567	154744.44	145312.5	
4	C	konsol	lantai	150	25	35	-72.8	1.38E-02	1038.08	1134	415.23	567	98791.44	91000	as bl. anak
5	C	konsol	lantai	200	25	35	-87.24	1.69E-02	1271.12	1418	508.45	567	121228.58	109050	as bl. anak
6	C	konsol	lantai	150	25	35	-72.8	1.38E-02	1038.08	1140	415.23	760	99238.70	91000	as bl. induk
7	C	konsol	lantai	200	25	35	-87.24	1.69E-02	1271.12	1521	508.45	760	129493.98	109050	as bl. induk
8	C	anak	lantai	150	25	30	-14.29	4.38E-03	273.44	567	109.38	567	43812.03	17862.5	
9	C	anak	lantai	300	25	35	-36.5	6.61E-03	495.83	567	198.33	567	52911.59	45625	
10	C	lisplank	lantai	300	25	30	-16.11	4.38E-03	273.44	402	109.38	402	32633.49	20137.5	
11	C	lisplank	lantai	250	25	30	-6.63	4.38E-03	273.44	402	109.38	402	32633.49	8287.5	
12	D	anak	lantai	800	30	60	-234.24	1.08E-02	1784.78	1985	713.91	851	326389.39	292800	
13	B	anak	atap	600	25	40	-29.77	4.38E-03	382.81	567	153.13	567	61834.29	37212.5	
14	B	anak	atap	250	25	30	-2.59	4.38E-03	273.44	402	109.38	402	32633.49	3237.5	
15	B	anak	atap	300	25	30	-13.12	4.38E-03	273.44	402	109.38	402	32633.49	16400	
16	C	konsol	atap	200	25	35	-36.7	6.65E-03	498.67	567	199.47	567	52763.73	45875	
17	C	lisplank	atap	300	25	30	-5.04	4.38E-03	273.44	402	109.38	402	32633.49	6300	
18	D	anak	atap	800	30	50	-20.95	4.38E-03	590.63	851	236.25	567	118095.59	26187.5	

Tabel 6.3.2.a. Perencanaan lentur

No blk.	Mu lap. (kNm)	ro perlu	As (mm2)		As' (mm2)		bE (mm)	Mn di lap. (Nm)		retak Z (MN/m)		cek lendutan
			perlu	pakai	perlu	pakai		terpasang	perlu	di tump.	di lap.	
1	46.01	5.71E-03	533.95	567	213.58	567	1500	173686.97	57512.5	14.63	18.43	ok
2	39.73	7.23E-03	541.89	567	216.75	567	1250	130170.97	49662.5	14.63	18.43	ok
3	111.14	7.50E-03	1012.40	1134	404.96	567	1500	259696.98	138925	15.55	15.55	ok
4	-29.89	5.37E-03	402.77	567	161.11	567		52911.59	37362.5	14.63	18.43	ok
5	-37.34	6.77E-03	507.77	567	203.11	567		52911.59	46675	13.58	18.43	ok
6	-29.89	5.37E-03	402.77	760	161.11	760		68361.27	37362.5	16.10	18.43	ok
7	-37.34	6.77E-03	507.77	760	203.11	760		68361.27	46675	14.63	18.43	ok
8	-3.57	4.38E-03	273.44	567	109.38	567		43812.03	4462.5	18.43	18.43	ok
9	-2.45	4.38E-03	328.13	567	131.25	567		20711.75	3062.5	18.43	18.43	ok
10	6.92	4.38E-03	273.44	402	109.38	402	750	67829.97	8650	18.43	18.43	ok
11	9.66	4.38E-03	273.44	402	109.38	402	625	58434.67	12075	18.43	18.43	ok
12	169.1	7.65E-03	1261.52	1418	504.61	567	2000	405538.15	211375	12.90	14.43	ok
13	19.14	4.38E-03	382.81	567	153.13	567		61834.29	23925	18.43	18.43	ok
14	7.07	4.38E-03	273.44	402	109.38	402		32633.49	8837.5	18.43	18.43	ok
15	6.49	4.38E-03	273.44	402	109.38	402		32633.49	8112.5	18.43	18.43	ok
16	-18.15	4.38E-03	328.13	567	131.25	567		52763.73	22687.5	18.43	18.43	ok
17	10.76	4.38E-03	273.44	402	109.38	402		32633.49	13450	18.43	18.43	ok
18	32.81	4.38E-03	590.63	851	236.25	567		118095.59	41012.5	17.11	17.11	ok

Tabel 6.3.2.a. (lanjutan - 1)

No blk.	Portal	Balok anak	level tipikal	L (cm)	Ln (cm)	Tu perlu (kNm)	x2. y (mm3)	Tu batas (kNm)	Tc (kNm)	Vu perlu (kN)		Vc (N)	Vs perlu (N)
										c to c	m. tump.		
1	A	anak	lantai	600	560	0.67	4.30E+07	7.07	15.55	96.1	89.69333333	79876.21	69612.68
2	A	anak	lantai	500	460	0.29	3.63E+07	5.96	12.72	82.6	75.992	68465.32	58188.01
3	B	anak	lantai	600	560	0.21	6.23E+07	10.23	20.21	147.53	137.6946667	123237.58	106253.54
4	C	konsol	lantai	150	130	0.04	2.37E+07	3.89	5.68	60.85	52.73666667	68465.32	19429.12
5	C	konsol	lantai	200	180	0.04	2.55E+07	4.19	5.64	66.43	59.787	68465.32	31179.68
6	C	anak	lantai	150	130	0.02	2.06E+07	3.38	4.50	19.06	16.51866667	57054.43	-29523.32
7	C	anak	lantai	300	260	0.18	2.91E+07	4.78	10.26	43.86	38.012	68465.32	-5111.99
8	C	lisplank	lantai	300	275	2.37	1.88E+07	3.08	6.85	27.75	25.4375	57054.43	-14658.60
9	C	lisplank	lantai	250	225	1.45	1.82E+07	2.98	6.63	25.82	23.238	57054.43	-18324.43
10	D	anak	lantai	800	760		7.85E+07	12.90		201.65	191.5675	150623.70	168655.46
11	B	anak	atap	600	570	1.07	4.30E+07	7.07	15.68	26.58	25.251	79876.21	-37791.21
12	B	anak	atap	250	220		2.42E+07	3.97		15.45	13.596	57054.43	-34394.43
13	B	anak	atap	300	270	0.1	2.60E+07	4.26	8.88	22.34	20.106	57054.43	-23544.43
14	C	konsol	atap	200	180		2.55E+07	4.19		19.81	17.829	68465.32	-38750.32
15	C	lisplank	atap	300	270		2.60E+07	4.26		23.37	21.033	57054.43	-21999.43
16	D	anak	atap	800	760		6.95E+07	11.42		22.08	20.976	123237.58	-88277.58

Tabel 6.3.2.b. Perencanaan geser

No blk.	Kategori desain geser (N)				Syarat jarak (mm)			D tul (mm)	S (mm)		pasang di x (cm)	Vu perlu di x (N)	Vs perlu (N)	D tul (mm)	S (mm)	
	0,5.phi.Vc	phi.vc	syarat 3	syarat 4	d/2	600	S ger min.		perlu	pasang					perlu	pasang
1	23962.86	47925.72	65425.72	143777.17	175	600	387.84	8	162.50	150	105	56058.33	13554.35	8	834.57	150
2	20539.60	41079.19	56079.19	123237.58	150	600	387.84	8	166.63	100	100	42952.00	3121.35	8	3106.35	150
3	36971.27	73942.55	100942.55	221827.64	225	600	323.20	8	136.88	100	100	88518.00	24292.42	8	598.71	200
4	20539.60	41079.19	56079.19	123237.58	150	600	387.84	8	499.04	100	80	30425.00	-17756.99	8		150
5	20539.60	41079.19	56079.19	123237.58	150	600	387.84	8	310.97	100	100	33215.00	-13106.99	8		150
6	17116.33	34232.66	46732.66	102697.98	125	600	387.84	8		200	150					
7	20539.60	41079.19	56079.19	123237.58	150	600	387.84	8		100	80	14620.00	-44098.65	8		200
8	17116.33	34232.66	46732.66	102697.98	125	600	387.84	8		100	50	16187.50	-30075.27	8		200
9	17116.33	34232.66	46732.66	102697.98	125	600	387.84	8		100	50	12910.00	-35537.77	8		200
10	45187.11	90374.22	123374.22	271122.67	275	600	323.20	8	105.40	100	100	141155.00	84634.63	8	210.03	200
11	23962.86	47925.72	65425.72	143777.17	175	600	387.84	8		150	105	15948.00	-53296.21	8		200
12	17116.33	34232.66	46732.66	102697.98	125	600	387.84	8		200	250					
13	17116.33	34232.66	46732.66	102697.98	125	600	387.84	8		100	50	12659.33	-35955.54	8		200
14	20539.60	41079.19	56079.19	123237.58	150	600	387.84	8		200	200					
15	17116.33	34232.66	46732.66	102697.98	125	600	387.84	8		100	50	13243.00	-34982.77	8		200
16	36971.27	73942.55	100942.55	221827.64	225	600	323.20	8		200	800					

Tabel 6.3.2.b Perencanaan geser

BAB VII

DINDING LIFT

7.1. DESKRIPSI

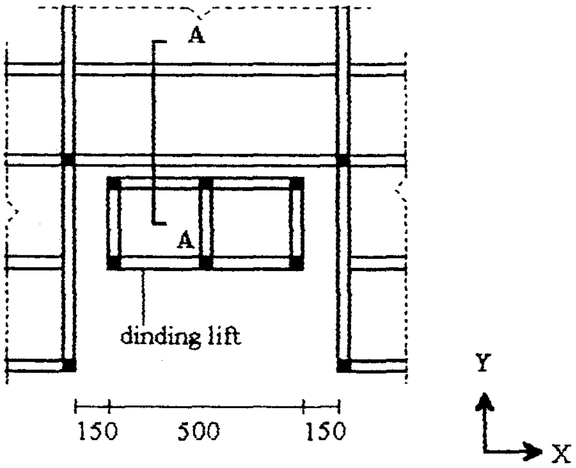
- Pada struktur terdapat dinding untuk lift,
- Ditinjau dari denah arsitektural, letak dinding lift tidak simetris secara struktural, karena penempatan lebih menuju ke salah satu sisi struktur. Dari penempatan ini dapat diperkirakan bahwa eksentrisitas antara *centre of mass* (CM) dan *centre of rigidity* (CR) struktur cukup besar.

7.2. DESAIN DAN PERENCANAAN

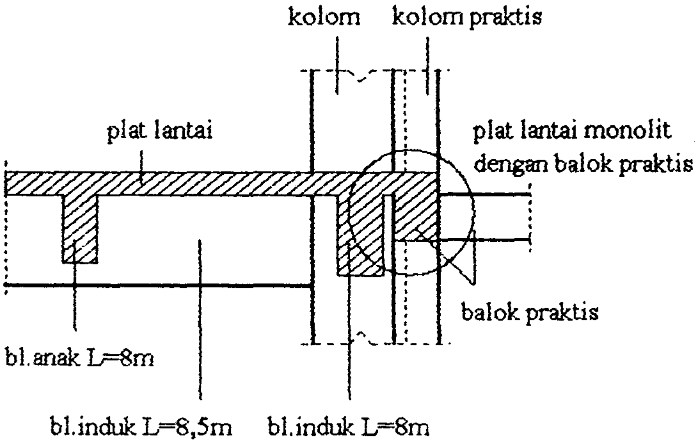
- Melihat letak dinding yang tidak simetris, dinding lift tidak direncanakan berperan dalam kestabilan struktur utama arah lateral. Dinding lift direncanakan sebagai bangunan yang terbuat dari pasangan bata/dinding tembok,
- Dinding lift cukup langsing. Akibat kelangsingan ini dinding lift tidak direncanakan mempunyai mode simpangan sendiri, namun direncanakan sehingga perilaku dinding mengikuti perilaku struktur utama,
- Sehingga antara dinding lift dan struktur utama terdapat sambungan yang menyatu,
- Detail sambungan antara struktur utama dan dinding lift dapat dilihat pada sket.

7.3. ELEMEN

Pada tepi pertemuan dinding direncanakan penebalan yaitu balok praktis dan kolom praktis, dimensi 40 x 40 cm.



sket Struktur utama dan dinding lift



sket potongan A - A

BAB VIII

ANALISA STRUKTUR UTAMA

8.1. BENTUK STRUKTUR

Model atau bentuk struktur :

1. Kesimetrisan

Tonjolan pada struktur tidak memenuhi persyaratan pada PPTGIUG 1983 bab 3.2.2. Tonjolan yang ada melebihi batas 0,25. A atau 0,25. B. Sehingga struktur dianggap sebagai struktur sangat tidak beraturan.

2. Loncatan bidang muka/set back

Struktur mempunyai rumah atap atau penthouse satu tingkat. Ukuran denah penthouse memenuhi 75% dari denah lantai dibawahnya, sehingga tonjolan rumah atap atau penthouse bukan merupakan loncatan bidang muka atau set back.

3. Tinggi total struktur kurang dari 40 m

Dari bentuk stuktur dan persyaratan diatas, harus digunakan analisa struktur dengan cara analisa dinamis tiga dimensi.

8.2. PEMODELAN STRUKTUR

Struktur dimodelkan sebagai rangka terbuka tiga dimensi (*three dimensional open frame)* . Elemen- elemen yang terdapat dalam struktur utama yaitu :

1. Balok induk,
2. Kolom,

Perencanaan elemen struktur diatas dengan cara *running program* secara bersama.

8.3. PEMBEBANAN

☐ **Beban yang bekerja**

- Berat sendiri elemen struktur,
- Beban mati dan hidup merata (akibat beban plat dan beban yang bekerja diatas plat, dan akibat tumpuan tangga),
- Beban terpusat akibat tumpuan balok anak, dan kuda-kuda,
- Beban gempa.

Data beban untuk elemen balok induk dapat dilihat pada bab IX Perencanaan Balok Induk.

8.4. ANALISA STRUKTUR

Untuk mendapatkan gaya dalam yang terjadi pada elemen struktur, digunakan program analisa struktur ETABS.

☐ **Silabus perencanaan**

- Struktur berupa rangka terbuka tiga dimensi,
- Hubungan antar elemen adalah jepit,
- Input data dimensi awal elemen balok, telah dihitung pada bab III Desain Pendahuluan,
- Plat lantai dianggap elemen kaku atau bersifat bersifat sebagai Rigid Body Motion. Sehingga tiap titik dalam plat tidak terjadi relatif deformasi,
- Perencanaan elemen struktur dengan beberapa kali running. Dari beberapa running tersebut dicari dimensi elemen yang optimum, yang cukup memenuhi kekakuan dan kemampuan pikul terhadap beban atau memenuhi penulangan perlu elemen.

☐ **Input data program**

- Jumlah tingkat/lantai 10 tingkat. Penomoran lantai :

  - Lantai 1 = 1ST,
  - Lantai 2 = 2ND,
  - Lantai 3, 4, ... = 3RD, 4TH, ...
  - Atap = ROOF

- Struktur terdiri dari satu frame, yaitu struktur utama rangka beton,
- Jenis material yang digunakan :

  - Material beton untuk rangka/frame, Ec = 2,9. 10^7 kN/m^2

- Beban yang bekerja :

  1. Beban gempa direncanakan dengan gempa Elcentro respon spektrum. Periode percepatan spektrum diambil berdasar pada referensi ETABS CSI Users Manual. Beban gempa yang bekerja ditinjau atas dua arah gerakan berdasar PPTGIUG bab 3.3.2. Arah gerakan masing-masing 0° dan 90°. Gaya gempa dalam arah gerakan utama dengan kombinasi 0,3 tegak lurus arah utama,
  2. Beban merata :

  - Beban mati akibat tumpuan tangga. Beban akibat tumpuan tangga ini membebani balok induk lantai (L = 8m). Reaksi perletakan atau beban q tangga telah dihitung pada bab V Perencanaan Tangga.

    q mati = 3280,44 kg/m' = 32,8 kN/m'

  - Beban hidup. q hidup untuk masing-masing balok induk dapat dilihat pada tabel 9.1.2. bab IX Perencanaan Balok Induk.
  - Beban mati. Idem beban hidup.

3. Beban terpusat :

- Beban akibat tumpuan kuda-kuda dan balok anak atap (pada balok induk atap). Besarnya P terpusat pada balok induk atap pada tabel 9.1.2. Bab IX,
- Beban terpusat akibat tumpuan balok anak lantai pada balok induk lantai. Besarnya P terpusat pada tabel 9.1.2. Bab IX.

◆ Kombinasi pembebanan berdasar SKSNI.

Dari hasil analisa struktur (faktor beban 1), beban dikombinasi :

1. $U = 1,2.\ DL + 1,6.\ LL$
2. $U = 0,9.\ (DL \pm E)$
3. $U = 1,05.\ (DL + Lr \pm E)$

dimana : U = beban *ultimate* yang dicari

DL = beban akibat beban mati

LL = beban akibat beban hidup

Lr = beban akibat beban hidup setelah direduksi

E = beban akibat beban gempa

(tanda + dan - tergantung arah atau arah bolak-balik)

◆ Jumlah mode shape/bentuk mode simpangan direncanakan tujuh mode,

- Perhitungan otomatis dengan menggunakan fasilitas ETABS :
  1. Beban akibat berat sendiri, $\gamma b = 24$ kN/m^3,
  2. Perhitungan massa :
     - Massa tingkat,
     - Momen inersia massa,
     - Pusat massa.

Massa ditentukan sebagai berikut :

1. Massa atap

Berdasarkan bab II Perencanaan Atap, telah didapat dimensi profil kuda-kuda dan berat atap.

- Perhitungan massa atap A :

  - Berat genting = (50. 3,66. 26). 2 = 8418 kg

  - Berat gording = 11. 23. 6 = 1518 kg

  - Berat kuda-kuda = 25. 3,66. 2. 4 = 732 kg

  -------------- +

  Total massa A = 10668 kg

$$\frac{\text{Total massa}}{\text{unit area}} = \frac{10668}{6.\ 23} = 77{,}3\ \text{kg/m}^2 = 0{,}773\ \text{kN/m}^2$$

- Perhitungan massa atap B :

- Berat penutup atap/genting = (50. 3,66. 18,5). 2 = 6771 kg
- Berat gording = 11. 18,5. 8 = 1628 kg
- Berat kuda-kuda = 25. 3,66. 2. 4 = 732 kg

--------------- +

Total massa B = 9131 kg

$$\frac{9131}{6.\ 18{,}5} = 82{,}26\ \text{kg/m}^2 = 0{,}823\ \text{kN/m}^2$$

- Perhitungan massa atap C :

- Berat genting = (50. 3,66. 2,5). 2 = 915 kg
- Berat gording = 11. 2,5. 6 = 165 kg
- Berat kuda-kuda = 25. 3,66. 2. 2 = 366 kg

------------ +

Total massa C = 1446 kg

$$\frac{1446}{2{,}5.\ 6} = 96{,}4\ \text{kg/m}^2 = 0{,}964\ \text{kN/m}^2$$

2. Massa lantai

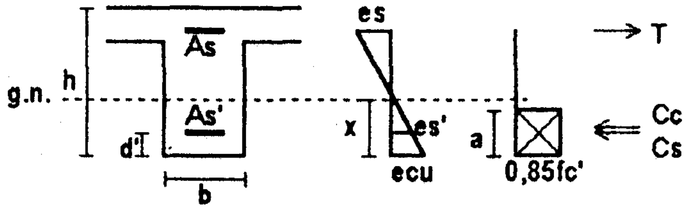
Berdasarkan PPI 83, pasal 3.5. beban hidup dapat direduksi untuk peninjauan gempa. Koefisien reduksi beban hidup untuk perumahan/hotel = 0,3 (tabel 3.3 PPI 83).

q hidup = 300. 0,3 = 90 kg/m^2

q mati = 918 kg/m^2

Massa q total = 918 + 90 = 1008 kg/m^2 = 10 kN/m^2

2. Perhitungan Mn - balok



T = Cc + Cs

$3801.320 = 0,85.\ 30.(x.\ 0,85).400 + (2.10^5.\ (\frac{0,003.\ x - 0,15}{x}) - 0,85.30).\ 1901$

didapat x = 88,6 mm > d'

$a = \beta.\ x = 0,85.\ 88,6 = 75,3$ mm

$fs' = 2.\ 10^5.\ (\frac{0,003.\ 88,6 - 0,15}{88,6}) - 0,85.\ 30 = 261,4$ MPa (belum leleh)

Cc = 0,85. 30. 75,3. 400 = 768162 N

Cs = 261,4. 1901 = 448445 N

$Mn - balok = Cc.\ (d - \frac{a}{2}) + Cs.\ (d - d')$

$= 768162.\ (650 - \frac{75,3}{2}) + 448445.\ (650 - 50)$

= 739447 Nm > Mn - perlu (OK)

Cek tul. longitudinal berdasar SKSNI 3.14.3.2 :

1. Mn + harus lebih besar dari ($\frac{1}{2}$. Mn -).
2. Kuat momen positif dan negatif di tiap bentang harus lebih besar dari $\frac{1}{4}$ momen maksimum di kedua ujung joint.

☐ **Penulangan lentur di lapangan**

Mu = 1,2. 89,5 + 1,6. 3,4 = 112,8 kNm

Rn = 0,8 MPa

ρ perlu = 0,0021 , pakai ρ min = 0,00438

As perlu = 0,00438. 400 (700 - 50) = 1137,5 mm^2

(Pakai tul. 5 D 22 mm, As = 1901 mm^2)

As' = 0,5. 1137,5 = 568,8 mm^2 (Pakai tul. 2 D 22 mm, As' = 760 mm^2)

Perhitungan Mn balok :

Dengan cara yang sama seperti di tumpuan :

$$\frac{0{,}003}{es'} = \frac{x}{x - 50}$$

T = Cc + Cs

As. fy = 0,85. fc'. a. bE + As'. (fs' - 0,85. fc')

$$1901.\ 320 = 0{,}85.\ 30.\ (x.\ 0{,}85).1250 + 760.\ (2.\ 10^5.\ (\frac{0{,}003.x - 0{,}15}{x}) - 0{,}85.30)$$

didapat x = 22,3 mm < d' (50 mm) (garis netral diatas tulangan tekan)

Anggap g.n. diatas tul. tekan :

T + Cs = Cc

As. fy + As'. fs' = 0,85. fc'. (x. β). bE

$$1901.\ 320 + 760.\ 2.\ 10^5.\ \left(\frac{0{,}15-0{,}003.\ x}{x}\right) - 0{,}85.\ 30.\ (x.\ 0{,}85).\ 1250 = 0$$

didapat x = 32 mm, a = 32. 0,85 = 27,2 mm

$$\varepsilon s' = \left(\frac{0{,}15-0{,}003.32}{32}\right) = 0{,}0017$$

fs' = 200000. 0,0017 = 337,5 MPa > 320 MPa (tul. leleh, pakai fy)

$$\text{Mn terpasang} = \text{Cc. } (d - \frac{a}{2}) - \text{Cs. } (d - d')$$

$$= 0{,}85.\ 30.\ 27{,}2.\ 1250.\ (650 - \frac{27{,}2}{2}) - 760.\ 320.\ (650 - 50)$$

= 405838,8 Nm > Mn perlu (OK)

☐ **Penulangan geser lentur dan torsi**

- *Penulangan di tumpuan*

Geser rencana balok :

$$Vu,b = 0,7.\ \Phi o. \left[\frac{Mnak,b + Mnak,b'}{ln}\right] + 1,05.\ Vg$$

Dari analisa struktur telah didapat (tanpa faktor) :

VD = 121 kN

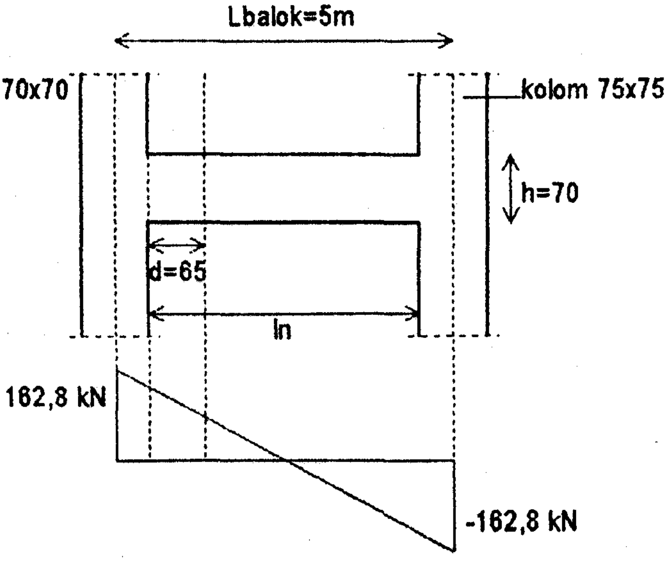
VL = 11 kN VE = 198,2 kN

Vg = 1,2. 121 + 1,6. 11 = 162,8 kN

Vg diatas adalah geser balok akibat gaya gravitasi dari as ke as sumbu kolom.

Vg balok direncanakan dari muka tumpuan kolom.

Vg muka tumpuan :



sket Diagram geser Vg balok

$$\frac{\frac{1}{2}.\ln}{\frac{1}{2}.L} = \frac{\text{V muka tump}}{\text{Vg}}$$

ln balok = 500 - 70/2 - 75/2 = 427,5 cm

$$\text{Vg muka tumpuan} = \frac{427,5}{500}.\ 162,8 = 139,2 \text{ kN}$$

$$\text{Vu,b} = 0,7.\ 1,25. \left[\frac{402320,3 + 739447,2}{4,275}\right] + 1,05.\ 139200 = 379849 \text{ N}$$

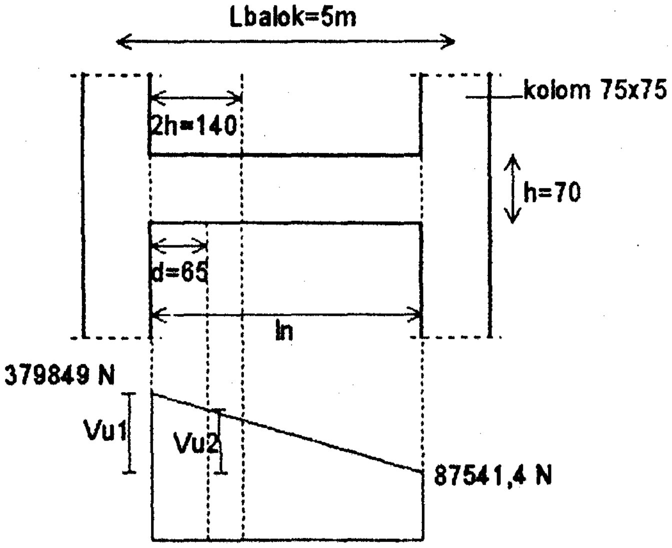
$$\text{Vu,b pada ujung yang lain} = 0,7.\ 1,25. \left[\frac{402320,3 + 739447,2}{4,275}\right] - 1,05.\ 139200$$

$$= 87541,4 \text{ N}$$

Berdasar SKSNI 3.4.1.2 :

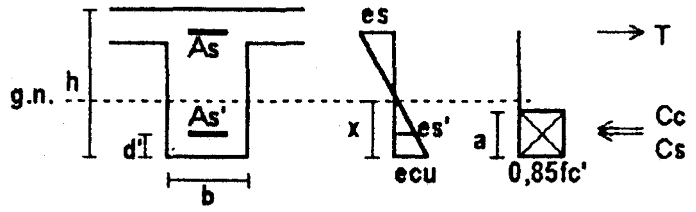
- Vu perlu boleh direncanakan pada penampang dengan jarak d dari muka tumpuan.

Dari Vu,b diatas didapat Vu,b di jarak d dengan rumus segitiga :



sket Diagram geser Vu balok

2. Perhitungan Mn - balok



$T = Cc + Cs$

$3801.320 = 0,85.\ 30.(x.\ 0,85).400 + (2.10^5.\ (\frac{0,003.\ x - 0,15}{x}) - 0,85.30).\ 1901$

didapat $x = 88,6$ mm $> d'$

$a = \beta .\ x = 0,85.\ 88,6 = 75,3$ mm

$fs' = 2.\ 10^5.\ (\frac{0,003.\ 88,6 - 0,15}{88,6}) - 0,85.\ 30 = 261,4$ MPa (belum leleh)

$Cc = 0,85.\ 30.\ 75,3.\ 400 = 768162$ N

$Cs = 261,4.\ 1901 = 448445$ N

Mn - balok $= Cc.\ (d - \frac{a}{2}) + Cs.\ (d - d')$

$= 768162.\ (650 - \frac{75,3}{2}) + 448445.\ (650 - 50)$

$= 739447$ Nm $> Mn$ - perlu (OK)

<u>Cek tul. longitudinal berdasar SKSNI 3.14.3.2 :</u>

1. Mn + harus lebih besar dari $(\frac{1}{2}.\ Mn -)$.
2. Kuat momen positif dan negatif di tiap bentang harus lebih besar dari $\frac{1}{4}$ momen maksimum di kedua ujung joint.

☐ **Penulangan lentur di lapangan**

Mu = 1,2. 89,5 + 1,6. 3,4 = 112,8 kNm

Rn = 0,8 MPa

ρ perlu = 0,0021 , pakai ρ min = 0,00438

As perlu = 0,00438. 400 (700 - 50) = 1137,5 mm^2

(Pakai tul. 5 D 22 mm, As = 1901 mm^2)

As' = 0,5. 1137,5 = 568,8 mm^2 (Pakai tul. 2 D 22 mm, As' = 760 mm^2)

Perhitungan Mn balok :

Dengan cara yang sama seperti di tumpuan :

$$\frac{0{,}003}{es'} = \frac{x}{x - 50}$$

T = Cc + Cs

As. fy = 0,85. fc'. a. bE + As'. (fs' - 0,85. fc')

$$1901.\ 320 = 0{,}85.\ 30.\ (x.\ 0{,}85).1250 + 760.\ (2.\ 10^5.\ (\frac{0{,}003.x - 0{,}15}{x}) - 0{,}85.30)$$

didapat x = 22,3 mm < d' (50 mm) (garis netral diatas tulangan tekan)

Anggap g.n. diatas tul. tekan :

T + Cs = Cc

As. fy + As'. fs' = 0,85. fc'. (x. β). bE

$$1901.\ 320 + 760.\ 2.\ 10^5.\ \left(\frac{0{,}15-0{,}003.\ x}{x}\right) - 0{,}85.\ 30.\ (x.\ 0{,}85).\ 1250 = 0$$

didapat x = 32 mm, a = 32. 0,85 = 27,2 mm

$$\varepsilon s' = \left(\frac{0{,}15-0{,}003.32}{32}\right) = 0{,}0017$$

fs' = 200000. 0,0017 = 337,5 MPa > 320 MPa (tul. leleh, pakai fy)

$$\text{Mn terpasang} = \text{Cc}.\ (d - \frac{a}{2}) - \text{Cs}.\ (d - d')$$

$$= 0{,}85.\ 30.\ 27{,}2.\ 1250.\ (650 - \frac{27{,}2}{2}) - 760.\ 320.\ (650 - 50)$$

= 405838,8 Nm > Mn perlu (OK)

Vu1 = Vu,b - Vu,b ujung yang lain

= 379849 - 87541,4 = 292307,6 N

$$\frac{\text{ln}}{\text{ln - d}} = \frac{\text{Vu1}}{\text{Vu2}}$$

$$\text{Vu2} = 292307{,}6.\ \frac{427{,}5 - (70 - 5)}{427{,}5} = 247863{,}2\ \text{N}$$

Vu,b di d = Vu2 + Vu,b ujung yang lain

= 247863,2 + 87541,4 = 335404,4 N (pakai dalam perenc. geser)

Geser balok tidak perlu lebih dari :

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

$$= 1{,}05.\ (121 + 11 + 4.\ 198{,}2).\ 1000 = 971040\ \text{N}$$

Torsi :

Dari analisa struktur balok anak (file scndflor.frm) telah didapat torsi akibat beban statis Tu = 28,02 kNm

Berdasar SKSNI 3.4.6 :

$$\text{Tu batas} = \Phi.\ \frac{\sqrt{fc'}}{20}.\ \Sigma\ (x^2.\ y)$$

$$\Sigma\ (x^2.\ y) = b^2.\ h + 2.\ t\ \text{plat}^2.\ \frac{(bE - b)}{2}$$

$$= 400^2.\ 700 + 2.\ 120^2.\ \frac{1250-400}{2} = 156240000\ \text{mm}^3$$

$$\Sigma(x^2.\ y) = b^2.\ (h - t) + t\ \text{plat}^2.\ bE$$

$$= 400^2.\ (700 - 120) + 120^2.\ 1250 = 110800000\ \text{mm}^3\ \text{(menentukan)}$$

$$\text{Tu batas} = 0{,}6.\frac{\sqrt{30}}{20}.\ 110800000 = 18206297{,}8\ \text{Nmm}$$

$$= 18{,}21\ \text{kNm} \qquad < \text{Tu perlu}$$

(Maka torsi diperhitungkan bersama geser dan lentur)

Perhitungan tul. geser lentur dan torsi :

- Sendi plastis dari muka tumpuan sampai 2. h = 2. 700 = 1,4 m
- Di dalam sendi plastis, tul sengkang harus merupakan sengkang tertutup.

Vc di daerah sendi plastis = 0 (SKSNI 3.14.7.2) :

$$Vn = Vc + Vs$$

$$Vs\ perlu = \frac{Vu,b}{\Phi} = \frac{335404,4}{0,6} = 559007\ N$$

Kuat torsi oleh beton (SKSNI 3.4.6.6) :

$$Tc = \frac{\frac{\sqrt{fc'}}{15}.\sum x^2.y}{\sqrt{1+\left(\frac{0,4.Vu}{Ct.\ Tu}\right)^2}}$$

dimana : $Ct = \frac{bW.\ d}{\sum x^2.\ y} = \frac{400.650}{110800000} = 0,0024\ /mm$

$$Tc = \frac{\frac{\sqrt{30}}{15}.\ 110800000}{\sqrt{1+\left(\frac{0,4.\ 335404,4}{0,0024.\ 28020000}\right)^2}} = 17,8\ kNm$$

$$Tn = Tc + Ts \qquad (SKSNI\ 3.4.6.5)$$

$$Ts\ perlu = \frac{28,02}{0,6} - 17,8 = 28,9\ kNm$$

Kuat momen torsi :

$$Ts = \frac{At.\ \alpha t.\ x1.\ y1.\ fy}{S} \qquad \text{(SKSNI 3.4.6.9)}$$

dimana : $\alpha t = \frac{2 + \frac{y1}{x1}}{3}$, $\alpha t\ max = 1{,}5$

y1 = dimensi panjang dari elemen persegi dari penampang

x1 = dimensi pendek dari elemen persegi dari penampang

tebal selimut beton ke tulangan paling tepi = 50 mm

$y1 = 700 - 2.\ 50 = 600$ mm

$x1 = 400 - 2.\ 50 = 300$ mm

$$\alpha t = \frac{2 + \frac{600}{300}}{3} = 1{,}3$$

Hitung tul transversal :

Torsi :

$$\frac{At}{S} = \frac{28900000}{1{,}3.\ 300.\ 600.\ 320} = 0{,}33\ mm^2/mm$$

(At = luas satu kaki tul torsi)

Geser :

$$Vs\ perlu = \frac{Av.\ fy.\ d}{S}$$

$$\frac{Av}{S} = \frac{559007}{320.\ 650} = 2{,}7\ mm^2/mm$$

$$\frac{Av\ total}{S} = 2.\ \frac{At}{S} + \frac{Av}{S}$$

$$= 2.\ 0{,}33 + 2{,}7 = 3{,}36\ mm^2/mm$$

(menentukan)

Sengkang tertutup minimum SKSNI 3.4.5.5.5. :

$$(Av + 2.\ At) = \frac{bw.\ S}{3.\ fy}$$

$$\min \frac{Av\ total}{S} = \frac{400}{3.\ 320}$$

$$= 0{,}42\ mm^2/mm \qquad < \left(\frac{Av\ total}{S}\right) perlu \qquad \text{(OK)}$$

Dicoba tul. D 12 mm, Av 1 kaki tul .= 113 mm^2 :

$$S \text{ perlu} = \frac{\text{Av total}}{3{,}36}$$

$$= \frac{2.\ 113}{3{,}36} = 66{,}5 \text{ mm}$$ = > jarak terlalu kecil, coba dengan 3 kaki :

$$S \text{ perlu} = \frac{3.\ 113}{3{,}36} = 101 \text{ mm}$$

Syarat jarak sengkang di daerah sendi plastis berdasar SKSNI 3.14.3.3 :

- $S = \frac{d}{4}$

  $= \frac{650}{4} = 162{,}5$ mm
- $S = 8.\ \varnothing$ tul lentur

  $= 8.\ 22 = 176$ mm
- $S = 24.\ \varnothing$ sengkang

  $= 24.\ 12 = 288$ mm
- $S = 200$ mm
- $S = 1600.\ fy.\ \left(\frac{As1}{(As,a + As,b).\ fy}\right)$

  $= 1600.\ 320.\ \frac{113}{(380 + 380).\ 320} = 237{,}9$ mm

Syarat jarak sengkang torsi berdasar SKSNI 3.4.6.8. :

- $S = \frac{x1 + y1}{4}$

  $= \frac{300 + 600}{4} = 225$ mm
- $S = 300$ mm

(Dari syarat jarak diatas, pakai sengkang 3 D12 - 100 mm)

(Dipasang sampai dengan jarak 1,4 m dari muka tumpuan)

Tulangan memanjang (SKSNI 3.4.6.9) :

Pakai terbesar :

$$\text{Al perlu 1} = 2.\ \text{At}.\ \frac{\text{xl} + \text{yl}}{\text{S}}$$

dimana : $\frac{\text{At}}{\text{S}} = 0{,}33\ \text{mm}^2/\text{mm}$

$$\text{At} = 100.\ 0{,}33 = 33\ \text{mm}^2$$

$$= 2.\ 33.\ \frac{300 + 600}{100} = 602\ \text{mm}^2$$

$$\text{Al perlu 2} = \left[\frac{2{,}8.\ \text{x}.\ \text{S}}{\text{fy}}\left(\frac{\text{Tu}}{\text{Tu} + \frac{\text{Vu}}{3.\ \text{Ct}}}\right) - 2.\ \text{At}\right].\left(\frac{\text{xl} + \text{yl}}{\text{S}}\right)$$

dimana : Ct = 0,0024 /mm

$$= \left[\frac{2{,}8.\ 300.\ 100}{320}.\left(\frac{28020000}{28020000 + \frac{335404{,}4}{3.\ 0{,}0024}}\right) - 2.\ 33\right].\left(\frac{300 + 600}{100}\right) = 273\ \text{mm}^2$$

Al tidak perlu lebih dari :

$$\text{Al max} = \left[\frac{2{,}8.\ \text{x}.\ \text{S}}{\text{fy}}\left(\frac{\text{Tu}}{\text{Tu} + \frac{\text{Vu}}{3.\ \text{Ct}}}\right) - 2.\ \text{At}\right].\left(\frac{\text{xl} + \text{yl}}{\text{S}}\right)$$

dimana : $2.\ \text{At} = \frac{\text{bw}.\ \text{S}}{3.\ \text{fy}} = \frac{400.\ 100}{3.\ 320}$

$$= 41{,}7\ \text{mm}^2$$

$$= \left[\frac{2{,}8.\ 300.\ 100}{320}.\left(\frac{28020000}{28020000 + \frac{335404{,}4}{3.\ 0{,}0024}}\right) - 41{,}7\right].\left(\frac{300 + 600}{100}\right) = 500\ \text{mm}^2$$

Dari luas tulangan memanjang diatas, pakai Al = 500 mm²

(pakai tul. memanjang 2 D 19 mm, As = 567 mm²)

(pemasangan tul. disebarkan pada sengkang)

- Penulangan di lapangan

Di luar sendi plastis, tul sengkang direncanakan sengkang tertutup.

Dengan cara yang sama seperti di sub bab geser di tumpuan,

Vu,b luar sendi plastis (2. h = 140 cm) :

Vu1 = 292307,4 N (telah dihitung di sub bab geser di tumpuan)

$$Vu2 = 292307{,}4 \,.\, \frac{427{,}5 - 140}{427{,}5} = 196581 \text{ N}$$

Vu,b di (2. h) = Vu2 + Vu,b ujung yang lain

= 196581 + 87541,4 = 284122 N

Geser beton (SKSNI 3.14.7.2) :

$$Vc = \frac{\sqrt{fc'}}{6}.\ bw.\ d = \frac{\sqrt{30}}{6}.\ 400.\ 650 = 237346 \text{ N}$$

Syarat jarak sengkang :

$$(\Phi.\ Vc + \min \Phi.\ Vs) < Vu \leq (\Phi.\ Vc + \Phi.\ \frac{1}{3}.\ \sqrt{fc'}\ .\ bw.\ d)$$

$$(0{,}6.\ 237346 + 0{,}6.\ \frac{1}{3}.\ 400.\ 650) < 284122 \leq (0{,}6.\ 237346 + 0{,}6.\ \frac{1}{3}.\ \sqrt{30}\ .\ 400.\ 650)$$

$194407{,}9 < 284122 \leq 427223{,}6$ N (OK)

Geser perlu :

Vn = Vc + Vs

$$Vs\ perlu = \frac{284122}{0{,}6} - 237346 = 236191 \text{ N}$$

$$Vs = \frac{Av.\ fy.\ d}{S}$$

Torsi perlu :

Anggap torsi bekerja pada seluruh penampang, Tu = 28,02 kNm

Ts perlu = 29,1 kNm (perhitungan seperti di tumpuan)

Hitung tul transversal :

$$\frac{Av}{S} = \frac{236191}{320.\ 650} = 1{,}1\ \text{mm}^2/\text{mm}$$

tul. min. = 0,42 mm^2/mm

tul. perlu :

$$(\frac{Av}{S})\ \text{tot} = (\frac{2.\ At}{S} + \frac{Av}{S})$$

$$= 2.\ 0{,}33 + 1{,}1 = 1{,}8\ \text{mm}^2/\text{mm}$$ (menentukan)

Dicoba tul. D 12 mm, Av 1 kaki tul .= 113 mm^2 :

$$S\ \text{perlu} = \frac{2.\ 113}{1{,}8} = 127{,}6\ \text{mm}$$

Syarat jarak sengkang di luar sendi plastis berdasar SKSNI 3.14.3.3 :

- $S = \frac{d}{2} = \frac{650}{2} = 325$ mm
- S = 600 mm

Syarat jarak sengkang torsi :

- S = 225 mm
- S = 300 mm

(Dari syarat jarak diatas, pakai sengkang D12 - 100 mm)

Tul. memanjang :

Tul. memanjang di lapangan sama seperti di tumpuan.

(pakai tul. memanjang 2D19)

☐ Kontrol retak

Berdasar SKSNI 3.3.6, balok dengan fy tulangan tarik melebihi 300 MPa, harus dikontrol terjadinya retak. Pada balok ini, kontrol retak pada saat beban layan (akibat beban hidup dan mati).

$Z = fs^3\sqrt{dc.\ A}$

dimana : dc = jarak titik berat tul. ke serat tarik terluar beton

$A = \dfrac{2.\ dc.\ bw}{jml\ tul.}$

Z untuk di dalam ruangan < 30 MN/m

Di tumpuan (serat atas) :

$dc = 40 + 12 + \frac{1}{2}.22 = 63$ mm

fs = 0,6. 320 = 192 MPa

$A = \dfrac{2.\ 63.\ 400}{10} = 5040\ mm^2$

$Z = 192^3\sqrt{63.\ 5040} = 13100$ N/mm = 13,1 MN/m < 30 MN/m (OK)

Di lapangan (serat bawah) :

$A = \dfrac{2.\ 63.\ 400}{5} = 10080\ mm^2$

$Z = 192^3\sqrt{63.10080} = 16,5$ MN/m (OK)

☐ Kontrol lendutan

Berdasar SKSNI tabel 3.2.5(a), untuk balok non pratekan dengan dimensi lebih dari koefisien pada tabel, maka lendutan tidak perlu dihitung

$h\ min = \dfrac{L}{16}.\ (0,4 + fy/700)$

$= \dfrac{5000}{16}.\ (0,4 + 320/700) = 268$ mm < h terpasang (70 cm)

☐ **Pemutusan tulangan**

$$Lo \approx \frac{1}{4} . L$$

$$= \frac{1}{4} 500 = 125 \text{ cm} \qquad \text{(dari muka tumpuan)}$$

☐ **Panjang penyaluran**

Panjang penyaluran min. tulangan lentur berdasarkan referensi Seismic Design of ..., bab 3.6.2, T paulay.

Panjang penyaluran tulangan baik tarik dan tekan ini juga disesuaikan dengan kondisi tumpuan, apakah tulangan tersebut diputus atau diteruskan/dilewatkan untuk penulangan pada balok yang bersebelahan.

Contoh perhitungan :

Pada tulangan deform tarik dengan kait standar 90°, batang 22 :

$150 \text{ mm} < l\ dh = mhb.\ l\ hb > 8.\ db$

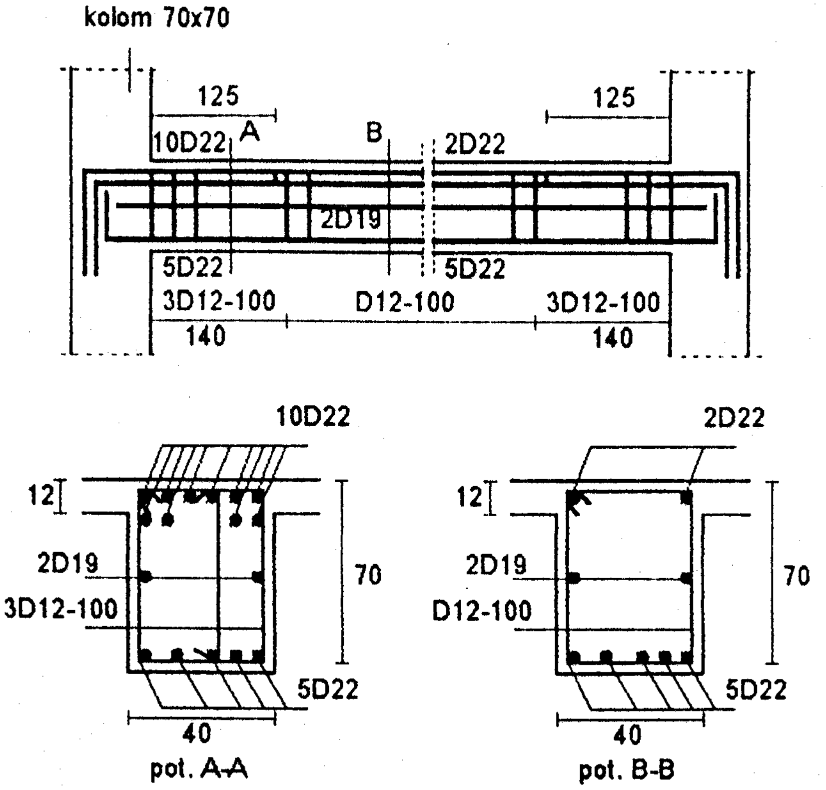
dimana : mhb = faktor modifikasi

= 0,7 untuk selimut beton pada kait > 40 mm

$$l\ hb = \frac{1}{\sqrt{fc'}} 0{,}24.\ db.\ fy$$

$$= 0{,}24.\ 22.\ 320/\sqrt{30} = 308{,}5 \text{ mm}$$

$l\ dh\ min = 0{,}7.\ 308{,}5 = 217 \text{ mm}$



sket Penulangan geser dan torsi
balok induk 40/70 L=5m

9.3.2. Perencanaan balok induk yang lain

- Perencanaan lentur dapat dilihat pada tabel 9.3.2.a.
- Perencanaan geser dapat dilihat pada tabel 9.3.2.b.

No	Portal	Balok		L	h	b	m=	span (kN/m')		pakai q	span (kN/m')		pakai q	P balok	P kuda2
		induk		(cm)	(cm)	(cm)	S/L	short	long	hidup (kN/m')	short	long	mati (kN/m')	anak (kN)	(kN)
1	A	induk	lantai	500	70	40	0.83	2.5		5	7.65		15.30	167.06	
2	B	induk	lantai	600	70	40	0.50		4.13	8.25		12.62	25.25	149.86	
3	B	induk	lantai	850	80	40	0.50	3		6	9.18		18.36	197.65	
4	C	induk	lantai	300	70	40	1.00	3		6	9.18		18.36		
5	D	induk	lantai	800	70	40	0.38		4.29	4.29		13.12	45.92		
6	D	induk	lantai	850	90	40	0.38	3		6	9.18		18.36	345.07	
7	A	induk	atap	500	50	30									24.38
8	B	induk	atap	600	50	30							8	8.5	
9	B	induk	atap	850	60	30								30	24.38
10	C	induk	atap	300	50	30									
11	D	induk	atap	800	50	30									12
12	D	induk	atap	850	60	30								30	24.38

Tabel 9.1.2. Beban pada balok induk

No	Portal	Balok	lantai	L	b	h	Mu + tump	ro	As (mm2)		As' (mm2)		Mu - tump	ro	As (mm2)		As' (mm2)	
blk.					(cm)		(kNm)	perlu	perlu	pasang	perlu	pasang	(kNm)	perlu	perlu	pasang	perlu	pasang
1	A	induk	1 to 6	500	40	70	271.26	6.54E-03	1699.91	1901	849.95	1140	-536.42	1.36E-02	3523.30	3801	1761.65	1901
2	B	induk	1 to 6	600	40	70	235.84	5.65E-03	1469.42	1521	734.71	760	-539.32	1.36E-02	3544.30	3801	1772.15	1901
3	B	induk	1 to 6	850	40	80	52.92	4.38E-03	1312.50	1521	656.25	760	-673.70	1.27E-02	3812.96	4181	1906.48	2281
4	C	induk	1 to 6	300	40	70	473.83	1.18E-02	3075.87	3421	1537.94	1901	-596.05	1.52E-02	3960.64	4181	1980.32	2281
5	D	induk	1 to 6	800	40	70	97.70	4.38E-03	1137.50	1140	568.75	760	-517.70	1.30E-02	3388.27	3421	1694.13	1901
6	D	induk	1 to 6	850	40	90	121.16	4.38E-03	1487.50	1521	743.75	760	-929.38	1.37E-02	4552.27	4561	2276.14	2281
7	A	induk	7 to 9	500	40	70	53.50	4.38E-03	1137.50	1140	568.75	760	-392.86	9.67E-03	2513.38	2661	1256.69	1521
8	B	induk	7 to 9	600	40	70	77.82	4.38E-03	1137.50	1140	568.75	760	-383.67	9.43E-03	2450.65	2661	1225.33	1521
9	B	induk	7 to 9	850	40	80	5.19	4.38E-03	1312.50	1521	656.25	760	-615.45	1.15E-02	3455.16	3801	1727.58	1901
10	C	induk	7 to 9	300	40	70	216.30	5.17E-03	1343.44	1521	671.72	760	-315.48	7.66E-03	1991.67	2281	995.83	1521
11	D	induk	7 to 9	800	40	70	46.67	4.38E-03	1137.50	1140	568.75	760	-461.69	1.15E-02	2990.37	3041	1495.18	1521
12	D	induk	7 to 9	850	40	90	8.82	4.38E-03	1487.50	1521	743.75	760	-796.59	1.16E-02	3948.56	4181	1974.28	2281
13	A	induk	roof	500	30	50							-55.44	4.38E-03	590.63	851	295.31	567
14	B	induk	roof	600	30	50							-42.74	4.38E-03	590.63	851	295.31	567
15	B	induk	roof	850	30	60	19.20	4.38E-03	721.88	851	360.94	567	-84.00	4.38E-03	721.88	851	360.94	567
16	C	induk	roof	300	30	50	11.23	4.38E-03	590.63	603	295.31	402	-26.80	4.38E-03	590.63	851	295.31	567
17	D	induk	roof	800	30	60	9.32	4.38E-03	721.88	851	360.94	567	-64.05	4.38E-03	721.88	851	360.94	567
18	D	induk	roof	850	30	60							-138.71	6.21E-03	1025.08	1134	512.54	567

Tabel 9.3.2.a. Perencanaan lentur

No	Pakai (mm2)		bE	Mn + tump (Nm)		Mn - tump (Nm)	
blk.	atas	bawah	(mm)	terpasang	perlu	terpasang	perlu
1	3801	1901	1250	402320.28	339075	739447.18	670530
2	3801	1901	1500	404172.85	294800	739447.18	674152.5
3	4181	2281	2125	498240.50	66150	888948.94	842126.25
4	4181	2281	750	657072.11	592287.5	858577.09	745066.88
5	3421	1901	2000	420342.34	122125	668200.19	647128.13
6	4561	2281	2125	691412.44	151450	1262571.03	1161720
7	2661	1521	1250	324897.41	66875	523384.55	491071.875
8	2661	1521	1500	329857.22	97275	523384.55	479587.5
9	3801	1901	2125	481156.40	6487.5	861107.89	769308.75
10	2281	1521	750	314325.16	270375	450327.84	394353.75
11	3041	1521	2000	345826.76	58337.5	595204.77	577106.25
12	4181	2281	2125	688173.45	11025	1139938.09	995741.25
13	851	567		59950.26		85623.51	69300
14	851	567		59950.26		85623.51	53418.75
15	851	567		99862.80	24000	145338.96	105000
16	851	567		59950.26	14040	85623.51	33495
17	851	567		99862.80	11650	145338.96	80062.5
18	1134	567		99508.48		191055.34	173381.25

Tabel 9.3.2.a. (Lanjutan - 1)

No blk.	Portal	Balok	lantai	L	b (cm)	h	Tu perlu (kNm)	x2. y (mm3)	Tu batas (kNm)	Tc (kNm)	Ts perlu (kNm)	At/S perlu (mm2/mm)
1	A	induk	1 to 6	500	40	70	28.02	1.11E+08	18.21	17.80	28.90	0.33
2	B	induk	1 to 6	600	40	70	27.72	1.14E+08	18.80	17.73	28.47	0.33
3	B	induk	1 to 6	850	40	80	54.16	1.39E+08	22.91	30.85	59.41	0.59
4	C	induk	1 to 6	300	40	70	0.57	1.04E+08	17.02	0.22	0.73	
5	D	induk	1 to 6	800	40	70	0.40	1.22E+08	19.98	0.31	0.36	
6	D	induk	1 to 6	850	40	90	37.08	1.55E+08	25.53	21.62	40.18	0.35
7	A	induk	7 to 9	500	40	70	28.02	1.11E+08	18.21	19.73	26.97	0.31
8	B	induk	7 to 9	600	40	70	27.72	1.14E+08	18.80	20.00	26.20	0.30
9	B	induk	7 to 9	850	40	80	54.16	1.39E+08	22.91	31.13	59.14	0.59
10	C	induk	7 to 9	300	40	70	0.57	1.04E+08	17.02	0.43	0.52	
11	D	induk	7 to 9	800	40	70	0.40	1.22E+08	19.98	0.33	0.34	
12	D	induk	7 to 9	850	40	90	37.08	1.55E+08	25.53	22.20	39.60	0.34
13	A	induk	roof	500	30	50	0.44	4.50E+07	7.39	1.14	-0.41	
14	B	induk	roof	600	30	50	5.69	4.50E+07	7.39	10.42	-0.94	
15	B	induk	roof	850	30	60	13.04	5.40E+07	8.87	17.88	3.86	0.08
16	C	induk	roof	300	30	50	0.29	4.50E+07	7.39	0.60	-0.12	
17	D	induk	roof	800	30	60	1.82	5.40E+07	8.87	5.59	-2.55	
18	D	induk	roof	850	30	60	20.95	5.40E+07	8.87	17.07	17.84	0.37

Tabel 9.3.2.b. Perencanaan geser dan torsi

No	Mn tump (Nm)		Vg (N)		Vu renc m.tump (N)		Vu max	Vu renc di	Vs perlu	Av/S	Av/S tot
blk.	+	-	c to c	m. tump	kiri	kanan	(N)	s.plastis (N)	(N)	perlu	perlu
1	402320.28	739447.18	162800	139194	379848.79	87541.39	971040	335404.39	559007.32	2.69	3.36
2	404172.85	739447.18	210120	185606	383691.49	-6081.11	807030	335889.19	559815.32	2.69	3.35
3	498240.50	888948.94	292400	266600	436548.16	-123311.84	700035	382368.16	637280.27	2.66	3.83
4	657072.11	858577.09	47920	35940	627156.13	551682.13	2411640	605352.53	1008920.89	4.85	4.85
5	420342.34	668200.19	227760	206408	348103.70	-85352.05	566790	309242.15	515403.58	2.48	2.48
6	691412.44	1262571.03	366440	327640	568987.70	-119057.29	922740	492035.30	820058.83	3.01	3.71
7	324897.41	523384.55	193160	165152	347034.35	215.57	552195	294301.67	490502.79	2.36	2.98
8	329857.22	523384.55	211280	186631	336827.59	-55096.81	513135	288761.39	481268.98	2.31	2.92
9	481156.40	861107.89	292040	266272	431131.32	-128039.38	546000	377018.03	628363.38	2.62	3.79
10	314325.16	450327.84	55720	41790	341244.55	253485.55	913080	315891.95	526486.59	2.53	2.53
11	345826.76	595204.77	227760	206408	330300.65	-103155.10	459270	291439.10	485731.83	2.34	2.34
12	688173.45	1139938.09	365840	327104	553932.57	-132985.83	701715	477106.17	795176.95	2.92	3.61
13	59950.26	85623.51	24720	21259	51944.73	7300.41	33390	47272.65	55650.00	0.39	0.39
14	59950.26	85623.51	36360	32118	57757.31	-9690.49	52395	52030.61	87325.00	0.61	0.61
15	99862.80	145338.96	22800	20922	49475.08	5538.14	60690	46376.96	77294.93	0.44	0.60
16	59950.26	85623.51	7680	5888	61563.73	49198.93	78120	59144.53	98574.21	0.68	0.68
17	99862.80	145338.96	21720	19820	50201.10	8580.15	56385	47065.27	78442.12	0.45	0.45
18	99508.48	191055.34	73200	65880	102408.42	-35939.58	101010	92461.84	154103.06	0.88	1.62

Tabel 9.3.2.b. (Lanjutan - 1)

No	Syarat jarak sengkang geser (mm)					Syarat jarak torsi		D tul.	kaki	S (mm)		At	Al perlu 1	Al perlu 2	Al max	pakai Al
blk.	d/4	8.d lt	24.d s	200	1600.fy.As/(As.fy)	(x1+y1)/4	300	(mm)		perlu	pakai	(mm2)	(mm2)	(mm2)	(mm2)	(mm2)
1	162.5	176	288	200	237.89	225	300	12	3	101.00	100	33.44	601.98	272.90	499.88	567
2	162.5	176	288	200	237.89	225	300	12	3	101.18	100	32.95	593.03	257.65	475.68	567
3	187.5	176	288	200	237.89	250	300	12	4	117.89	100	58.94	703.62	75.03	837.21	760
4	162.5	176	288	200	237.89	225	300	12	4	93.18	90					
5	162.5	176	288	200	237.89	225	300	12	3	136.81	100					
6	212.5	176	288	200	237.89	275	300	12	4	121.75	100	34.87	767.23	188.37	497.27	567
7	162.5	176	288	200	237.89	225	300	12	3	113.66	100	31.22	561.90	386.13	573.03	567
8	162.5	176	288	200	237.89	225	300	12	3	116.09	100	30.32	545.78	388.81	559.59	567
9	187.5	176	288	200	237.89	250	300	12	4	119.21	100	58.67	736.65	89.71	846.44	760
10	162.5	176	288	200	237.89	225	300	12	3	133.93	100					
11	162.5	176	288	200	237.89	225	300	12	3	145.17	100					
12	212.5	176	288	200	237.89	275	300	12	4	125.17	100	34.38	756.26	219.14	517.07	567
13	112.5	128	240	200	314.43	150	300	10	2	408.84	100					
14	112.5	128	240	200	314.43	150	300	10	2	260.54	100					
15	137.5	128	240	200	314.43	175	300	10	2	263.37	100	8.04	112.52	770.06	543.10	567
16	112.5	128	240	200	314.43	150	300	10	2	230.81	100					
17	137.5	128	240	200	314.43	175	300	10	2	354.50	100					
18	137.5	128	240	200	314.43	175	300	10	3	146.38	100	37.17	520.43	306.45	608.13	567

Tabel 9.3.2.b. (Lanjutan - 2)

No blk.	Vu renc. luar s.plastis (N)	Vc (N)	Vs perlu (N)	Av/S perlu	Av/S tot perlu	Kategori desain geser (lihat sub bab)				Syarat jarak		D tul (mm)	kaki	S perlu (mm)	pakai S (mm)
						0,5.phi.Vc	phi.Vc	syarat 3	syarat 4	d/2	600				
1	284122.39	237346.44	236190.88	1.14	1.80	71203.93	142407.86	194407.86	427223.59	325	600	12	2	125.25	100
2	276257.92	237346.44	223083.42	1.07	1.73	71203.93	142407.86	194407.86	427223.59	325	600	12	2	130.53	100
3	223110.25	273861.28	97989.14	0.41	1.59	82158.38	164316.77	224316.77	492950.30	375	600	12	2	142.40	100
4	580194.53	237346.44	729644.45	3.51	3.51	71203.93	142407.86	194407.86	427223.59	325	600				
5	195531.62	237346.44	88539.59	0.43	0.43	71203.93	142407.86	194407.86	427223.59	325	600	10	2	371.18	200
6	315170.16	310376.12	214907.49	0.79	1.49	93112.83	186225.67	254225.67	558677.01	425	600	10	2	106.21	100
7	233456.27	237346.44	151747.35	0.73	1.35	71203.93	142407.86	194407.86	427223.59	325	600	10	2	116.70	100
8	192757.45	237346.44	83915.97	0.40	1.01	71203.93	142407.86	194407.86	427223.59	325	600	10	2	156.46	150
9	214084.18	273861.28	82945.69	0.35	1.52	82158.38	164316.77	224316.77	492950.30	375	600	10	2	104.02	100
10	286638.95	237346.44	240385.15	1.16	1.16	71203.93	142407.86	194407.86	427223.59	325	600				
11	163363.35	237346.44	34925.81	0.17	0.17	71203.93	142407.86	194407.86	427223.59	325	600	10	2	940.97	200
12	289752.18	310376.12	172544.19	0.63	1.32	93112.83	186225.67	254225.67	558677.01	425	600	10	2	119.53	100
13	41562.33	123237.58	-53967.03	0.31	0.31	36971.27	73942.55	100942.55	221827.64	225	600	10	2	505.60	200
14	37169.21	123237.58	-61288.90	0.31	0.31	36971.27	73942.55	100942.55	221827.64	225	600	10	2	505.60	200
15	42715.55	150623.70	-79431.12	0.31	0.47	45187.11	90374.22	123374.22	271122.67	275	600	10	2	333.87	200
16	56187.73	123237.58	-29591.37	0.31	0.31	36971.27	73942.55	100942.55	221827.64	225	600				
17	43359.30	150623.70	-78358.21	0.31	0.31	45187.11	90374.22	123374.22	271122.67	275	600	10	2	505.60	200
18	50404.78	150623.70	-66615.73	0.31	1.06	45187.11	90374.22	123374.22	271122.67	275	600	10	2	149.62	100

Tabel 9.3.2.b. (Lanjutan - 3)

Vu1 = Vu,b - Vu,b ujung yang lain

= 379849 - 87541,4 = 292307,6 N

$$\frac{\text{ln}}{\text{ln - d}} = \frac{\text{Vu1}}{\text{Vu2}}$$

$$\text{Vu2} = 292307{,}6.\ \frac{427{,}5 - (70 - 5)}{427{,}5} = 247863{,}2\ \text{N}$$

Vu,b di d = Vu2 + Vu,b ujung yang lain

= 247863,2 + 87541,4 = 335404,4 N (pakai dalam perenc. geser)

Geser balok tidak perlu lebih dari :

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

$$= 1{,}05.\ (121 + 11 + 4.\ 198{,}2).\ 1000 = 971040\ \text{N}$$

Torsi :

Dari analisa struktur balok anak (file scndflor.frm) telah didapat torsi akibat beban statis Tu = 28,02 kNm

Berdasar SKSNI 3.4.6 :

$$\text{Tu batas} = \Phi.\ \frac{\sqrt{fc'}}{20}.\ \Sigma\ (x^2.\ y)$$

$$\Sigma\ (x^2.\ y) = b^2.\ h + 2.\ t\ \text{plat}^2.\ \frac{(bE - b)}{2}$$

$$= 400^2.\ 700 + 2.\ 120^2.\ \frac{1250{-}400}{2} = 156240000\ \text{mm}^3$$

$$\Sigma (x^2.\ y) = b^2.\ (h - t) + t\ \text{plat}^2.\ bE$$

$$= 400^2.\ (700 - 120) + 120^2.\ 1250 = 110800000\ \text{mm}^3\ \text{(menentukan)}$$

$$\text{Tu batas} = 0{,}6.\frac{\sqrt{30}}{20}.\ 110800000 = 18206297{,}8\ \text{Nmm}$$

$$= 18{,}21\ \text{kNm} \qquad < \text{Tu perlu}$$

(Maka torsi diperhitungkan bersama geser dan lentur)

Perhitungan tul. geser lentur dan torsi :

- Sendi plastis dari muka tumpuan sampai 2. h = 2. 700 = 1,4 m
- Di dalam sendi plastis, tul sengkang harus merupakan sengkang tertutup.

Vc di daerah sendi plastis = 0 (SKSNI 3.14.7.2) :

$$Vn = Vc + Vs$$

$$Vs\ perlu = \frac{Vu,b}{\Phi} = \frac{335404,4}{0,6} = 559007\ N$$

Kuat torsi oleh beton (SKSNI 3.4.6.6) :

$$Tc = \frac{\frac{\sqrt{fc'}}{15}.\sum x^2.y}{\sqrt{1+\left(\frac{0,4.Vu}{Ct.Tu}\right)^2}}$$

dimana : $Ct = \frac{bW.\ d}{\sum x^2.\ y} = \frac{400.650}{110800000} = 0,0024\ /mm$

$$Tc = \frac{\frac{\sqrt{30}}{15}.\ 110800000}{\sqrt{1+\left(\frac{0,4.\ 335404,4}{0,0024.\ 28020000}\right)^2}} = 17,8\ kNm$$

$$Tn = Tc + Ts \qquad (SKSNI\ 3.4.6.5)$$

$$Ts\ perlu = \frac{28,02}{0,6} - 17,8 = 28,9\ kNm$$

Kuat momen torsi :

$$Ts = \frac{At.\ \alpha t.\ x1.\ y1.\ fy}{S} \qquad \text{(SKSNI 3.4.6.9)}$$

dimana : $\alpha t = \frac{2 + \frac{y1}{x1}}{3}$, αt max = 1,5

y1 = dimensi panjang dari elemen persegi dari penampang

x1 = dimensi pendek dari elemen persegi dari penampang

tebal selimut beton ke tulangan paling tepi = 50 mm

y1 = 700 - 2. 50 = 600 mm

x1 = 400 - 2. 50 = 300 mm

$$\alpha t = \frac{2 + \frac{600}{300}}{3} = 1,3$$

Hitung tul transversal :

Torsi :

$$\frac{At}{S} = \frac{28900000}{1,3.\ 300.\ 600.\ 320} = 0,33\ mm^2/mm$$ (At = luas satu kaki tul torsi)

Geser :

$$Vs\ perlu = \frac{Av.\ fy.\ d}{S}$$

$$\frac{Av}{S} = \frac{559007}{320.\ 650} = 2,7\ mm^2/mm$$

$$\frac{Av\ total}{S} = 2.\ \frac{At}{S} + \frac{Av}{S}$$

$$= 2.\ 0,33 + 2,7 = 3,36\ mm^2/mm$$ (menentukan)

Sengkang tertutup minimum SKSNI 3.4.5.5.5. :

$$(Av + 2.\ At) = \frac{bw.\ S}{3.\ fy}$$

$$\min \frac{Av\ total}{S} = \frac{400}{3.\ 320}$$

$$= 0,42\ mm^2/mm \qquad < \left(\frac{Av\ total}{S}\right) perlu$$ (OK)

Dicoba tul. D 12 mm, Av 1 kaki tul .= 113 mm^2 :

$$S\ \text{perlu} = \frac{\text{Av total}}{3{,}36}$$

$$= \frac{2.\ 113}{3{,}36} = 66{,}5\ \text{mm}$$ = > jarak terlalu kecil, coba dengan 3 kaki :

$$S\ \text{perlu} = \frac{3.\ 113}{3{,}36} = 101\ \text{mm}$$

Syarat jarak sengkang di daerah sendi plastis berdasar SKSNI 3.14.3.3 :

- $S = \frac{d}{4}$
  $= \frac{650}{4} = 162{,}5$ mm
- $S = 8.\ \varnothing$ tul lentur
  $= 8.\ 22 = 176$ mm
- $S = 24.\ \varnothing$ sengkang
  $= 24.\ 12 = 288$ mm
- $S = 200$ mm
- $S = 1600.\ fy. \left(\frac{As1}{(As,a + As,b).\ fy}\right)$
  $= 1600.\ 320.\ \frac{113}{(380 + 380).\ 320} = 237{,}9$ mm

Syarat jarak sengkang torsi berdasar SKSNI 3.4.6.8. :

- $S = \frac{x1 + y1}{4}$
  $= \frac{300 + 600}{4} = 225$ mm
- $S = 300$ mm

(Dari syarat jarak diatas, pakai sengkang 3 D12 - 100 mm)

(Dipasang sampai dengan jarak 1,4 m dari muka tumpuan)

Tulangan memanjang (SKSNI 3.4.6.9) :

Pakai terbesar :

$$\text{Al perlu 1} = 2.\ At.\ \frac{x1 + y1}{S}$$

dimana : $\frac{At}{S} = 0{,}33\ \text{mm}^2/\text{mm}$

$$At = 100.\ 0{,}33 = 33\ \text{mm}^2$$

$$= 2.\ 33.\ \frac{300 + 600}{100} = 602\ \text{mm}^2$$

$$\text{Al perlu 2} = \left[\frac{2{,}8.\ x.\ S}{fy}\left(\frac{Tu}{Tu + \frac{Vu}{3.\ Ct}}\right) - 2.\ At\right].\left(\frac{x1 + y1}{S}\right)$$

dimana : $Ct = 0{,}0024\ /\text{mm}$

$$= \left[\frac{2{,}8.\ 300.\ 100}{320}.\left(\frac{28020000}{28020000 + \frac{335404{,}4}{3.\ 0{,}0024}}\right) - 2.\ 33\right].\left(\frac{300 + 600}{100}\right) = 273\ \text{mm}^2$$

Al tidak perlu lebih dari :

$$\text{Al max} = \left[\frac{2{,}8.\ x.\ S}{fy}\left(\frac{Tu}{Tu + \frac{Vu}{3.\ Ct}}\right) - 2.\ At\right].\left(\frac{x1 + y1}{S}\right)$$

dimana : $2.\ At = \frac{bw.\ S}{3.\ fy} = \frac{400.\ 100}{3.\ 320}$

$$= 41{,}7\ \text{mm}^2$$

$$= \left[\frac{2{,}8.\ 300.\ 100}{320}.\left(\frac{28020000}{28020000 + \frac{335404{,}4}{3.\ 0{,}0024}}\right) - 41{,}7\right].\left(\frac{300 + 600}{100}\right) = 500\ \text{mm}^2$$

Dari luas tulangan memanjang diatas, pakai Al = 500 mm^2

(pakai tul. memanjang 2 D 19 mm, As = 567 mm^2)

(pemasangan tul. disebarkan pada sengkang)

- Penulangan di lapangan

Di luar sendi plastis, tul sengkang direncanakan sengkang tertutup.

Dengan cara yang sama seperti di sub bab geser di tumpuan,

Vu,b luar sendi plastis (2. h = 140 cm) :

Vu1 = 292307,4 N (telah dihitung di sub bab geser di tumpuan)

$$Vu2 = 292307{,}4 \,.\, \frac{427{,}5 - 140}{427{,}5} = 196581 \text{ N}$$

Vu,b di (2. h) = Vu2 + Vu,b ujung yang lain

= 196581 + 87541,4 = 284122 N

Geser beton (SKSNI 3.14.7.2) :

$$Vc = \frac{\sqrt{fc'}}{6}.\ bw.\ d = \frac{\sqrt{30}}{6}.\ 400.\ 650 = 237346 \text{ N}$$

Syarat jarak sengkang :

$$(\Phi.\ Vc + \min \Phi.\ Vs) < Vu \leq (\Phi.\ Vc + \Phi.\ \frac{1}{3}.\ \sqrt{fc'}\ .\ bw.\ d)$$

$$(0{,}6.\ 237346 + 0{,}6.\ \frac{1}{3}.\ 400.\ 650) < 284122 \leq (0{,}6.\ 237346 + 0{,}6.\ \frac{1}{3}.\ \sqrt{30}\ .\ 400.\ 650)$$

$$194407{,}9 < 284122 \leq 427223{,}6 \text{ N} \qquad \text{(OK)}$$

Geser perlu :

$$Vn = Vc + Vs$$

$$Vs\ perlu = \frac{284122}{0{,}6} - 237346 = 236191 \text{ N}$$

$$Vs = \frac{Av.\ fy.\ d}{S}$$

Torsi perlu :

Anggap torsi bekerja pada seluruh penampang, Tu = 28,02 kNm

Ts perlu = 29,1 kNm (perhitungan seperti di tumpuan)

Hitung tul transversal :

$\frac{Av}{S} = \frac{236191}{320.\ 650} = 1,1$ mm^2/mm

tul. min. = 0,42 mm^2/mm

tul. perlu :

$(\frac{Av}{S})$ tot $= (\frac{2.\ At}{S} + \frac{Av}{S})$

$= 2.\ 0,33 + 1,1 = 1,8$ mm^2/mm (menentukan)

Dicoba tul. D 12 mm, Av 1 kaki tul .= 113 mm^2 :

S perlu $= \frac{2.\ 113}{1,8} = 127,6$ mm

Syarat jarak sengkang di luar sendi plastis berdasar SKSNI 3.14.3.3 :

- $S = \frac{d}{2} = \frac{650}{2} = 325$ mm
- S = 600 mm

Syarat jarak sengkang torsi :

- S = 225 mm
- S = 300 mm

(Dari syarat jarak diatas, pakai sengkang D12 - 100 mm)

Tul. memanjang :

Tul. memanjang di lapangan sama seperti di tumpuan.

(pakai tul. memanjang 2D19)

☐ Kontrol retak

Berdasar SKSNI 3.3.6, balok dengan fy tulangan tarik melebihi 300 MPa, harus dikontrol terjadinya retak. Pada balok ini, kontrol retak pada saat beban layan (akibat beban hidup dan mati).

$Z = fs^3\sqrt{dc.\,A}$

dimana : dc = jarak titik berat tul. ke serat tarik terluar beton

$A = \frac{2.\,dc.\,bw}{jml\ tul.}$

Z untuk di dalam ruangan < 30 MN/m

Di tumpuan (serat atas) :

$dc = 40 + 12 + \frac{1}{2}.22 = 63$ mm

$fs = 0{,}6.\,320 = 192$ MPa

$A = \frac{2.\,63.\,400}{10} = 5040\ mm^2$

$Z = 192^3\sqrt{63.\,5040} = 13100$ N/mm = 13,1 MN/m < 30 MN/m (OK)

Di lapangan (serat bawah) :

$A = \frac{2.\,63.\,400}{5} = 10080\ mm^2$

$Z = 192^3\sqrt{63.10080} = 16{,}5$ MN/m (OK)

☐ Kontrol lendutan

Berdasar SKSNI tabel 3.2.5(a), untuk balok non pratekan dengan dimensi lebih dari koefisien pada tabel, maka lendutan tidak perlu dihitung

$h\ min = \frac{L}{16}.\ (0{,}4 + fy/700)$

$= \frac{5000}{16}.\ (0{,}4 + 320/700) = 268$ mm < h terpasang (70 cm)

☐ **Pemutusan tulangan**

$$Lo \approx \frac{1}{4} . L$$

$$= \frac{1}{4} 500 = 125 \text{ cm}$$ (dari muka tumpuan)

☐ **Panjang penyaluran**

Panjang penyaluran min. tulangan lentur berdasarkan referensi Seismic Design of ..., bab 3.6.2, T paulay.

Panjang penyaluran tulangan baik tarik dan tekan ini juga disesuaikan dengan kondisi tumpuan, apakah tulangan tersebut diputus atau diteruskan/dilewatkan untuk penulangan pada balok yang bersebelahan.

Contoh perhitungan :

Pada tulangan deform tarik dengan kait standar 90°, batang 22 :

$150 \text{ mm} < l\ dh = mhb.\ l\ hb > 8.\ db$

dimana : mhb = faktor modifikasi

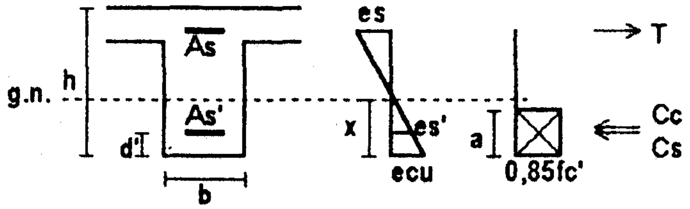
= 0,7 untuk selimut beton pada kait > 40 mm

$$l\ hb = \frac{1}{\sqrt{fc'}} 0,24.\ db.\ fy$$

$$= 0,24.\ 22.\ 320/\sqrt{30} = 308,5 \text{ mm}$$

$l\ dh\ min = 0,7.\ 308,5 = 217 \text{ mm}$

2. Perhitungan Mn - balok



T = Cc + Cs

$3801.320 = 0,85.\ 30.(x.\ 0,85).400 + (2.10^5.\ (\frac{0,003.\ x - 0,15}{x}) - 0,85.30).\ 1901$

didapat x = 88,6 mm > d'

$a = \beta.\ x = 0,85.\ 88,6 = 75,3$ mm

$fs' = 2.\ 10^5.\ (\frac{0,003.\ 88,6 - 0,15}{88,6}) - 0,85.\ 30 = 261,4$ MPa (belum leleh)

Cc = 0,85. 30. 75,3. 400 = 768162 N

Cs = 261,4. 1901 = 448445 N

$Mn\text{ - balok} = Cc.\ (d - \frac{a}{2}) + Cs.\ (d - d')$

$= 768162.\ (650 - \frac{75,3}{2}) + 448445.\ (650 - 50)$

= 739447 Nm > Mn - perlu (OK)

<u>Cek tul. longitudinal berdasar SKSNI 3.14.3.2 :</u>

1. Mn + harus lebih besar dari $(\frac{1}{2}.\ Mn\ -)$.
2. Kuat momen positif dan negatif di tiap bentang harus lebih besar dari $\frac{1}{4}$ momen maksimum di kedua ujung joint.

☐ **Penulangan lentur di lapangan**

Mu = 1,2. 89,5 + 1,6. 3,4 = 112,8 kNm

Rn = 0,8 MPa

ρ perlu = 0,0021 , pakai ρ min = 0,00438

As perlu = 0,00438. 400 (700 - 50) = 1137,5 mm^2

(Pakai tul. 5 D 22 mm, As = 1901 mm^2)

As' = 0,5. 1137,5 = 568,8 mm^2 (Pakai tul. 2 D 22 mm, As' = 760 mm^2)

Perhitungan Mn balok :

Dengan cara yang sama seperti di tumpuan :

$$\frac{0{,}003}{es'} = \frac{x}{x - 50}$$

T = Cc + Cs

As. fy = 0,85. fc'. a. bE + As'. (fs' - 0,85. fc')

$$1901.\ 320 = 0{,}85.\ 30.\ (x.\ 0{,}85).1250 + 760.\ (2.\ 10^5.\ (\frac{0{,}003.x - 0{,}15}{x}) - 0{,}85.30)$$

didapat x = 22,3 mm < d' (50 mm) (garis netral diatas tulangan tekan)

Anggap g.n. diatas tul. tekan :

T + Cs = Cc

As. fy + As'. fs' = 0,85. fc'. (x. β). bE

$$1901.\ 320 + 760.\ 2.\ 10^5.\ \left(\frac{0{,}15 - 0{,}003.\ x}{x}\right) - 0{,}85.\ 30.\ (x.\ 0{,}85).\ 1250 = 0$$

didapat x = 32 mm, a = 32. 0,85 = 27,2 mm

$$\varepsilon s' = \left(\frac{0{,}15 - 0{,}003.32}{32}\right) = 0{,}0017$$

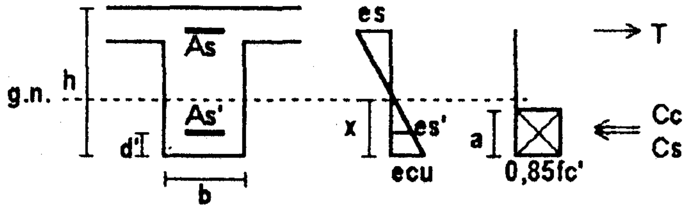
fs' = 200000. 0,0017 = 337,5 MPa > 320 MPa (tul. leleh, pakai fy)

$$\text{Mn terpasang} = Cc.\ (d - \frac{a}{2}) - Cs.\ (d - d')$$

$$= 0{,}85.\ 30.\ 27{,}2.\ 1250.\ (650 - \frac{27{,}2}{2}) - 760.\ 320.\ (650 - 50)$$

= 405838,8 Nm > Mn perlu (OK)

2. Perhitungan Mn - balok



T = Cc + Cs

$3801.320 = 0,85.\ 30.(x.\ 0,85).400 + (2.10^5.\ (\frac{0,003.\ x - 0,15}{x}) - 0,85.30).\ 1901$

didapat x = 88,6 mm > d'

$a = \beta.\ x = 0,85.\ 88,6 = 75,3$ mm

$fs' = 2.\ 10^5.\ (\frac{0,003.\ 88,6 - 0,15}{88,6}) - 0,85.\ 30 = 261,4$ MPa (belum leleh)

Cc = 0,85. 30. 75,3. 400 = 768162 N

Cs = 261,4. 1901 = 448445 N

$Mn - balok = Cc.\ (d - \frac{a}{2}) + Cs.\ (d - d')$

$= 768162.\ (650 - \frac{75,3}{2}) + 448445.\ (650 - 50)$

= 739447 Nm > Mn - perlu (OK)

Cek tul. longitudinal berdasar SKSNI 3.14.3.2 :

1. Mn + harus lebih besar dari $(\frac{1}{2}.$ Mn -).
2. Kuat momen positif dan negatif di tiap bentang harus lebih besar dari $\frac{1}{4}$ momen maksimum di kedua ujung joint.

☐ **Penulangan lentur di lapangan**

$Mu = 1{,}2.\ 89{,}5 + 1{,}6.\ 3{,}4 = 112{,}8$ kNm

$Rn = 0{,}8$ MPa

ρ perlu = 0,0021 , pakai ρmin = 0,00438

As perlu = 0,00438. 400 (700 - 50) = 1137,5 mm^2

(Pakai tul. 5 D 22 mm, As = 1901 mm^2)

As' = 0,5. 1137,5 = 568,8 mm^2 (Pakai tul. 2 D 22 mm, As' = 760 mm^2)

Perhitungan Mn balok :

Dengan cara yang sama seperti di tumpuan :

$$\frac{0{,}003}{es'} = \frac{x}{x - 50}$$

$$T = Cc + Cs$$

$$As.\ fy = 0{,}85.\ fc'.\ a.\ bE + As'.\ (fs' - 0{,}85.\ fc')$$

$$1901.\ 320 = 0{,}85.\ 30.\ (x.\ 0{,}85).1250 + 760.\ (2.\ 10^5.\ (\frac{0{,}003.x - 0{,}15}{x}) - 0{,}85.30)$$

didapat x = 22,3 mm < d' (50 mm) (garis netral diatas tulangan tekan)

Anggap g.n. diatas tul. tekan :

$$T + Cs = Cc$$

$$As.\ fy + As'.\ fs' = 0{,}85.\ fc'.\ (x.\ \beta).\ bE$$

$$1901.\ 320 + 760.\ 2.\ 10^5.\ \left(\frac{0{,}15 - 0{,}003.\ x}{x}\right) - 0{,}85.\ 30.\ (x.\ 0{,}85).\ 1250 = 0$$

didapat x = 32 mm, a = 32. 0,85 = 27,2 mm

$$\varepsilon s' = \left(\frac{0{,}15 - 0{,}003.32}{32}\right) = 0{,}0017$$

fs' = 200000. 0,0017 = 337,5 MPa > 320 MPa (tul. leleh, pakai fy)

$$Mn\ terpasang = Cc.\ (d - \frac{a}{2}) - Cs.\ (d - d')$$

$$= 0{,}85.\ 30.\ 27{,}2.\ 1250.\ (650 - \frac{27{,}2}{2}) - 760.\ 320.\ (650 - 50)$$

= 405838,8 Nm > Mn perlu (OK)

Perhitungan tul. geser lentur dan torsi :

- Sendi plastis dari muka tumpuan sampai 2. h = 2. 700 = 1,4 m
- Di dalam sendi plastis, tul sengkang harus merupakan sengkang tertutup.

Vc di daerah sendi plastis = 0 (SKSNI 3.14.7.2) :

$$Vn = Vc + Vs$$

$$Vs\ perlu = \frac{Vu,b}{\Phi} = \frac{335404,4}{0,6} = 559007\ N$$

Kuat torsi oleh beton (SKSNI 3.4.6.6) :

$$Tc = \frac{\frac{\sqrt{fc'}}{15} . \sum x^2.y}{\sqrt{1+\left(\frac{0,4.Vu}{Ct.\ Tu}\right)^2}}$$

dimana : $Ct = \frac{bW.\ d}{\sum x^2.\ y} = \frac{400.650}{110800000} = 0,0024\ /mm$

$$Tc = \frac{\frac{\sqrt{30}}{15} .\ 110800000}{\sqrt{1+\left(\frac{0,4.\ 335404,4}{0,0024.\ 28020000}\right)^2}} = 17,8\ kNm$$

$Tn = Tc + Ts$ (SKSNI 3.4.6.5)

$$Ts\ perlu = \frac{28,02}{0,6} - 17,8 = 28,9\ kNm$$

Kuat momen torsi :

$$Ts = \frac{At.\ \alpha t.\ x1.\ y1.\ fy}{S} \qquad \text{(SKSNI 3.4.6.9)}$$

dimana : $\alpha t = \dfrac{2 + \frac{y1}{x1}}{3}$, αt max = 1,5

y1 = dimensi panjang dari elemen persegi dari penampang

x1 = dimensi pendek dari elemen persegi dari penampang

tebal selimut beton ke tulangan paling tepi = 50 mm

$y1 = 700 - 2.\ 50 = 600$ mm

$x1 = 400 - 2.\ 50 = 300$ mm

$$\alpha t = \frac{2 + \frac{600}{300}}{3} = 1,3$$

Hitung tul transversal :

Torsi :

$$\frac{At}{S} = \frac{28900000}{1,3.\ 300.\ 600.\ 320} = 0,33 \text{ mm}^2/\text{mm} \qquad \text{(At = luas satu kaki tul torsi)}$$

Geser :

$$Vs \text{ perlu} = \frac{Av.\ fy.\ d}{S}$$

$$\frac{Av}{S} = \frac{559007}{320.\ 650} = 2,7 \text{ mm}^2/\text{mm}$$

$$\frac{Av\ total}{S} = 2.\ \frac{At}{S} + \frac{Av}{S}$$

$$= 2.\ 0,33 + 2,7 = 3,36 \text{ mm}^2/\text{mm} \qquad \text{(menentukan)}$$

Sengkang tertutup minimum SKSNI 3.4.5.5.5. :

$$(Av + 2.\ At) = \frac{bw.\ S}{3.\ fy}$$

$$\min \frac{Av\ total}{S} = \frac{400}{3.\ 320}$$

$$= 0,42 \text{ mm}^2/\text{mm} \qquad < \left(\frac{Av\ total}{S}\right) \text{perlu} \qquad \text{(OK)}$$

Dicoba tul. D 12 mm, Av 1 kaki tul .= 113 mm^2 :

$$S\ perlu = \frac{Av\ total}{3,36}$$
$$= \frac{2.\ 113}{3,36} = 66,5\ mm$$ = > jarak terlalu kecil, coba dengan 3 kaki :
$$S\ perlu = \frac{3.\ 113}{3,36} = 101\ mm$$

Syarat jarak sengkang di daerah sendi plastis berdasar SKSNI 3.14.3.3 :

- $S = \frac{d}{4}$
  $= \frac{650}{4} = 162,5\ mm$
- $S = 8.\ \varnothing$ tul lentur
  $= 8.\ 22 = 176\ mm$
- $S = 24.\ \varnothing$ sengkang
  $= 24.\ 12 = 288\ mm$
- $S = 200\ mm$
- $S = 1600.\ fy.\ \left(\frac{As1}{(As,a + As,b).\ fy}\right)$
  $= 1600.\ 320.\ \frac{113}{(380 + 380).\ 320} = 237,9\ mm$

Syarat jarak sengkang torsi berdasar SKSNI 3.4.6.8. :

- $S = \frac{x1 + y1}{4}$
  $= \frac{300 + 600}{4} = 225\ mm$
- $S = 300\ mm$

(Dari syarat jarak diatas, pakai sengkang 3 D12 - 100 mm)

(Dipasang sampai dengan jarak 1,4 m dari muka tumpuan)

Tulangan memanjang (SKSNI 3.4.6.9) :

Pakai terbesar :

$$\text{Al perlu 1} = 2.\ \text{At}.\ \frac{\text{xl} + \text{yl}}{\text{S}}$$

dimana : $\frac{\text{At}}{\text{S}} = 0{,}33\ \text{mm}^2/\text{mm}$

$$\text{At} = 100.\ 0{,}33 = 33\ \text{mm}^2$$

$$= 2.\ 33.\ \frac{300 + 600}{100} = 602\ \text{mm}^2$$

$$\text{Al perlu 2} = \left[\frac{2{,}8.\ \text{x}.\ \text{S}}{\text{fy}}\left(\frac{\text{Tu}}{\text{Tu} + \frac{\text{Vu}}{3.\ \text{Ct}}}\right) - 2.\ \text{At}\right].\left(\frac{\text{xl} + \text{yl}}{\text{S}}\right)$$

dimana : $\text{Ct} = 0{,}0024\ /\text{mm}$

$$= \left[\frac{2{,}8.\ 300.\ 100}{320}.\left(\frac{28020000}{28020000 + \frac{335404{,}4}{3.\ 0{,}0024}}\right) - 2.\ 33\right].\left(\frac{300 + 600}{100}\right) = 273\ \text{mm}^2$$

Al tidak perlu lebih dari :

$$\text{Al max} = \left[\frac{2{,}8.\ \text{x}.\ \text{S}}{\text{fy}}\left(\frac{\text{Tu}}{\text{Tu} + \frac{\text{Vu}}{3.\ \text{Ct}}}\right) - 2.\ \text{At}\right].\left(\frac{\text{xl} + \text{yl}}{\text{S}}\right)$$

dimana : $2.\ \text{At} = \frac{\text{bw}.\ \text{S}}{3.\ \text{fy}} = \frac{400.\ 100}{3.\ 320}$

$$= 41{,}7\ \text{mm}^2$$

$$= \left[\frac{2{,}8.\ 300.\ 100}{320}.\left(\frac{28020000}{28020000 + \frac{335404{,}4}{3.\ 0{,}0024}}\right) - 41{,}7\right].\left(\frac{300 + 600}{100}\right) = 500\ \text{mm}^2$$

Dari luas tulangan memanjang diatas, pakai Al = 500 mm^2

(pakai tul. memanjang 2 D 19 mm, As = 567 mm^2)

(pemasangan tul. disebarkan pada sengkang)

- Penulangan di lapangan

Di luar sendi plastis, tul sengkang direncanakan sengkang tertutup.

Dengan cara yang sama seperti di sub bab geser di tumpuan,

Vu,b luar sendi plastis (2. h = 140 cm) :

Vu1 = 292307,4 N (telah dihitung di sub bab geser di tumpuan)

$$Vu2 = 292307{,}4 \ . \ \frac{427{,}5 - 140}{427{,}5} = 196581 \text{ N}$$

Vu,b di (2. h) = Vu2 + Vu,b ujung yang lain

= 196581 + 87541,4 = 284122 N

Geser beton (SKSNI 3.14.7.2) :

$$Vc = \frac{\sqrt{fc'}}{6} . \ bw. \ d = \frac{\sqrt{30}}{6} . \ 400. \ 650 = 237346 \text{ N}$$

Syarat jarak sengkang :

$$(\Phi. \ Vc + \min \Phi. \ Vs) < Vu \leq (\Phi. \ Vc + \Phi. \ \frac{1}{3}. \ \sqrt{fc'} \ . \ bw. \ d)$$

$$(0{,}6. \ 237346 + 0{,}6. \ \frac{1}{3}. \ 400. \ 650) < 284122 \leq (0{,}6. \ 237346 + 0{,}6. \ \frac{1}{3}. \ \sqrt{30} \ . \ 400. \ 650)$$

$$194407{,}9 < 284122 \leq 427223{,}6 \text{ N} \qquad \text{(OK)}$$

Geser perlu :

$$Vn = Vc + Vs$$

$$Vs \text{ perlu} = \frac{284122}{0{,}6} - 237346 = 236191 \text{ N}$$

$$Vs = \frac{Av. \ fy. \ d}{S}$$

Torsi perlu :

Anggap torsi bekerja pada seluruh penampang, Tu = 28,02 kNm

Ts perlu = 29,1 kNm (perhitungan seperti di tumpuan)

Hitung tul transversal :

$\frac{Av}{S} = \frac{236191}{320.\ 650} = 1,1\ mm^2/mm$

tul. min. = 0,42 mm^2/mm

tul. perlu :

$(\frac{Av}{S})\ tot = (\frac{2.\ At}{S} + \frac{Av}{S})$

$= 2.\ 0,33 + 1,1 = 1,8\ mm^2/mm$ (menentukan)

Dicoba tul. D 12 mm, Av 1 kaki tul .= 113 mm^2 :

$S\ perlu = \frac{2.\ 113}{1,8} = 127,6\ mm$

Syarat jarak sengkang di luar sendi plastis berdasar SKSNI 3.14.3.3 :

- $S = \frac{d}{2} = \frac{650}{2} = 325$ mm
- S = 600 mm

Syarat jarak sengkang torsi :

- S = 225 mm
- S = 300 mm

(Dari syarat jarak diatas, pakai sengkang D12 - 100 mm)

Tul. memanjang :

Tul. memanjang di lapangan sama seperti di tumpuan.

(pakai tul. memanjang 2D19)

☐ Kontrol retak

Berdasar SKSNI 3.3.6, balok dengan fy tulangan tarik melebihi 300 MPa, harus dikontrol terjadinya retak. Pada balok ini, kontrol retak pada saat beban layan (akibat beban hidup dan mati).

$Z = fs^3 \sqrt{dc.\ A}$

dimana : dc = jarak titik berat tul. ke serat tarik terluar beton

$A = \frac{2.\ dc.\ bw}{jml\ tul.}$

Z untuk di dalam ruangan < 30 MN/m

Di tumpuan (serat atas) :

$dc = 40 + 12 + \frac{1}{2}.22 = 63$ mm

$fs = 0,6.\ 320 = 192$ MPa

$A = \frac{2.\ 63.\ 400}{10} = 5040\ mm^2$

$Z = 192^3 \sqrt{63.\ 5040} = 13100$ N/mm = 13,1 MN/m < 30 MN/m (OK)

Di lapangan (serat bawah) :

$A = \frac{2.\ 63.\ 400}{5} = 10080\ mm^2$

$Z = 192^3 \sqrt{63.10080} = 16,5$ MN/m (OK)

☐ Kontrol lendutan

Berdasar SKSNI tabel 3.2.5(a), untuk balok non pratekan dengan dimensi lebih dari koefisien pada tabel, maka lendutan tidak perlu dihitung

$h\ min = \frac{L}{16}.\ (0,4 + fy/700)$

$= \frac{5000}{16}.\ (0,4 + 320/700) = 268$ mm < h terpasang (70 cm)

No	Portal	Balok		L	h	b	m=	span (kN/m')		pakai q	span (kN/m')		pakai q	P balok	P kuda2
		induk		(cm)	(cm)	(cm)	S/L	short	long	hidup (kN/m')	short	long	mati (kN/m')	anak (kN)	(kN)
1	A	induk	lantai	500	70	40	0.83	2.5		5	7.65		15.30	167.06	
2	B	induk	lantai	600	70	40	0.50		4.13	8.25		12.62	25.25	149.86	
3	B	induk	lantai	850	80	40	0.50	3		6	9.18		18.36	197.65	
4	C	induk	lantai	300	70	40	1.00	3		6	9.18		18.36		
5	D	induk	lantai	800	70	40	0.38		4.29	4.29		13.12	45.92		
6	D	induk	lantai	850	90	40	0.38	3		6	9.18		18.36	345.07	
7	A	induk	atap	500	50	30									24.38
8	B	induk	atap	600	50	30							8	8.5	
9	B	induk	atap	850	60	30								30	24.38
10	C	induk	atap	300	50	30									
11	D	induk	atap	800	50	30									12
12	D	induk	atap	850	60	30								30	24.38

Tabel 9.1.2. Beban pada balok induk

No	Portal	Balok	lantai	L	b	h	Mu + tump	ro	As (mm2)		As' (mm2)		Mu - tump	ro	As (mm2)		As' (mm2)	
blk.					(cm)		(kNm)	perlu	perlu	pasang	perlu	pasang	(kNm)	perlu	perlu	pasang	perlu	pasang
1	A	induk	1 to 6	500	40	70	271.26	6.54E-03	1699.91	1901	849.95	1140	-536.42	1.36E-02	3523.30	3801	1761.65	1901
2	B	induk	1 to 6	600	40	70	235.84	5.65E-03	1469.42	1521	734.71	760	-539.32	1.36E-02	3544.30	3801	1772.15	1901
3	B	induk	1 to 6	850	40	80	52.92	4.38E-03	1312.50	1521	656.25	760	-673.70	1.27E-02	3812.96	4181	1906.48	2281
4	C	induk	1 to 6	300	40	70	473.83	1.18E-02	3075.87	3421	1537.94	1901	-596.05	1.52E-02	3960.64	4181	1980.32	2281
5	D	induk	1 to 6	800	40	70	97.70	4.38E-03	1137.50	1140	568.75	760	-517.70	1.30E-02	3388.27	3421	1694.13	1901
6	D	induk	1 to 6	850	40	90	121.16	4.38E-03	1487.50	1521	743.75	760	-929.38	1.37E-02	4552.27	4561	2276.14	2281
7	A	induk	7 to 9	500	40	70	53.50	4.38E-03	1137.50	1140	568.75	760	-392.86	9.67E-03	2513.38	2661	1256.69	1521
8	B	induk	7 to 9	600	40	70	77.82	4.38E-03	1137.50	1140	568.75	760	-383.67	9.43E-03	2450.65	2661	1225.33	1521
9	B	induk	7 to 9	850	40	80	5.19	4.38E-03	1312.50	1521	656.25	760	-615.45	1.15E-02	3455.16	3801	1727.58	1901
10	C	induk	7 to 9	300	40	70	216.30	5.17E-03	1343.44	1521	671.72	760	-315.48	7.66E-03	1991.67	2281	995.83	1521
11	D	induk	7 to 9	800	40	70	46.67	4.38E-03	1137.50	1140	568.75	760	-461.69	1.15E-02	2990.37	3041	1495.18	1521
12	D	induk	7 to 9	850	40	90	8.82	4.38E-03	1487.50	1521	743.75	760	-796.59	1.16E-02	3948.56	4181	1974.28	2281
13	A	induk	roof	500	30	50							-55.44	4.38E-03	590.63	851	295.31	567
14	B	induk	roof	600	30	50							-42.74	4.38E-03	590.63	851	295.31	567
15	B	induk	roof	850	30	60	19.20	4.38E-03	721.88	851	360.94	567	-84.00	4.38E-03	721.88	851	360.94	567
16	C	induk	roof	300	30	50	11.23	4.38E-03	590.63	603	295.31	402	-26.80	4.38E-03	590.63	851	295.31	567
17	D	induk	roof	800	30	60	9.32	4.38E-03	721.88	851	360.94	567	-64.05	4.38E-03	721.88	851	360.94	567
18	D	induk	roof	850	30	60							-138.71	6.21E-03	1025.08	1134	512.54	567

Tabel 9.3.2.a. Perencanaan lentur

No	Pakai (mm2)		bE	Mn + tump (Nm)		Mn - tump (Nm)	
blk.	atas	bawah	(mm)	terpasang	perlu	terpasang	perlu
1	3801	1901	1250	402320.28	339075	739447.18	670530
2	3801	1901	1500	404172.85	294800	739447.18	674152.5
3	4181	2281	2125	498240.50	66150	888948.94	842126.25
4	4181	2281	750	657072.11	592287.5	858577.09	745066.88
5	3421	1901	2000	420342.34	122125	668200.19	647128.13
6	4561	2281	2125	691412.44	151450	1262571.03	1161720
7	2661	1521	1250	324897.41	66875	523384.55	491071.875
8	2661	1521	1500	329857.22	97275	523384.55	479587.5
9	3801	1901	2125	481156.40	6487.5	861107.89	769308.75
10	2281	1521	750	314325.16	270375	450327.84	394353.75
11	3041	1521	2000	345826.76	58337.5	595204.77	577106.25
12	4181	2281	2125	688173.45	11025	1139938.09	995741.25
13	851	567		59950.26		85623.51	69300
14	851	567		59950.26		85623.51	53418.75
15	851	567		99862.80	24000	145338.96	105000
16	851	567		59950.26	14040	85623.51	33495
17	851	567		99862.80	11650	145338.96	80062.5
18	1134	567		99508.48		191055.34	173381.25

Tabel 9.3.2.a. (Lanjutan - 1)

No blk.	Portal	Balok	lantai	L	b (cm)	h	Tu perlu (kNm)	x2. y (mm3)	Tu batas (kNm)	Tc (kNm)	Ts perlu (kNm)	At/S perlu (mm2/mm)
1	A	induk	1 to 6	500	40	70	28.02	1.11E+08	18.21	17.80	28.90	0.33
2	B	induk	1 to 6	600	40	70	27.72	1.14E+08	18.80	17.73	28.47	0.33
3	B	induk	1 to 6	850	40	80	54.16	1.39E+08	22.91	30.85	59.41	0.59
4	C	induk	1 to 6	300	40	70	0.57	1.04E+08	17.02	0.22	0.73	
5	D	induk	1 to 6	800	40	70	0.40	1.22E+08	19.98	0.31	0.36	
6	D	induk	1 to 6	850	40	90	37.08	1.55E+08	25.53	21.62	40.18	0.35
7	A	induk	7 to 9	500	40	70	28.02	1.11E+08	18.21	19.73	26.97	0.31
8	B	induk	7 to 9	600	40	70	27.72	1.14E+08	18.80	20.00	26.20	0.30
9	B	induk	7 to 9	850	40	80	54.16	1.39E+08	22.91	31.13	59.14	0.59
10	C	induk	7 to 9	300	40	70	0.57	1.04E+08	17.02	0.43	0.52	
11	D	induk	7 to 9	800	40	70	0.40	1.22E+08	19.98	0.33	0.34	
12	D	induk	7 to 9	850	40	90	37.08	1.55E+08	25.53	22.20	39.60	0.34
13	A	induk	roof	500	30	50	0.44	4.50E+07	7.39	1.14	-0.41	
14	B	induk	roof	600	30	50	5.69	4.50E+07	7.39	10.42	-0.94	
15	B	induk	roof	850	30	60	13.04	5.40E+07	8.87	17.88	3.86	0.08
16	C	induk	roof	300	30	50	0.29	4.50E+07	7.39	0.60	-0.12	
17	D	induk	roof	800	30	60	1.82	5.40E+07	8.87	5.59	-2.55	
18	D	induk	roof	850	30	60	20.95	5.40E+07	8.87	17.07	17.84	0.37

Tabel 9.3.2.b. Perencanaan geser dan torsi

No	Mn tump (Nm)		Vg (N)		Vu renc m.tump (N)		Vu max	Vu renc di	Vs perlu	Av/S	Av/S tot
blk.	+	-	c to c	m. tump	kiri	kanan	(N)	s.plastis (N)	(N)	perlu	perlu
1	402320.28	739447.18	162800	139194	379848.79	87541.39	971040	335404.39	559007.32	2.69	3.36
2	404172.85	739447.18	210120	185606	383691.49	-6081.11	807030	335889.19	559815.32	2.69	3.35
3	498240.50	888948.94	292400	266600	436548.16	-123311.84	700035	382368.16	637280.27	2.66	3.83
4	657072.11	858577.09	47920	35940	627156.13	551682.13	2411640	605352.53	1008920.89	4.85	4.85
5	420342.34	668200.19	227760	206408	348103.70	-85352.05	566790	309242.15	515403.58	2.48	2.48
6	691412.44	1262571.03	366440	327640	568987.70	-119057.29	922740	492035.30	820058.83	3.01	3.71
7	324897.41	523384.55	193160	165152	347034.35	215.57	552195	294301.67	490502.79	2.36	2.98
8	329857.22	523384.55	211280	186631	336827.59	-55096.81	513135	288761.39	481268.98	2.31	2.92
9	481156.40	861107.89	292040	266272	431131.32	-128039.38	546000	377018.03	628363.38	2.62	3.79
10	314325.16	450327.84	55720	41790	341244.55	253485.55	913080	315891.95	526486.59	2.53	2.53
11	345826.76	595204.77	227760	206408	330300.65	-103155.10	459270	291439.10	485731.83	2.34	2.34
12	688173.45	1139938.09	365840	327104	553932.57	-132985.83	701715	477106.17	795176.95	2.92	3.61
13	59950.26	85623.51	24720	21259	51944.73	7300.41	33390	47272.65	55650.00	0.39	0.39
14	59950.26	85623.51	36360	32118	57757.31	-9690.49	52395	52030.61	87325.00	0.61	0.61
15	99862.80	145338.96	22800	20922	49475.08	5538.14	60690	46376.96	77294.93	0.44	0.60
16	59950.26	85623.51	7680	5888	61563.73	49198.93	78120	59144.53	98574.21	0.68	0.68
17	99862.80	145338.96	21720	19820	50201.10	8580.15	56385	47065.27	78442.12	0.45	0.45
18	99508.48	191055.34	73200	65880	102408.42	-35939.58	101010	92461.84	154103.06	0.88	1.62

Tabel 9.3.2.b. (Lanjutan - 1)

No	Syarat jarak sengkang geser (mm)					Syarat jarak torsi		D tul.	kaki	S (mm)		At	Al perlu 1	Al perlu 2	Al max	pakai Al
blk.	d/4	8.d lt	24.d s	200	1600.fy.As/(As.fy)	(x1+y1)/4	300	(mm)		perlu	pakai	(mm2)	(mm2)	(mm2)	(mm2)	(mm2)
1	162.5	176	288	200	237.89	225	300	12	3	101.00	100	33.44	601.98	272.90	499.88	567
2	162.5	176	288	200	237.89	225	300	12	3	101.18	100	32.95	593.03	257.65	475.68	567
3	187.5	176	288	200	237.89	250	300	12	4	117.89	100	58.94	703.62	75.03	837.21	760
4	162.5	176	288	200	237.89	225	300	12	4	93.18	90					
5	162.5	176	288	200	237.89	225	300	12	3	136.81	100					
6	212.5	176	288	200	237.89	275	300	12	4	121.75	100	34.87	767.23	188.37	497.27	567
7	162.5	176	288	200	237.89	225	300	12	3	113.66	100	31.22	561.90	386.13	573.03	567
8	162.5	176	288	200	237.89	225	300	12	3	116.09	100	30.32	545.78	388.81	559.59	567
9	187.5	176	288	200	237.89	250	300	12	4	119.21	100	58.67	738.65	89.71	846.44	760
10	162.5	176	288	200	237.89	225	300	12	3	133.93	100					
11	162.5	176	288	200	237.89	225	300	12	3	145.17	100					
12	212.5	176	288	200	237.89	275	300	12	4	125.17	100	34.38	756.26	219.14	517.07	567
13	112.5	128	240	200	314.43	150	300	10	2	408.84	100					
14	112.5	128	240	200	314.43	150	300	10	2	260.54	100					
15	137.5	128	240	200	314.43	175	300	10	2	263.37	100	8.04	112.52	770.06	543.10	567
16	112.5	128	240	200	314.43	150	300	10	2	230.81	100					
17	137.5	128	240	200	314.43	175	300	10	2	354.50	100					
18	137.5	128	240	200	314.43	175	300	10	3	146.38	100	37.17	520.43	306.45	608.13	567

Tabel 9.3.2.b. (Lanjutan - 2)

No blk.	Vu renc. luar s.plastis (N)	Vc (N)	Vs perlu (N)	Av/S perlu	Av/S tot perlu	Kategori desain geser (lihat sub bab)				Syarat jarak		D tul (mm)	kaki	S perlu (mm)	pakai S (mm)
						0,5.phi.Vc	phi.Vc	syarat 3	syarat 4	d/2	600				
1	284122.39	237346.44	236190.88	1.14	1.80	71203.93	142407.86	194407.86	427223.59	325	600	12	2	125.25	100
2	276257.92	237346.44	223083.42	1.07	1.73	71203.93	142407.86	194407.86	427223.59	325	600	12	2	130.53	100
3	223110.25	273861.28	97989.14	0.41	1.59	82158.38	164316.77	224316.77	492950.30	375	600	12	2	142.40	100
4	580194.53	237346.44	729644.45	3.51	3.51	71203.93	142407.86	194407.86	427223.59	325	600				
5	195531.62	237346.44	88539.59	0.43	0.43	71203.93	142407.86	194407.86	427223.59	325	600	10	2	371.18	200
6	315170.16	310376.12	214907.49	0.79	1.49	93112.83	186225.67	254225.67	558677.01	425	600	10	2	106.21	100
7	233456.27	237346.44	151747.35	0.73	1.35	71203.93	142407.86	194407.86	427223.59	325	600	10	2	116.70	100
8	192757.45	237346.44	83915.97	0.40	1.01	71203.93	142407.86	194407.86	427223.59	325	600	10	2	156.46	150
9	214084.18	273861.28	82945.69	0.35	1.52	82158.38	164316.77	224316.77	492950.30	375	600	10	2	104.02	100
10	286638.95	237346.44	240385.15	1.16	1.16	71203.93	142407.86	194407.86	427223.59	325	600				
11	163363.35	237346.44	34925.81	0.17	0.17	71203.93	142407.86	194407.86	427223.59	325	600	10	2	940.97	200
12	289752.18	310376.12	172544.19	0.63	1.32	93112.83	186225.67	254225.67	558677.01	425	600	10	2	119.53	100
13	41562.33	123237.58	-53967.03	0.31	0.31	36971.27	73942.55	100942.55	221827.64	225	600	10	2	505.60	200
14	37169.21	123237.58	-61288.90	0.31	0.31	36971.27	73942.55	100942.55	221827.64	225	600	10	2	505.60	200
15	42715.55	150623.70	-79431.12	0.31	0.47	45187.11	90374.22	123374.22	271122.67	275	600	10	2	333.87	200
16	56187.73	123237.58	-29591.37	0.31	0.31	36971.27	73942.55	100942.55	221827.64	225	600				
17	43359.30	150623.70	-78358.21	0.31	0.31	45187.11	90374.22	123374.22	271122.67	275	600	10	2	505.60	200
18	50404.78	150623.70	-66615.73	0.31	1.06	45187.11	90374.22	123374.22	271122.67	275	600	10	2	149.62	100

Tabel 9.3.2.b. (Lanjutan - 3)

Perhitungan tul. geser lentur dan torsi :

- Sendi plastis dari muka tumpuan sampai 2. h = 2. 700 = 1,4 m
- Di dalam sendi plastis, tul sengkang harus merupakan sengkang tertutup.

Vc di daerah sendi plastis = 0 (SKSNI 3.14.7.2) :

$$\mathrm{Vn} = \mathrm{Vc} + \mathrm{Vs}$$

$$\mathrm{Vs\ perlu} = \frac{\mathrm{Vu,b}}{\Phi} = \frac{335404,4}{0,6} = 559007\ \mathrm{N}$$

Kuat torsi oleh beton (SKSNI 3.4.6.6) :

$$\mathrm{Tc} = \frac{\frac{\sqrt{fc'}}{15}.\sum x^2.y}{\sqrt{1+\left(\frac{0,4.\mathrm{Vu}}{\mathrm{Ct.\ Tu}}\right)^2}}$$

dimana : $\mathrm{Ct} = \frac{\mathrm{bW.\ d}}{\sum x^2.\ y} = \frac{400.650}{110800000} = 0,0024\ /\mathrm{mm}$

$$\mathrm{Tc} = \frac{\frac{\sqrt{30}}{15}.\ 110800000}{\sqrt{1+\left(\frac{0,4.\ 335404,4}{0,0024.\ 28020000}\right)^2}} = 17,8\ \mathrm{kNm}$$

$\mathrm{Tn} = \mathrm{Tc} + \mathrm{Ts}$ (SKSNI 3.4.6.5)

$$\mathrm{Ts\ perlu} = \frac{28,02}{0,6} - 17,8 = 28,9\ \mathrm{kNm}$$

Kuat momen torsi :

$$Ts = \frac{At.\ \alpha t.\ x1.\ y1.\ fy}{S} \qquad \text{(SKSNI 3.4.6.9)}$$

dimana : $\alpha t = \frac{2 + \frac{y1}{x1}}{3}$, αt max = 1,5

y1 = dimensi panjang dari elemen persegi dari penampang

x1 = dimensi pendek dari elemen persegi dari penampang

tebal selimut beton ke tulangan paling tepi = 50 mm

y1 = 700 - 2. 50 = 600 mm

x1 = 400 - 2. 50 = 300 mm

$$\alpha t = \frac{2 + \frac{600}{300}}{3} = 1{,}3$$

Hitung tul transversal :

Torsi :

$$\frac{At}{S} = \frac{28900000}{1{,}3.\ 300.\ 600.\ 320} = 0{,}33\ mm^2/mm \qquad \text{(At = luas satu kaki tul torsi)}$$

Geser :

$$Vs\ perlu = \frac{Av.\ fy.\ d}{S}$$

$$\frac{Av}{S} = \frac{559007}{320.\ 650} = 2{,}7\ mm^2/mm$$

$$\frac{Av\ total}{S} = 2.\ \frac{At}{S} + \frac{Av}{S}$$

$$= 2.\ 0{,}33 + 2{,}7 = 3{,}36\ mm^2/mm \qquad \text{(menentukan)}$$

Sengkang tertutup minimum SKSNI 3.4.5.5.5. :

$$(Av + 2.\ At) = \frac{bw.\ S}{3.\ fy}$$

$$\min \frac{Av\ total}{S} = \frac{400}{3.\ 320}$$

$$= 0{,}42\ mm^2/mm \qquad < \left(\frac{Av\ total}{S}\right) perlu \qquad \text{(OK)}$$

Dicoba tul. D 12 mm, Av 1 kaki tul .= 113 mm^2 :

$$S\ perlu = \frac{Av\ total}{3{,}36}$$
$$= \frac{2.\ 113}{3{,}36} = 66{,}5\ mm$$ = > jarak terlalu kecil, coba dengan 3 kaki :
$$S\ perlu = \frac{3.\ 113}{3{,}36} = 101\ mm$$

Syarat jarak sengkang di daerah sendi plastis berdasar SKSNI 3.14.3.3 :

- $S = \frac{d}{4}$
  $= \frac{650}{4} = 162{,}5\ mm$
- $S = 8.\ \varnothing$ tul lentur
  $= 8.\ 22 = 176\ mm$
- $S = 24.\ \varnothing$ sengkang
  $= 24.\ 12 = 288\ mm$
- $S = 200\ mm$
- $S = 1600.\ fy.\ \left(\frac{As1}{(As,a + As,b).\ fy}\right)$
  $= 1600.\ 320.\ \frac{113}{(380 + 380).\ 320} = 237{,}9\ mm$

Syarat jarak sengkang torsi berdasar SKSNI 3.4.6.8. :

- $S = \frac{x1 + y1}{4}$
  $= \frac{300 + 600}{4} = 225\ mm$
- $S = 300\ mm$

(Dari syarat jarak diatas, pakai sengkang 3 D12 - 100 mm)

(Dipasang sampai dengan jarak 1,4 m dari muka tumpuan)

Tulangan memanjang (SKSNI 3.4.6.9) :

Pakai terbesar :

$$\text{Al perlu 1} = 2.\ \text{At}.\ \frac{\text{x1} + \text{y1}}{\text{S}}$$

dimana : $\frac{\text{At}}{\text{S}} = 0{,}33\ \text{mm}^2/\text{mm}$

$$\text{At} = 100.\ 0{,}33 = 33\ \text{mm}^2$$

$$= 2.\ 33.\ \frac{300 + 600}{100} = 602\ \text{mm}^2$$

$$\text{Al perlu 2} = \left[\frac{2{,}8.\ \text{x}.\ \text{S}}{\text{fy}}\left(\frac{\text{Tu}}{\text{Tu} + \frac{\text{Vu}}{3.\text{Ct}}}\right) - 2.\ \text{At}\right].\left(\frac{\text{x1} + \text{y1}}{\text{S}}\right)$$

dimana : $\text{Ct} = 0{,}0024\ /\text{mm}$

$$= \left[\frac{2{,}8.\ 300.\ 100}{320}.\left(\frac{28020000}{28020000 + \frac{335404{,}4}{3.\ 0{,}0024}}\right) - 2.\ 33\right].\left(\frac{300 + 600}{100}\right) = 273\ \text{mm}^2$$

Al tidak perlu lebih dari :

$$\text{Al max} = \left[\frac{2{,}8.\ \text{x}.\ \text{S}}{\text{fy}}\left(\frac{\text{Tu}}{\text{Tu} + \frac{\text{Vu}}{3.\text{Ct}}}\right) - 2.\ \text{At}\right].\left(\frac{\text{x1} + \text{y1}}{\text{S}}\right)$$

dimana : $2.\ \text{At} = \frac{\text{bw. S}}{3.\ \text{fy}} = \frac{400.\ 100}{3.\ 320}$

$$= 41{,}7\ \text{mm}^2$$

$$= \left[\frac{2{,}8.\ 300.\ 100}{320}.\left(\frac{28020000}{28020000 + \frac{335404{,}4}{3.\ 0{,}0024}}\right) - 41{,}7\right].\left(\frac{300 + 600}{100}\right) = 500\ \text{mm}^2$$

Dari luas tulangan memanjang diatas, pakai Al = 500 mm^2

(pakai tul. memanjang 2 D 19 mm, As = 567 mm^2)

(pemasangan tul. disebarkan pada sengkang)

- Penulangan di lapangan

Di luar sendi plastis, tul sengkang direncanakan sengkang tertutup.

Dengan cara yang sama seperti di sub bab geser di tumpuan,

Vu,b luar sendi plastis (2. h = 140 cm) :

$Vu1 = 292307{,}4$ N (telah dihitung di sub bab geser di tumpuan)

$$Vu2 = 292307{,}4 \,.\, \frac{427{,}5 - 140}{427{,}5} = 196581 \text{ N}$$

Vu,b di (2. h) = Vu2 + Vu,b ujung yang lain

$= 196581 + 87541{,}4 = 284122$ N

Geser beton (SKSNI 3.14.7.2) :

$$Vc = \frac{\sqrt{fc'}}{6} \,.\, bw.\, d = \frac{\sqrt{30}}{6} \,.\, 400.\, 650 = 237346 \text{ N}$$

Syarat jarak sengkang :

$$(\Phi.\, Vc + \min \Phi.\, Vs) < Vu \leq (\Phi.\, Vc + \Phi.\, \frac{1}{3}.\, \sqrt{fc'} \,.\, bw.\, d)$$

$$(0{,}6.\, 237346 + 0{,}6.\, \frac{1}{3}.\, 400.\, 650) < 284122 \leq (0{,}6.\, 237346 + 0{,}6.\, \frac{1}{3}.\, \sqrt{30} \,.\, 400.\, 650)$$

$194407{,}9 < 284122 \leq 427223{,}6$ N (OK)

Geser perlu :

$Vn = Vc + Vs$

$$Vs \text{ perlu} = \frac{284122}{0{,}6} - 237346 = 236191 \text{ N}$$

$$Vs = \frac{Av.\, fy.\, d}{S}$$

Torsi perlu :

Anggap torsi bekerja pada seluruh penampang, Tu = 28,02 kNm

Ts perlu = 29,1 kNm (perhitungan seperti di tumpuan)

Hitung tul transversal :

$$\frac{Av}{S} = \frac{236191}{320.\,650} = 1{,}1 \text{ mm}^2/\text{mm}$$

tul. min. = 0,42 mm²/mm

tul. perlu :

$$(\frac{Av}{S})\text{ tot} = (\frac{2.\,At}{S} + \frac{Av}{S})$$

$$= 2.\ 0{,}33 + 1{,}1 = 1{,}8 \text{ mm}^2/\text{mm} \quad \text{(menentukan)}$$

Dicoba tul. D 12 mm, Av 1 kaki tul .= 113 mm² :

$$S \text{ perlu} = \frac{2.\,113}{1{,}8} = 127{,}6 \text{ mm}$$

Syarat jarak sengkang di luar sendi plastis berdasar SKSNI 3.14.3.3 :

- $S = \frac{d}{2} = \frac{650}{2} = 325$ mm
- S = 600 mm

Syarat jarak sengkang torsi :

- S = 225 mm
- S = 300 mm

(Dari syarat jarak diatas, pakai sengkang D12 - 100 mm)

Tul. memanjang :

Tul. memanjang di lapangan sama seperti di tumpuan.

(pakai tul. memanjang 2D19)

☐ Kontrol retak

Berdasar SKSNI 3.3.6, balok dengan fy tulangan tarik melebihi 300 MPa, harus dikontrol terjadinya retak. Pada balok ini, kontrol retak pada saat beban layan (akibat beban hidup dan mati).

$Z = fs^3 \sqrt{dc.\,A}$

dimana : dc = jarak titik berat tul. ke serat tarik terluar beton

$A = \frac{2.\,dc.\,bw}{jml\ tul.}$

Z untuk di dalam ruangan < 30 MN/m

Di tumpuan (serat atas) :

$dc = 40 + 12 + \frac{1}{2}.22 = 63$ mm

$fs = 0{,}6.\ 320 = 192$ MPa

$A = \frac{2.\,63.\,400}{10} = 5040\ mm^2$

$Z = 192^3 \sqrt{63.\ 5040} = 13100$ N/mm = 13,1 MN/m < 30 MN/m (OK)

Di lapangan (serat bawah) :

$A = \frac{2.\,63.\,400}{5} = 10080\ mm^2$

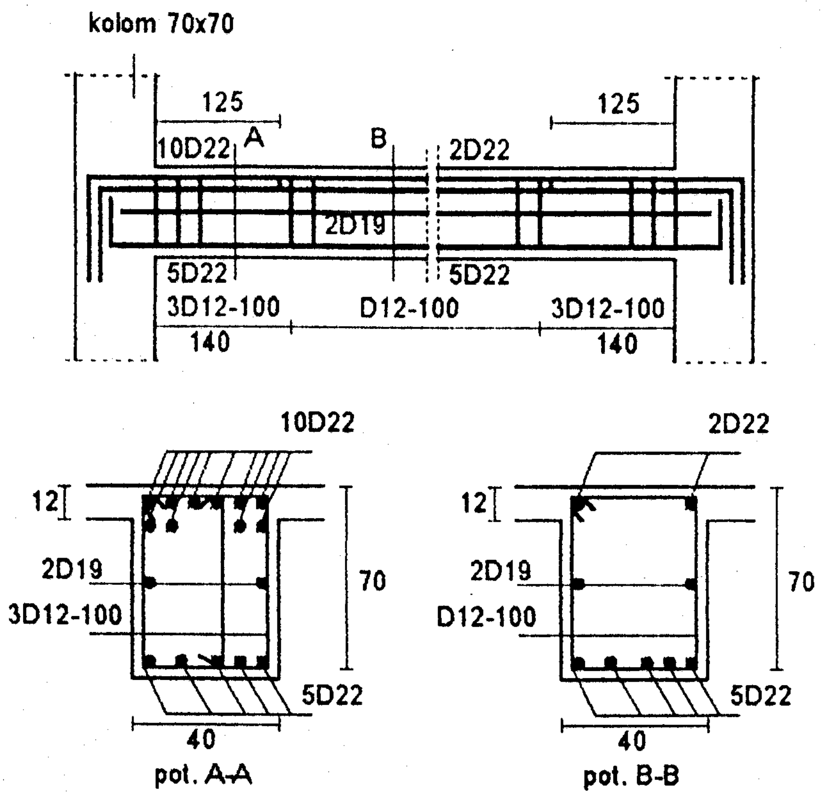
$Z = 192^3 \sqrt{63.10080} = 16{,}5$ MN/m (OK)

☐ Kontrol lendutan

Berdasar SKSNI tabel 3.2.5(a), untuk balok non pratekan dengan dimensi lebih dari koefisien pada tabel, maka lendutan tidak perlu dihitung

$h\ min = \frac{L}{16}.\ (0{,}4 + fy/700)$

$= \frac{5000}{16}.\ (0{,}4 + 320/700) = 268$ mm < h terpasang (70 cm)



sket Penulangan geser dan torsi
balok induk 40/70 L=5m

9.3.2. Perencanaan balok induk yang lain

- Perencanaan lentur dapat dilihat pada tabel 9.3.2.a.
- Perencanaan geser dapat dilihat pada tabel 9.3.2.b.

No	Portal	Balok	lantai	L	b	h	Mu + tump	ro	As (mm2)		As' (mm2)		Mu - tump	ro	As (mm2)		As' (mm2)	
blk.				(cm)			(kNm)	perlu	perlu	pasang	perlu	pasang	(kNm)	perlu	perlu	pasang	perlu	pasang
1	A	induk	1 to 6	500	40	70	271.26	6.54E-03	1699.91	1901	849.95	1140	-536.42	1.36E-02	3523.30	3801	1761.65	1901
2	B	induk	1 to 6	600	40	70	235.84	5.65E-03	1469.42	1521	734.71	760	-539.32	1.36E-02	3544.30	3801	1772.15	1901
3	B	induk	1 to 6	850	40	80	52.92	4.38E-03	1312.50	1521	656.25	760	-673.70	1.27E-02	3812.96	4181	1906.48	2281
4	C	induk	1 to 6	300	40	70	473.83	1.18E-02	3075.87	3421	1537.94	1901	-596.05	1.52E-02	3960.64	4181	1980.32	2281
5	D	induk	1 to 6	800	40	70	97.70	4.38E-03	1137.50	1140	568.75	760	-517.70	1.30E-02	3388.27	3421	1694.13	1901
6	D	induk	1 to 6	850	40	90	121.16	4.38E-03	1487.50	1521	743.75	760	-929.38	1.37E-02	4552.27	4561	2276.14	2281
7	A	induk	7 to 9	500	40	70	53.50	4.38E-03	1137.50	1140	568.75	760	-392.86	9.67E-03	2513.38	2661	1256.69	1521
8	B	induk	7 to 9	600	40	70	77.82	4.38E-03	1137.50	1140	568.75	760	-383.67	9.43E-03	2450.65	2661	1225.33	1521
9	B	induk	7 to 9	850	40	80	5.19	4.38E-03	1312.50	1521	656.25	760	-615.45	1.15E-02	3455.16	3801	1727.58	1901
10	C	induk	7 to 9	300	40	70	216.30	5.17E-03	1343.44	1521	671.72	760	-315.48	7.66E-03	1991.67	2281	995.83	1521
11	D	induk	7 to 9	800	40	70	46.67	4.38E-03	1137.50	1140	568.75	760	-461.69	1.15E-02	2990.37	3041	1495.18	1521
12	D	induk	7 to 9	850	40	90	8.82	4.38E-03	1487.50	1521	743.75	760	-796.59	1.16E-02	3948.56	4181	1974.28	2281
13	A	induk	roof	500	30	50							-55.44	4.38E-03	590.63	851	295.31	567
14	B	induk	roof	600	30	50							-42.74	4.38E-03	590.63	851	295.31	567
15	B	induk	roof	850	30	60	19.20	4.38E-03	721.88	851	360.94	567	-84.00	4.38E-03	721.88	851	360.94	567
16	C	induk	roof	300	30	50	11.23	4.38E-03	590.63	603	295.31	402	-26.80	4.38E-03	590.63	851	295.31	567
17	D	induk	roof	800	30	60	9.32	4.38E-03	721.88	851	360.94	567	-64.05	4.38E-03	721.88	851	360.94	567
18	D	induk	roof	850	30	60							-138.71	6.21E-03	1025.08	1134	512.54	567

Tabel 9.3.2.a. Perencanaan lentur

No	Pakai (mm2)		bE	Mn + tump (Nm)		Mn - tump (Nm)	
blk.	atas	bawah	(mm)	terpasang	perlu	terpasang	perlu
1	3801	1901	1250	402320.28	339075	739447.18	670530
2	3801	1901	1500	404172.85	294800	739447.18	674152.5
3	4181	2281	2125	498240.50	66150	888948.94	842126.25
4	4181	2281	750	657072.11	592287.5	858577.09	745066.88
5	3421	1901	2000	420342.34	122125	668200.19	647128.13
6	4561	2281	2125	691412.44	151450	1262571.03	1161720
7	2661	1521	1250	324897.41	66875	523384.55	491071.875
8	2661	1521	1500	329857.22	97275	523384.55	479587.5
9	3801	1901	2125	481156.40	6487.5	861107.89	769308.75
10	2281	1521	750	314325.16	270375	450327.84	394353.75
11	3041	1521	2000	345826.76	58337.5	595204.77	577106.25
12	4181	2281	2125	688173.45	11025	1139938.09	995741.25
13	851	567		59950.26		85623.51	69300
14	851	567		59950.26		85623.51	53418.75
15	851	567		99862.80	24000	145338.96	105000
16	851	567		59950.26	14040	85623.51	33495
17	851	567		99862.80	11650	145338.96	80062.5
18	1134	567		99508.48		191055.34	173381.25

Tabel 9.3.2.a. (Lanjutan - 1)

No blk.	Portal	Balok	lantai	L	b (cm)	h	Tu perlu (kNm)	x2. y (mm3)	Tu batas (kNm)	Tc (kNm)	Ts perlu (kNm)	At/S perlu (mm2/mm)
1	A	induk	1 to 6	500	40	70	28.02	1.11E+08	18.21	17.80	28.90	0.33
2	B	induk	1 to 6	600	40	70	27.72	1.14E+08	18.80	17.73	28.47	0.33
3	B	induk	1 to 6	850	40	80	54.16	1.39E+08	22.91	30.85	59.41	0.59
4	C	induk	1 to 6	300	40	70	0.57	1.04E+08	17.02	0.22	0.73	
5	D	induk	1 to 6	800	40	70	0.40	1.22E+08	19.98	0.31	0.36	
6	D	induk	1 to 6	850	40	90	37.08	1.55E+08	25.53	21.62	40.18	0.35
7	A	induk	7 to 9	500	40	70	28.02	1.11E+08	18.21	19.73	26.97	0.31
8	B	induk	7 to 9	600	40	70	27.72	1.14E+08	18.80	20.00	26.20	0.30
9	B	induk	7 to 9	850	40	80	54.16	1.39E+08	22.91	31.13	59.14	0.59
10	C	induk	7 to 9	300	40	70	0.57	1.04E+08	17.02	0.43	0.52	
11	D	induk	7 to 9	800	40	70	0.40	1.22E+08	19.98	0.33	0.34	
12	D	induk	7 to 9	850	40	90	37.08	1.55E+08	25.53	22.20	39.60	0.34
13	A	induk	roof	500	30	50	0.44	4.50E+07	7.39	1.14	-0.41	
14	B	induk	roof	600	30	50	5.69	4.50E+07	7.39	10.42	-0.94	
15	B	induk	roof	850	30	60	13.04	5.40E+07	8.87	17.88	3.86	0.08
16	C	induk	roof	300	30	50	0.29	4.50E+07	7.39	0.60	-0.12	
17	D	induk	roof	800	30	60	1.82	5.40E+07	8.87	5.59	-2.55	
18	D	induk	roof	850	30	60	20.95	5.40E+07	8.87	17.07	17.84	0.37

Tabel 9.3.2.b. Perencanaan geser dan torsi

No blk.	Mn tump (Nm)		Vg (N)		Vu renc m.tump (N)		Vu max (N)	Vu renc di s.plastis (N)	Vs perlu (N)	Av/S perlu	Av/S tot perlu
	+	-	c to c	m. tump	kiri	kanan					
1	402320.28	739447.18	162800	139194	379848.79	87541.39	971040	335404.39	559007.32	2.69	3.36
2	404172.85	739447.18	210120	185606	383691.49	-6081.11	807030	335889.19	559815.32	2.69	3.35
3	498240.50	888948.94	292400	266600	436548.16	-123311.84	700035	382368.16	637280.27	2.66	3.83
4	657072.11	858577.09	47920	35940	627156.13	551682.13	2411640	605352.53	1008920.89	4.85	4.85
5	420342.34	668200.19	227760	206408	348103.70	-85352.05	566790	309242.15	515403.58	2.48	2.48
6	691412.44	1262571.03	366440	327640	568987.70	-119057.29	922740	492035.30	820058.83	3.01	3.71
7	324897.41	523384.55	193160	165152	347034.35	215.57	552195	294301.67	490502.79	2.36	2.98
8	329857.22	523384.55	211280	186631	336827.59	-55096.81	513135	288761.39	481268.98	2.31	2.92
9	481156.40	861107.89	292040	266272	431131.32	-128039.38	546000	377018.03	628363.38	2.62	3.79
10	314325.16	450327.84	55720	41790	341244.55	253485.55	913080	315891.95	526486.59	2.53	2.53
11	345826.76	595204.77	227760	206408	330300.65	-103155.10	459270	291439.10	485731.83	2.34	2.34
12	688173.45	1139938.09	365840	327104	553932.57	-132985.83	701715	477106.17	795176.95	2.92	3.61
13	59950.26	85623.51	24720	21259	51944.73	7300.41	33390	47272.65	55650.00	0.39	0.39
14	59950.26	85623.51	36360	32118	57757.31	-9690.49	52395	52030.61	87325.00	0.61	0.61
15	99862.80	145338.96	22800	20922	49475.08	5538.14	60690	46376.96	77294.93	0.44	0.60
16	59950.26	85623.51	7680	5888	61563.73	49198.93	78120	59144.53	98574.21	0.68	0.68
17	99862.80	145338.96	21720	19820	50201.10	8580.15	56385	47065.27	78442.12	0.45	0.45
18	99508.48	191055.34	73200	65880	102408.42	-35939.58	101010	92461.84	154103.06	0.88	1.62

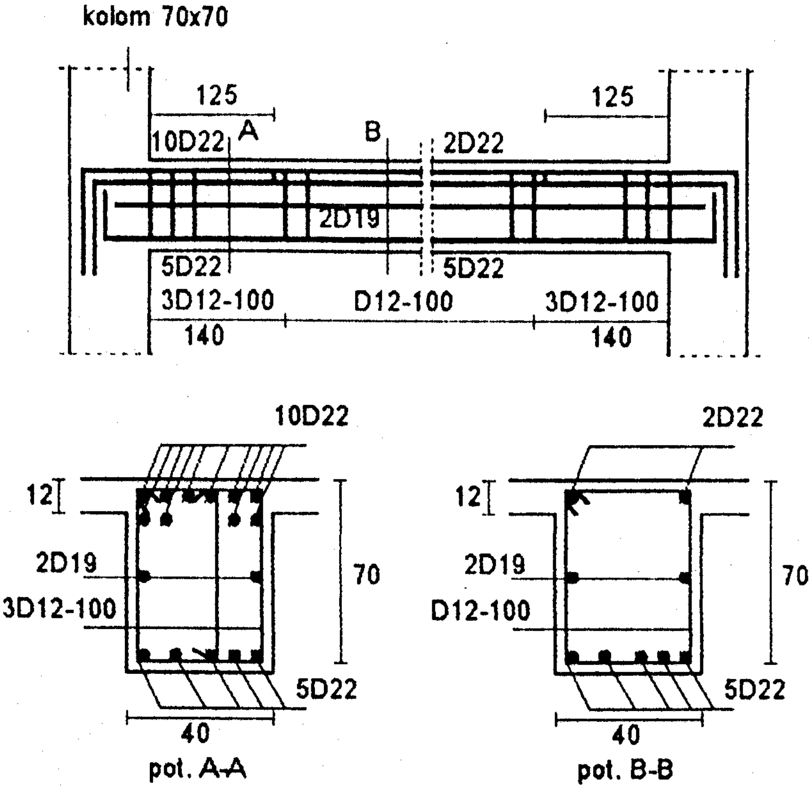
Tabel 9.3.2.b. (Lanjutan - 1)

No	Syarat jarak sengkang geser (mm)					Syarat jarak torsi		D tul.	kaki	S (mm)		At	Al perlu 1	Al perlu 2	Al max	pakai Al
blk.	d/4	8.d lt	24.d s	200	1600.fy.As/(As.fy)	(x1+y1)/4	300	(mm)		perlu	pakai	(mm2)	(mm2)	(mm2)	(mm2)	(mm2)
1	162.5	176	288	200	237.89	225	300	12	3	101.00	100	33.44	601.98	272.90	499.88	567
2	162.5	176	288	200	237.89	225	300	12	3	101.18	100	32.95	593.03	257.65	475.68	567
3	187.5	176	288	200	237.89	250	300	12	4	117.89	100	58.94	703.62	75.03	837.21	760
4	162.5	176	288	200	237.89	225	300	12	4	93.18	90					
5	162.5	176	288	200	237.89	225	300	12	3	136.81	100					
6	212.5	176	288	200	237.89	275	300	12	4	121.75	100	34.87	767.23	188.37	497.27	567
7	162.5	176	288	200	237.89	225	300	12	3	113.66	100	31.22	561.90	386.13	573.03	567
8	162.5	176	288	200	237.89	225	300	12	3	116.09	100	30.32	545.78	388.81	559.59	567
9	187.5	176	288	200	237.89	250	300	12	4	119.21	100	58.67	738.65	89.71	846.44	760
10	162.5	176	288	200	237.89	225	300	12	3	133.93	100					
11	162.5	176	288	200	237.89	225	300	12	3	145.17	100					
12	212.5	176	288	200	237.89	275	300	12	4	125.17	100	34.38	756.26	219.14	517.07	567
13	112.5	128	240	200	314.43	150	300	10	2	408.84	100					
14	112.5	128	240	200	314.43	150	300	10	2	260.54	100					
15	137.5	128	240	200	314.43	175	300	10	2	263.37	100	8.04	112.52	770.06	543.10	567
16	112.5	128	240	200	314.43	150	300	10	2	230.81	100					
17	137.5	128	240	200	314.43	175	300	10	2	354.50	100					
18	137.5	128	240	200	314.43	175	300	10	3	146.38	100	37.17	520.43	306.45	608.13	567

Tabel 9.3.2.b. (Lanjutan - 2)

No blk.	Vu renc. luar s.plastis (N)	Vc (N)	Vs perlu (N)	Av/S perlu	Av/S tot perlu	Kategori desain geser (lihat sub bab)				Syarat jarak		D tul (mm)	kaki	S perlu (mm)	pakai S (mm)
						0,5.phi.Vc	phi.Vc	syarat 3	syarat 4	d/2	600				
1	284122.39	237346.44	236190.88	1.14	1.80	71203.93	142407.86	194407.86	427223.59	325	600	12	2	125.25	100
2	276257.92	237346.44	223083.42	1.07	1.73	71203.93	142407.86	194407.86	427223.59	325	600	12	2	130.53	100
3	223110.25	273861.28	97989.14	0.41	1.59	82158.38	164316.77	224316.77	492950.30	375	600	12	2	142.40	100
4	580194.53	237346.44	729644.45	3.51	3.51	71203.93	142407.86	194407.86	427223.59	325	600				
5	195531.62	237346.44	88539.58	0.43	0.43	71203.93	142407.86	194407.86	427223.59	325	600	10	2	371.18	200
6	315170.16	310376.12	214907.49	0.79	1.49	93112.83	186225.67	254225.67	558677.01	425	600	10	2	106.21	100
7	233456.27	237346.44	151747.35	0.73	1.35	71203.93	142407.86	194407.86	427223.59	325	600	10	2	116.70	100
8	192757.45	237346.44	83915.97	0.40	1.01	71203.93	142407.86	194407.86	427223.59	325	600	10	2	156.46	150
9	214084.18	273861.28	82945.69	0.35	1.52	82158.38	164316.77	224316.77	492950.30	375	600	10	2	104.02	100
10	286638.95	237346.44	240385.15	1.16	1.16	71203.93	142407.86	194407.86	427223.59	325	600				
11	163363.35	237346.44	34925.81	0.17	0.17	71203.93	142407.86	194407.86	427223.59	325	600	10	2	940.97	200
12	289752.18	310376.12	172544.19	0.63	1.32	93112.83	186225.67	254225.67	558677.01	425	600	10	2	119.53	100
13	41562.33	123237.58	-53967.03	0.31	0.31	36971.27	73942.55	100942.55	221827.64	225	600	10	2	505.60	200
14	37169.21	123237.58	-61288.90	0.31	0.31	36971.27	73942.55	100942.55	221827.64	225	600	10	2	505.60	200
15	42715.55	150623.70	-79431.12	0.31	0.47	45187.11	90374.22	123374.22	271122.67	275	600	10	2	333.87	200
16	56187.73	123237.58	-29591.37	0.31	0.31	36971.27	73942.55	100942.55	221827.64	225	600				
17	43359.30	150623.70	-78358.21	0.31	0.31	45187.11	90374.22	123374.22	271122.67	275	600	10	2	505.60	200
18	50404.78	150623.70	-66615.73	0.31	1.06	45187.11	90374.22	123374.22	271122.67	275	600	10	2	149.62	100

Tabel 9.3.2.b. (Lanjutan - 3)



sket Penulangan geser dan torsi
balok induk 40/70 L=5m

9.3.2. Perencanaan balok induk yang lain

- Perencanaan lentur dapat dilihat pada tabel 9.3.2.a.
- Perencanaan geser dapat dilihat pada tabel 9.3.2.b.

No	Portal	Balok induk		L (cm)	h (cm)	b (cm)	m= S/L	span (kN/m')		pakai q hidup (kN/m')	span (kN/m')		pakai q mati (kN/m')	P balok anak (kN)	P kuda2 (kN)
								short	long		short	long			
1	A	induk	lantai	500	70	40	0.83	2.5		5	7.65		15.30	167.06	
2	B	induk	lantai	600	70	40	0.50		4.13	8.25		12.62	25.25	149.86	
3	B	induk	lantai	850	80	40	0.50	3		6	9.18		18.36	197.65	
4	C	induk	lantai	300	70	40	1.00	3		6	9.18		18.36		
5	D	induk	lantai	800	70	40	0.38		4.29	4.29		13.12	45.92		
6	D	induk	lantai	850	90	40	0.38	3		6	9.18		18.36	345.07	
7	A	induk	atap	500	50	30									24.38
8	B	induk	atap	600	50	30							8	8.5	
9	B	induk	atap	850	60	30								30	24.38
10	C	induk	atap	300	50	30									
11	D	induk	atap	800	50	30									12
12	D	induk	atap	850	60	30								30	24.38

Tabel 9.1.2. Beban pada balok induk

No	Portal	Balok	lantai	L	b	h	Mu + tump	ro	As (mm2)		As' (mm2)		Mu - tump	ro	As (mm2)		As' (mm2)	
blk.					(cm)		(kNm)	perlu	perlu	pasang	perlu	pasang	(kNm)	perlu	perlu	pasang	perlu	pasang
1	A	induk	1 to 6	500	40	70	271.26	6.54E-03	1699.91	1901	849.95	1140	-536.42	1.36E-02	3523.30	3801	1761.65	1901
2	B	induk	1 to 6	600	40	70	235.84	5.65E-03	1469.42	1521	734.71	760	-539.32	1.36E-02	3544.30	3801	1772.15	1901
3	B	induk	1 to 6	850	40	80	52.92	4.38E-03	1312.50	1521	656.25	760	-673.70	1.27E-02	3812.96	4181	1906.48	2281
4	C	induk	1 to 6	300	40	70	473.83	1.18E-02	3075.87	3421	1537.94	1901	-596.05	1.52E-02	3960.64	4181	1980.32	2281
5	D	induk	1 to 6	800	40	70	97.70	4.38E-03	1137.50	1140	568.75	760	-517.70	1.30E-02	3388.27	3421	1694.13	1901
6	D	induk	1 to 6	850	40	90	121.16	4.38E-03	1487.50	1521	743.75	760	-929.38	1.37E-02	4552.27	4561	2276.14	2281
7	A	induk	7 to 9	500	40	70	53.50	4.38E-03	1137.50	1140	568.75	760	-392.86	9.67E-03	2513.38	2661	1256.69	1521
8	B	induk	7 to 9	600	40	70	77.82	4.38E-03	1137.50	1140	568.75	760	-383.67	9.43E-03	2450.65	2661	1225.33	1521
9	B	induk	7 to 9	850	40	80	5.19	4.38E-03	1312.50	1521	656.25	760	-615.45	1.15E-02	3455.16	3801	1727.58	1901
10	C	induk	7 to 9	300	40	70	216.30	5.17E-03	1343.44	1521	671.72	760	-315.48	7.66E-03	1991.67	2281	995.83	1521
11	D	induk	7 to 9	800	40	70	46.67	4.38E-03	1137.50	1140	568.75	760	-461.69	1.15E-02	2990.37	3041	1495.18	1521
12	D	induk	7 to 9	850	40	90	8.82	4.38E-03	1487.50	1521	743.75	760	-796.59	1.16E-02	3948.56	4181	1974.28	2281
13	A	induk	roof	500	30	50							-55.44	4.38E-03	590.63	851	295.31	567
14	B	induk	roof	600	30	50							-42.74	4.38E-03	590.63	851	295.31	567
15	B	induk	roof	850	30	60	19.20	4.38E-03	721.88	851	360.94	567	-84.00	4.38E-03	721.88	851	360.94	567
16	C	induk	roof	300	30	50	11.23	4.38E-03	590.63	603	295.31	402	-26.80	4.38E-03	590.63	851	295.31	567
17	D	induk	roof	800	30	60	9.32	4.38E-03	721.88	851	360.94	567	-64.05	4.38E-03	721.88	851	360.94	567
18	D	induk	roof	850	30	60							-138.71	6.21E-03	1025.08	1134	512.54	567

Tabel 9.3.2.a. Perencanaan lentur

No	Pakai (mm2)		bE	Mn + tump (Nm)		Mn - tump (Nm)	
blk.	atas	bawah	(mm)	terpasang	perlu	terpasang	perlu
1	3801	1901	1250	402320.28	339075	739447.18	670530
2	3801	1901	1500	404172.85	294800	739447.18	674152.5
3	4181	2281	2125	498240.50	66150	888948.94	842126.25
4	4181	2281	750	657072.11	592287.5	858577.09	745066.88
5	3421	1901	2000	420342.34	122125	668200.19	647128.13
6	4561	2281	2125	691412.44	151450	1262571.03	1161720
7	2661	1521	1250	324897.41	66875	523384.55	491071.875
8	2661	1521	1500	329857.22	97275	523384.55	479587.5
9	3801	1901	2125	481156.40	6487.5	861107.89	769308.75
10	2281	1521	750	314325.16	270375	450327.84	394353.75
11	3041	1521	2000	345826.76	58337.5	595204.77	577106.25
12	4181	2281	2125	688173.45	11025	1139938.09	995741.25
13	851	567		59950.26		85623.51	69300
14	851	567		59950.26		85623.51	53418.75
15	851	567		99862.80	24000	145338.96	105000
16	851	567		59950.26	14040	85623.51	33495
17	851	567		99862.80	11650	145338.96	80062.5
18	1134	567		99508.48		191055.34	173381.25

Tabel 9.3.2.a. (Lanjutan - 1)

No blk.	Portal	Balok	lantai	L	b	h	Tu perlu (kNm)	x2. y (mm3)	Tu batas (kNm)	Tc (kNm)	Ts perlu (kNm)	At/S perlu (mm2/mm)
					(cm)							
1	A	induk	1 to 6	500	40	70	28.02	1.11E+08	18.21	17.80	28.90	0.33
2	B	induk	1 to 6	600	40	70	27.72	1.14E+08	18.80	17.73	28.47	0.33
3	B	induk	1 to 6	850	40	80	54.16	1.39E+08	22.91	30.85	59.41	0.59
4	C	induk	1 to 6	300	40	70	0.57	1.04E+08	17.02	0.22	0.73	
5	D	induk	1 to 6	800	40	70	0.40	1.22E+08	19.98	0.31	0.36	
6	D	induk	1 to 6	850	40	90	37.08	1.55E+08	25.53	21.62	40.18	0.35
7	A	induk	7 to 9	500	40	70	28.02	1.11E+08	18.21	19.73	26.97	0.31
8	B	induk	7 to 9	600	40	70	27.72	1.14E+08	18.80	20.00	26.20	0.30
9	B	induk	7 to 9	850	40	80	54.16	1.39E+08	22.91	31.13	59.14	0.59
10	C	induk	7 to 9	300	40	70	0.57	1.04E+08	17.02	0.43	0.52	
11	D	induk	7 to 9	800	40	70	0.40	1.22E+08	19.98	0.33	0.34	
12	D	induk	7 to 9	850	40	90	37.08	1.55E+08	25.53	22.20	39.60	0.34
13	A	induk	roof	500	30	50	0.44	4.50E+07	7.39	1.14	-0.41	
14	B	induk	roof	600	30	50	5.69	4.50E+07	7.39	10.42	-0.94	
15	B	induk	roof	850	30	60	13.04	5.40E+07	8.87	17.88	3.86	0.08
16	C	induk	roof	300	30	50	0.29	4.50E+07	7.39	0.60	-0.12	
17	D	induk	roof	800	30	60	1.82	5.40E+07	8.87	5.59	-2.55	
18	D	induk	roof	850	30	60	20.95	5.40E+07	8.87	17.07	17.84	0.37

Tabel 9.3.2.b. Perencanaan geser dan torsi

No blk.	Mn tump (Nm)		Vg (N)		Vu renc m.tump (N)		Vu max (N)	Vu renc di s.plastis (N)	Vs perlu (N)	Av/S perlu	Av/S tot perlu
	+	-	c to c	m. tump	kiri	kanan					
1	402320.28	739447.18	162800	139194	379848.79	87541.39	971040	335404.39	559007.32	2.69	3.36
2	404172.85	739447.18	210120	185606	383691.49	-6081.11	807030	335889.19	559815.32	2.69	3.35
3	498240.50	888948.94	292400	266600	436548.16	-123311.84	700035	382368.16	637280.27	2.66	3.83
4	657072.11	858577.09	47920	35940	627156.13	551682.13	2411640	605352.53	1008920.89	4.85	4.85
5	420342.34	668200.19	227760	206408	348103.70	-85352.05	566790	309242.15	515403.58	2.48	2.48
6	691412.44	1262571.03	366440	327640	568987.70	-119057.29	922740	492035.30	820058.83	3.01	3.71
7	324897.41	523384.55	193160	165152	347034.35	215.57	552195	294301.67	490502.79	2.36	2.98
8	329857.22	523384.55	211280	186631	336827.59	-55096.81	513135	288761.39	481268.98	2.31	2.92
9	481156.40	861107.89	292040	266272	431131.32	-128039.38	546000	377018.03	628363.38	2.62	3.79
10	314325.16	450327.84	55720	41790	341244.55	253485.55	913080	315891.95	526486.59	2.53	2.53
11	345826.76	595204.77	227760	206408	330300.65	-103155.10	459270	291439.10	485731.83	2.34	2.34
12	688173.45	1139938.09	365840	327104	553932.57	-132985.83	701715	477106.17	795176.95	2.92	3.61
13	59950.26	85623.51	24720	21259	51944.73	7300.41	33390	47272.65	55650.00	0.39	0.39
14	59950.26	85623.51	36360	32118	57757.31	-9690.49	52395	52030.61	87325.00	0.61	0.61
15	99862.80	145338.96	22800	20922	49475.08	5538.14	60690	46376.96	77294.93	0.44	0.60
16	59950.26	85623.51	7680	5888	61563.73	49198.93	78120	59144.53	98574.21	0.68	0.68
17	99862.80	145338.96	21720	19820	50201.10	8580.15	56385	47065.27	78442.12	0.45	0.45
18	99508.48	191055.34	73200	65880	102408.42	-35939.58	101010	92461.84	154103.06	0.88	1.62

Tabel 9.3.2.b. (Lanjutan - 1)

No	Syarat jarak sengkang geser (mm)					Syarat jarak torsi		D tul.	kaki	S (mm)		At	Al perlu 1	Al perlu 2	Al max	pakai Al
blk.	d/4	8.d lt	24.d s	200	1600.fy.As/(As.fy)	(x1+y1)/4	300	(mm)		perlu	pakai	(mm2)	(mm2)	(mm2)	(mm2)	(mm2)
1	162.5	176	288	200	237.89	225	300	12	3	101.00	100	33.44	601.98	272.90	499.88	567
2	162.5	176	288	200	237.89	225	300	12	3	101.18	100	32.95	593.03	257.65	475.68	567
3	187.5	176	288	200	237.89	250	300	12	4	117.89	100	58.94	703.62	75.03	837.21	760
4	162.5	176	288	200	237.89	225	300	12	4	93.18	90					
5	162.5	176	288	200	237.89	225	300	12	3	136.81	100					
6	212.5	176	288	200	237.89	275	300	12	4	121.75	100	34.87	767.23	188.37	497.27	567
7	162.5	176	288	200	237.89	225	300	12	3	113.66	100	31.22	561.90	386.13	573.03	567
8	162.5	176	288	200	237.89	225	300	12	3	116.09	100	30.32	545.78	388.81	559.59	567
9	187.5	176	288	200	237.89	250	300	12	4	119.21	100	58.67	738.65	89.71	846.44	760
10	162.5	176	288	200	237.89	225	300	12	3	133.93	100					
11	162.5	176	288	200	237.89	225	300	12	3	145.17	100					
12	212.5	176	288	200	237.89	275	300	12	4	125.17	100	34.38	756.26	219.14	517.07	567
13	112.5	128	240	200	314.43	150	300	10	2	408.84	100					
14	112.5	128	240	200	314.43	150	300	10	2	260.54	100					
15	137.5	128	240	200	314.43	175	300	10	2	263.37	100	8.04	112.52	770.06	543.10	567
16	112.5	128	240	200	314.43	150	300	10	2	230.81	100					
17	137.5	128	240	200	314.43	175	300	10	2	354.50	100					
18	137.5	128	240	200	314.43	175	300	10	3	146.38	100	37.17	520.43	306.45	608.13	567

Tabel 9.3.2.b. (Lanjutan - 2)

No blk.	Vu renc. luar s.plastis (N)	Vc (N)	Vs perlu (N)	Av/S perlu	Av/S tot perlu	Kategori desain geser (lihat sub bab)				Syarat jarak		D tul (mm)	kaki	S perlu (mm)	pakai S (mm)
						0,5.phi.Vc	phi.Vc	syarat 3	syarat 4	d/2	600				
1	284122.39	237346.44	236190.88	1.14	1.80	71203.93	142407.86	194407.86	427223.59	325	600	12	2	125.25	100
2	276257.92	237346.44	223083.42	1.07	1.73	71203.93	142407.86	194407.86	427223.59	325	600	12	2	130.53	100
3	223110.25	273861.28	97989.14	0.41	1.59	82158.38	164316.77	224316.77	492950.30	375	600	12	2	142.40	100
4	580194.53	237346.44	729644.45	3.51	3.51	71203.93	142407.86	194407.86	427223.59	325	600				
5	195531.62	237346.44	88539.59	0.43	0.43	71203.93	142407.86	194407.86	427223.59	325	600	10	2	371.18	200
6	315170.16	310376.12	214907.49	0.79	1.49	93112.83	186225.67	254225.67	558677.01	425	600	10	2	106.21	100
7	233456.27	237346.44	151747.35	0.73	1.35	71203.93	142407.86	194407.86	427223.59	325	600	10	2	116.70	100
8	192757.45	237346.44	83915.97	0.40	1.01	71203.93	142407.86	194407.86	427223.59	325	600	10	2	156.46	150
9	214084.18	273861.28	82945.69	0.35	1.52	82158.38	164316.77	224316.77	492950.30	375	600	10	2	104.02	100
10	286638.95	237346.44	240385.15	1.16	1.16	71203.93	142407.86	194407.86	427223.59	325	600				
11	163363.35	237346.44	34925.81	0.17	0.17	71203.93	142407.86	194407.86	427223.59	325	600	10	2	940.97	200
12	289752.18	310376.12	172544.19	0.63	1.32	93112.83	186225.67	254225.67	558677.01	425	600	10	2	119.53	100
13	41562.33	123237.58	-53967.03	0.31	0.31	36971.27	73942.55	100942.55	221827.64	225	600	10	2	505.60	200
14	37169.21	123237.58	-61288.90	0.31	0.31	36971.27	73942.55	100942.55	221827.64	225	600	10	2	505.60	200
15	42715.55	150623.70	-79431.12	0.31	0.47	45187.11	90374.22	123374.22	271122.67	275	600	10	2	333.87	200
16	56187.73	123237.58	-29591.37	0.31	0.31	36971.27	73942.55	100942.55	221827.64	225	600				
17	43359.30	150623.70	-78358.21	0.31	0.31	45187.11	90374.22	123374.22	271122.67	275	600	10	2	505.60	200
18	50404.78	150623.70	-66615.73	0.31	1.06	45187.11	90374.22	123374.22	271122.67	275	600	10	2	149.62	100

Tabel 9.3.2.b. (Lanjutan - 3)

BAB X

PERENCANAAN KOLOM

10.1. PROSEDUR PERENCANAAN

Konsep pada mekanisme penyebaran energi selama terjadi gempa kuat yang terjadi pada struktur rangka bertingkat, diperlukan sendi plastis yang terbentuk di balok harus lebih besar dari pada di kolom. Sehingga keruntuhan kolom akibat *soft story* dapat dicegah.

Berdasar referensi Seismic Design Of Reinf. Concrete ...., T. Paulay :

- Pendekatan perencanaan desain kapasitas

Momen lentur, geser, dan gaya aksial kolom dihasilkan dari analisa struktur elastis.

- Momen kolom akibat momen kapasitas balok

a. Kolom diatas kolom lantai dasar

Tujuan utama desain kapasitas kolom adalah mencegah terbentuknya sendi plastis pada kedua ujung kolom di setiap level lantai. Oleh karena itu kolom harus mampu menahan momen terbesar secara elastis, yang dihasilkan dari momen kapasitas balok.

b. Kolom di lantai dasar atau kolom 1st

Kolom di lantai dasar (*base level*), diasumsikan terjepit penuh di ujung bawah. Kolom di ujung bawah ini diijinkan terjadi sendi plastis. Maka desain momen kolom ujung bawah dapat dihitung berdasar pada momen akibat beban gravitasi dan beban gempa.

Sedangkan momen kolom di ujung atas dicari berdasar momen kapasitas balok seperti pada point a diatas.

c. Kolom di lantai atas (*top story*)

Di level ini diijinkan terbentuknya sendi plastis di kedua ujung kolom.

- Langkah dalam desain kolom :

1. Ditentukan momen lentur untuk semua elemen rangka yang dihasilkan akibat beban gravitasi dan gempa (tanpa faktor) dengan cara analisa elastis. Momen rencana akibat gempa dan gravitasi ditentukan kemudian dengan perhitungan manual,
2. Elemen balok di desain akibat momen lentur di penampang kritis, dengan penulangan sesuai momen perlu,
3. Tentukan momen nominal balok di kedua ujung balok yang diharapkan terjadi sendi plastis, pada setiap bentang balok pada kedua arah (- dan +). Kemudian tentukan geser balok akibat gempa yang didapat dari penulangan lentur balok,
4. Tentukan kapasitas balok akibat faktor Φo dan faktor pembesaran dinamis ωd pada setiap bentang dan kedua arah. Faktor diatas tidak digunakan pada kolom yang diharapkan terjadi sendi plastis, yaitu di kolom ujung bawah lantai dasar (base) dan kolom lantai atas (roof),
5. Desain momen rencana kolom ditentukan berdasar point 4. diatas,
6. Desain geser kolom ditentukan berdasar pada kedua momen rencana kolom di kedua ujung.

☐ **Mutu bahan**

Mutu beton fc' 30 MPa

Mutu baja tulangan fy 400 MPa

10.2. PERUMUSAN

10.2.1. Momen rencana kolom

Berdasar pada SKSNI 3.14.4.2 :

$\Sigma Mu,k \geq 0,7.\ \omega d.\ \Sigma M\ kap, b$
$M\ kap,b = \Phi o.\ M\ nak,b$

Dalam perencanaan ini digunakan perumusan berdasar referensi Desain Struktur Rangka Beton Bertulang ...., Gideon K., yaitu :

$$Mu, k\text{-}x = \frac{h}{hn}.\ 0,7.\ \omega d.\ \Phi o.\ \alpha k.\ \left[\Sigma \frac{l\,b}{ln\,b}.\ Mnak,b\ x + 0,3.\ \Sigma \frac{l\,b}{ln\,b}.\ Mnak,b\ y\right]$$

$$Mu, k\text{-}y = \frac{h}{hn}.\ 0,7.\ \omega d.\ \Phi o.\ \alpha k.\ \left[\Sigma \frac{l\,b}{ln\,b}.\ Mnak,b\ y + 0,3.\ \Sigma \frac{l\,b}{ln\,b}.\ Mnak,b\ x\right]$$

dimana : h = tinggi kolom antar titik pertemuan (as)

hn = tinggi bersih kolom

l b = bentang balok yang ditinjau antar titik pertemuan

ln b = bentang bersih balok

Mnak,b-x = momen nominal balok arah sumbu global x

Mnak,b-y = momen nominal balok arah sumbu global y

αk = faktor distribusi momen dari kolom yang ditinjau, yang dihitung dari kekakuan relatif unsur yang bertemu di titik pertemuan, di ujung atas dan bawah

$$\alpha k a\ i = \frac{ME,\ k\ lt\ i\ atas}{ME,\ k\ lt\ i\ atas + ME,\ k\ lt\ (i{+}1)\ bawah} \qquad \text{(ujung atas)}$$

$$\alpha k b\ i = \frac{ME,\ k\ lt\ i\ bawah}{ME,\ k\ lt\ i\ bawah + ME,\ k\ (i{-}1)\ atas} \qquad \text{(ujung bawah)}$$

Momen rencana kolom tidak perlu lebih dari :

$$\Sigma Mu,k = 1{,}05.\ \Sigma(M\ D,k + M\ L,k + \frac{4}{K}.\ M\ E,k)$$

10.2.2. Tekan rencana kolom

Berdasar SKSNI 3.14.4.3 :

$$Nu,k = \frac{0{,}7.\ Rv.\ \Phi o.\ \sum M\ nak,b}{l\ b} + 1{,}05.\ Ng,\ k$$

Tekan perlu kolom tidak perlu lebih dari :

$$Nu,k = 1{,}05.\ (Ng,\ k + \frac{4}{K}.\ NE,\ k)$$

dimana :

$\Phi o = 1{,}25$

$K = 1$

ωd = faktor pembesaran dinamis = 1,3

= 1 (kolom lantai satu/dasar dan lantai atas, diijinkan terjadinya s. plastis)

Rv = faktor reduksi = 1 untuk $1 < n \leq 4$

= 1,1 - 0,025. n untuk $4 < n \leq 20$

= 0,6 untuk $n > 20$

n = jumlah lantai tingkat diatas kolom yang ditinjau

ΣM nak,b = momen nominal balok di pusat joint dengan memperhitungkan kombinasi momen positif dan negatif l b = bentang balok yang ditinjau diukur dari pusat joint

Ng, k = gaya aksial akibat beban gravitasi terfaktor di pusat joint

NE, k = gaya aksial akibat beban gempa di pusat joint

10.2.3. Geser rencana kolom

Gaya geser rencana kolom :

$$Vu, k = \frac{(Mu,k \text{ atas} + Mu,k \text{ bawah})}{h\ n}$$

Gaya geser rencana kolom tidak perlu lebih dari :

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

Kontribusi beton terhadap geser :

$$Vc = 2. (1 + \frac{Nu}{14. Ag}). \frac{\sqrt{fc'}}{6}. bw. d \qquad \text{(SKSNI 3.4.3.2)}$$

dimana : Nu = gaya aksial minimum pada kolom yang ditinjau

h n = tinggi bersih kolom

Mu, k = momen rencana kolom ujung atas dan bawah

10.2.4. Sambungan balok - kolom (*Beam - column joint*)

$$V\ kol = 0,7. \frac{\left(\frac{l\ kr}{ln\ kr}. Mkap, b\ kr + \frac{l\ kn}{ln\ kn}. Mkap, b\ kn\right)}{\frac{1}{2}. (h, ka + h, kb)} \qquad \text{(SKSNI 3.14.6.)}$$

dimana :

Mkap, b kr dan Mkap, b kn = momen kapasitas balok sebelah kiri dan kanan joint

l kr dan l kn = bentang balok sebelah kiri dan kanan joint (as ke as)

ln kr dan ln kn = bentang bersih balok sebelah kiri dan kanan joint

h, ka dan h, kb = tinggi kolom diatas dan dibawah titik pertemuan

$$T = C = 0,7.\ \frac{Mkap, b}{z}$$

$$Vj, h = C\ kr + T\ kn - V\ kol$$

dimana : z = jarak titik berat tulangan tarik ke beton tertekan

10.3 PERENCANAAN KOLOM

Berikut adalah perencanaan kolom di as A1.

- Kolom A1 termasuk kolom exterior,
- Balok di sebelah kanan kolom arah sumbu x 40/70 L=6m,

  Mnak, b + = 404172,85 Nm

  Mnak, b - = 739447,2 Nm

- Balok di sebelah kanan kolom arah sumbu y 40/70 L=5m

  Mnak, b + = 402320,3 Nm

  Mnak, b - = 739447,2 Nm

(Mnak, b telah dihitung pada Bab IX Perencanaan Balok Induk)

A. Penulangan longitudinal/lentur kolom di lantai dua

A.1. Perhitungan momen kolom arah x

Momen kolom arah x tanpa faktor dari analisa struktur :

MD x = 96,4 kNm

ML x = 12,6 kNm

ME, k i atas = 247,8 kNm

ME, k i bawah = 486,5 kNm

ME, k i+1 bawah = 217 kNm

ME, k i-1 atas = 21,9 kNm

$$\alpha ka = \frac{247,8}{247,8 + 217} = 0,53$$

$$\alpha kb = \frac{486,5}{486,5+21,9} = 0,96$$

$$\text{Mu, k-x atas} = \tfrac{3,6}{2,9}.\ 0,7.\ 1,3.\ 1,25.\ 0,53.\ \left[\tfrac{6}{5,3}.\ 739447,2 + 0,3.\ \tfrac{5}{4,275}.\ 739447,2\right]$$

$$= 825516,2 \text{ Nm}$$

$$\text{Mu, k-x bawah} = \tfrac{3,6}{2,9}.\ 0,7.\ 1,3.\ 1,25.\ 0,96.\ [\tfrac{6}{5,3}.\ 739447,2 + 0,3.\ \tfrac{5}{4,275}.\ 739447,2]$$

$$= 1474588,4 \text{ Nm}$$

Momen kolom tidak perlu lebih dari :

Mu, k-x atas max = 1,05. (-96,4 - 12,6 - 4. (247,8 + 0,3. 288)). 1000

= -1518090 Nm (tanda negatif hanya menunjukkan arah)

Mu, k-x bawah max = 1,05. (96,4 + 12,6 + 4. (486,5 + 0,3. 520,7)). 1000

= 2813832 Nm

A.2. Perhitungan momen kolom arah y

Momen kolom arah y tanpa faktor :

MD y = 72,6 kNm

ML y = 6,1 kNm

ME, k i atas = 288 kNm

ME, k i bawah = 520,7 kNm

ME, k i+1 bawah = 234 kNm ME, k i-1 atas = 31,4 kNm

$$\alpha ka = \frac{288}{288 + 234} = 0,55$$

$$\alpha kb = \frac{520,7}{520,7 + 31,4} = 0,94$$

$$\text{Mu, k-y atas} = \tfrac{3,6}{2,9}.\ 0,7.\ 1,3.\ 1,25.\ 0,55.\left[\tfrac{5}{4,275}.\ 739447,2 + 0,3.\ \tfrac{6}{5,3}.\ 739447,2\right]$$

$$= 869432 \text{ Nm}$$

$$\text{Mu, k-y bawah} = \tfrac{3,6}{2,9}.\ 0,7.\ 1,3.\ 1,25.0,94.\ [\tfrac{5}{4,275}.739447,2 + 0,3.\tfrac{6}{5,3}.739447,2]$$

$$= 1500049 \text{ Nm}$$

Momen kolom tidak perlu lebih dari :

Mu, k-y atas max = 1,05. (-72,6 - 6,1 - 4. (288 + 0,3. 247,8)). 1000

= -1604463 Nm

Mu, k-y bawah max = 1,05. (72,6 + 6,1 + 4. (520,7 + 0,3. 486,5)). 1000

= 2882565 Nm

Cek pengaruh kelangsingan :

Berdasar SKSNI pasal 3.14.2.4, perencanaan dengan daktilitas 3 harus memenuhi SKSNI pasal 3.1 hingga 3.11. Hal ini berarti harus dilakukan cek kelangsingan kolom pada pasal 3.3.10.

Struktur rangka terdiri dari balok dan kolom. Kekakuan arah lateral struktur hanya mengandalkan kekakuan sambungan antara balok dan kolom. Sehingga struktur masih dimungkinkan untuk mengalami pergoyangan atau berdeformasi arah lateral.

$\frac{K.\ Lu}{r} < 22$, maka pengaruh kelangsingan boleh diabaikan

dimana :

K = faktor panjang efektif struktur tekan

Lu = panjang bersih struktur tekan

r = radius girasi

= 0,3. h (h = dimensi arah yang ditinjau) (SKSNI 3.3.11.2)

Perhitungan K arah sumbu x :

Mencari (EI) balok 40/70 L=6 m :

$Ec = wc^{1,5}.\ 0,043.\ \sqrt{fc'} = 2400^{1,5}.\ 0,043.\ \sqrt{30} = 29440$ MPa

$Ig = \frac{1}{12}.\ 400.\ 700^3 = 1,14.\ 10^{10}$ mm^4

$Icr = \frac{1}{2}.\ Ig = 5,72.\ 10^9$ mm^4

(EI) balok = 29440. 5,72. 10^9 = 1,7. 10^{14} Nmm^2

Mencari (EI) kolom :

Es = 200000 MPa

$Ig = \frac{1}{12}.\ 700^4 = 2.\ 10^{10}$ mm^4

Anggap dengan tulangan 4 D25 tiap sisi :

$d' = (50 + 12 + \frac{1}{2}.\ 25) = 74,5$ mm

$Is = \Sigma\ As.\ e^2$

$= 2.\ (4.\ 491.\ (\frac{700}{2} - 74,5)^2 + (2.\ 491.\ (\frac{700-100}{3}.\frac{1}{2})^2\ ) = 2,9.\ 10^8$ mm^4

(EI) kolom = 0,2. Ec. Ig + Es. Is

= 0,2. 29440. 2. 10^{10} + 2.10^5. 2,9. 10^8 = 1,76. 10^{14} Nmm^2

(EI) kolom = 0,4. Ec. Ig

= 0,4. 29440. 2. 10^{10} = 2,36. 10^{14} Nmm^2 (terbesar)

$$\psi a = \frac{2.(2{,}36.10^{14}/3600)}{1{,}7.10^{14}/6000} = 4{,}6 \qquad \text{(kolom exterior)}$$

$$\psi b = \frac{2{,}36.10^{14}/3600+2{,}36.10^{14}/3400}{1.7.10^{14}/6000} = 4{,}8$$

Dari diagram nomogram panjang tekuk kolom :

$K = 2{,}8$ (untuk kolom unbraced)

$$\frac{K.\ Lu}{r} = \frac{2{,}8.\ 2900}{0{,}3.\ 700} = 38{,}7 \quad > 22 \qquad \text{(diperhitungkan tekuk)}$$

Hitung faktor pembesaran momen :

$$Cm = 0{,}6 + 0{,}4.\ \frac{M1b}{M2b} = 0{,}6\ + 0{,}4.\ \frac{-100}{138{,}6} = 0{,}3 \qquad \text{, pakai min } 0{,}4$$

$$\beta d = \frac{MuD}{MuD + MuL} = \frac{1{,}2.96{,}4}{1{,}2.96{,}4 + 1{,}6.12{,}6} = 0{,}85$$

$$(EI) = \frac{(EI)\ kolom}{1+\beta d} = \frac{2{,}36.10^{14}}{1+0{,}85} = 1{,}3.\ 10^{14}\ Nmm^2$$

$$Pc = \frac{\Pi^2.(EI)}{(K.\ Lu)^2} = \frac{\Pi^2.\ 1{,}3.\ 10^{14}}{(2{,}8.\ 2900)^2} = 19459471\ N$$

$$\delta b = \frac{Cm}{1-\frac{Pu}{\Phi.\ Pc}} = \frac{0{,}4}{1-\frac{587520}{0{,}65.\ 19459471}} = 0{,}4 \qquad \text{, pakai } \delta b \text{ min} = 1$$

$\sum Pc$ kolom exterior as 1 lantai dua = 8. 19459471 = 155675768 N

$$\delta s = \frac{1}{1-\frac{\sum Pu}{\Phi.\ \sum Pc}} = \frac{1}{1-\frac{3842000}{0{,}65.\ 155675768}} = 1{,}1$$

Momen kolom arah x setelah pembesaran (terfaktor) :

$$Mc = \delta b.\ M2b + \delta s.\ M2s$$

$$= 138{,}6 + 1{,}1.\ 287{,}3 = 454{,}6\ kNm$$

Perhitungan K arah sumbu y :

Balok 40/70 L=5 m :

(EI) balok = $1{,}7.\ 10^{14}$ Nmm^2

Balok 40/80 L=8,5m :

(EI) balok = $29440.\ \frac{1}{2}.\frac{1}{12}.\ 400.\ 800^3 = 2{,}51.\ 10^{14}$ Nmm^2

Kolom 75x75 :

$Ig = \frac{1}{12}.\ 750^4 = 2{,}64.\ 10^{10}$ mm^4

(EI) kolom = $3{,}1.\ 10^{14}$ Nmm^2

Kolom yang ada di as A arah y :

- 2 kolom interior
- 2 kolom exterior

$$\psi a = \frac{2.(2{,}36.10^{14}/3600)}{1{,}7.10^{14}/5000} = 3{,}9$$ (kolom exterior)

$$\psi b = \frac{2{,}36.10^{14}/3400+2{,}36.10^{14}/3600}{1.7.10^{14}/5000} = 4$$

$K = 2{,}1$, $\frac{2{,}1.2900}{0{,}3.700} = 29$ > 22 (diperhitungkan tekuk)

$$\psi a = \frac{2.(3{,}1.10^{14}/3600)}{1{,}7.10^{14}/5000 + 2{,}51.10^{14}/8500} = 1{,}6$$ (kolom as A2 interior)

$$\psi b = \frac{3{,}1.10^{14}/3400+3{,}1.10^{14}/3600}{1{,}7.10^{14}/5000+2{,}51.10^{14}/8500} = 2{,}1$$

$K = 1{,}55$

Hitung faktor pembesaran momen :

$$\mathrm{Cm} = 0{,}6 + 0{,}4.\frac{-38}{96{,}8} = 0{,}4$$

$$\beta d = \frac{1{,}2.72{,}6}{1{,}2.72{,}6 + 1{,}6.6{,}1} = 0{,}9$$

$$(\mathrm{EI}) = \frac{2{,}36.10^{14}}{1+0{,}9} = 1{,}2.\ 10^{14}\ \mathrm{Nmm}^2$$

$$\mathrm{Pc} = \frac{\Pi^2.(\mathrm{EI})}{(\mathrm{K.\ Lu})^2} = \frac{\Pi^2.\ 1{,}2.\ 10^{14}}{(2{,}1.\ 2900)^2} = 31933492\ \mathrm{N} \qquad \text{(kolom exterior)}$$

$$\delta b = \frac{\mathrm{Cm}}{1-\frac{\mathrm{Pu}}{\Phi.\ \mathrm{Pc}}} = \frac{0{,}4}{1-\frac{587520}{0{,}65.\ 31933492}}\ 0{,}48 \qquad \text{, pakai } \delta b \text{ min} = 1$$

Untuk kolom interior :

$$(\mathrm{EI}) = \frac{3{,}1.10^{14}}{1+0{,}9} = 1{,}6.\ 10^{14}\ \mathrm{Nmm}^2$$

$$\mathrm{Pc} = \frac{\Pi^2.1{,}6.\ 10^{14}}{(1{,}55.2900)^2} = 58616732\ \mathrm{N}$$

ΣPc kolom lantai dua = 2. (31933492 + 58616732) = 181100448 N

$$\delta s = \frac{1}{1-\frac{\sum \mathrm{Pu}}{\Phi.\sum \mathrm{Pc}}} = \frac{1}{1-\frac{3842000}{0{,}65.\ 181100448}} = 1{,}03 = 1$$

Momen kolom arah y setelah pembesaran :

$$\mathrm{Mc} = \delta b.\ \mathrm{M2b} + \delta s.\ \mathrm{M2s}$$

$$= 96{,}8 + 307{,}5 = 404{,}3\ \mathrm{kNm}$$

Dari perhitungan kolom diatas, momen perlu kolom :

Arah x :

Mu, k = 1474588,4 Nm (pakai untuk perencanaan)

Mc = 454600. Φ = 454600. 0,65 = 295490 Nm

Arah y :

Mu, k = 1500049 Nm (pakai untuk perencanaan)

Mc = 404300. 0,65 = 262795 Nm

A.3. Perhitungan tekan kolom

Untuk kolom lantai dua, jumlah lantai yang dipikul = 8

Rv = 1,1 - 0,025. 8 = 0,9

Ng, k = 1,2. ND, k + 1,6. NL, k

= 1,2. 2776 + 1,6. 319,8 = 3842,9 kN

$$Nu,\ k\text{-}x = 0,7.\ Rv.\ \Phi o.\ \Sigma\left(\frac{Mnak,\ b\ x}{l\ b} + 0,3.\ \frac{Mnak\ b\ y}{l\ b}\right) + 1,05.\ Ng,\ k$$

$$Nu,\ k\text{-}y = 0,7.\ Rv.\ \Phi o. \Sigma\left(\frac{Mnak,\ b\ y}{l\ b} + 0,3.\ \frac{Mnak,\ b\ x}{l\ b}\right) + 1,05.\ Ng,\ k$$

Tekan maksimum kolom akibat Mnak, b - :

$$Nu,\ k\text{-}x = 0,7.\ 0,9.\ 1,25.\ \left(\frac{739447,2}{6} + \frac{0,3.\ 739447,2}{5}\right) + 1,05.\ 3842900$$

= 4167015 N

$$Nu,\ k\text{-}y = 0,7.\ 0,9.\ 1,25.\ \left(\frac{739447,2}{5} + \frac{0,3.739447,2}{6}\right) + 1,05.\ 3842900$$

= 4180603 N

Tekan minimum kolom akibat Mnak, b + :

$$Nu,\ k\ x = -\ 0,7.\ 0,9.\ 1,25.\ \left(\frac{404172,85}{6} + \frac{0,3.\ 402320,3}{5}\right) + 1,05.\ 3842900$$

= 3962967 N

$$Nu,\ k\ y = -\ 0,7.\ 0,9.\ 1,25.\ \left(\frac{402320,3}{5} + \frac{0,3.\ 404172,85}{6}\right) + 1,05.\ 3842900$$

= 3955744 N

Tekan kolom tidak perlu lebih dari :

$$Nu,k\text{-}x = 1{,}05.\ (Ng,k + \frac{4}{K}.\ (NE,k\text{-}x + 0{,}3.\ NE,k\text{-}y))$$

$$= 1{,}05.\ (3842{,}9 + 4.\ (1333{,}5 + 0{,}3.\ 1471{,}6)).\ 1000 = 11489940\ N$$

$$Nu,k\text{-}y = 1{,}05.\ (Ng,k + \frac{4}{K}.\ (0{,}3.\ NE,k\text{-}x + NE,k\text{-}y))$$

$$= 1{,}05.\ (3842{,}9 + 4.\ (0{,}3.\ 1333{,}5 + 1471{,}6)).\ 1000 = 11895954\ N$$

Penulangan lentur kolom arah x :

Penulangan lentur kolom dengan cara uniaxial atau perhitungan per satu sisi.

$fc' = 30$ MPa

$fy = 400$ MPa

(b x h) kolom = 70 x 70 cm

$$Mn\ perlu = \frac{Mu\ k}{\Phi} = \frac{1474588{,}4}{0{,}65} = 2268598\ Nm$$

$$Pn\ perlu = \frac{Nu,k}{\Phi} = \frac{4167015}{0{,}65} = 6410792\ N$$

$$e\ min = (15 + 0{,}03.\ h) = (15 + 0{,}03.\ 700) = 36\ mm$$

$$e = \frac{Mn.\ \Phi}{Nu} = \frac{2268598.\ 0{,}65}{4167015}.\ 100 = 11\ cm \qquad > e\ min$$

$$\frac{e}{h} = \frac{Mn.\ \Phi}{Nu.\ h} = \frac{2268598.\ 0{,}65}{4167015.\ 0{,}7} = 0{,}51$$

$$\gamma = \frac{700 - 2.\ 72{,}5}{700} = 0{,}78 \approx 0{,}75$$

$$K = \frac{Nu,k}{fc'.\ b.\ h} = \frac{4167015}{30.\ 700.\ 700} = 0{,}28$$

Dari diagram interaksi kolom, didapat :

$\rho = 2{,}5$ %

As total perlu = ρ. Ag = 0,025. 700. 700 = 12250 mm^2

As satu sisi = 0,25. Ast = 3062,5 mm^2

(pakai tul. 16 D 32, As satu sisi= 5. 804 = 4020 mm^2)

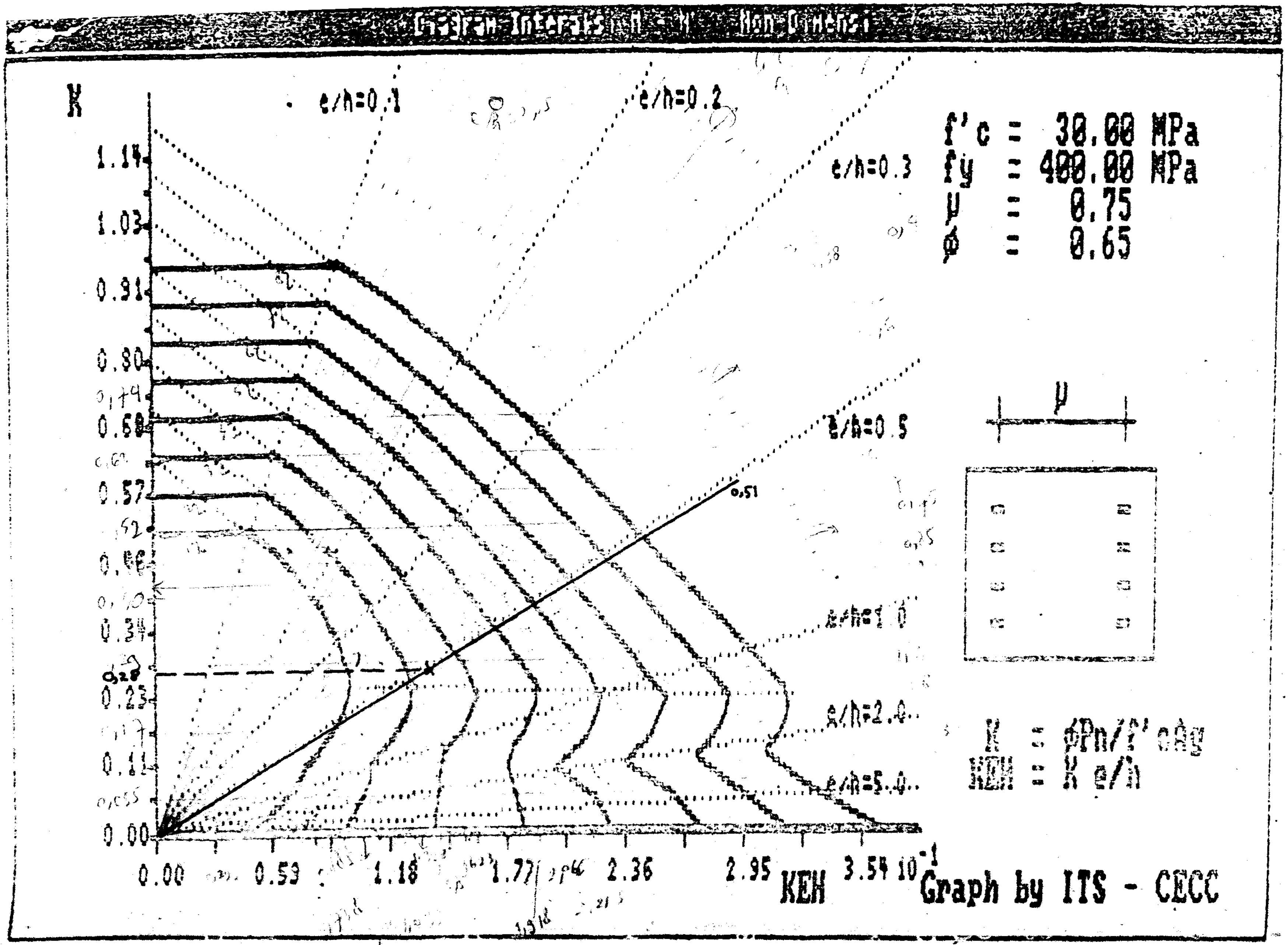
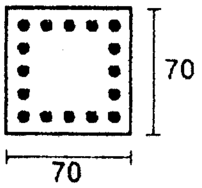


Diagram Interaksi K - K Non Dimensi
K
1.14
1.03
0.91
0.80
0,79
0.68
0,60
0.57
,52
0.46
0,40
0.34
0,28
0.23
0.17
0.11
0,055
0.00
e/h=0.1
e/h=0.2
e/h=0.3
e/h=0.5
e/h=1.0
e/h=2.0
e/h=5.0
0,51
0.00
0.53
1.18
1.77
2.36
2.95
3.54 10-1
KEH
f'c = 30.00 MPa
fy = 400.00 MPa
μ = 0.75
φ = 0.65
μ
K = φPn/f'cAg
KEH = K e/h
Graph by ITS - CECC

Momen kapasitas kolom :



Ast terpasang = 16. 804 = 12864 mm^2

ρ terpasang = $\frac{12864}{700.700}$ = 0,026

K = 0,29

Nu, k terpasang = 0,29. 30. 700. 700 = 4263000 N > 4167015 N (OK)

$K \frac{e}{h} = 1,35$

Mnak, k = $\frac{1,35}{0,29} . \frac{4263000.700}{0,65} . \frac{1}{1000}$ = 21371538 Nm > 2268598 Nm

Pn max = 0,8. Po

= 0,8. [(0,85. fc'. (Ag - Ast) + fy. Ast]

= 0,8. [(0,85. 30. (700. 700 - 12864) + 400. 12864]

= 13850054 N > 6410792 N

Penulangan lentur kolom arah y :

Mn perlu = $\frac{1500049}{0,65}$ = 2307768 Nm

Pn perlu = $\frac{4180603}{0,65}$ = 6431697 N

$e = \frac{Mn. \Phi}{Nu} = \frac{2307768. 0,65}{4180603} . 100$ = 12 cm > e min

$\frac{e}{h} = \frac{2307768. 0,65}{4180603. 0,7} = 0,51$

$\gamma \approx 0,75$

$K = \frac{4180603}{30. 700. 700} = 0,28$

Dari diagram interaksi kolom, didapat :

ρ = 2,5 %

As total perlu = 0,025. 700. 700 = 12250 mm^2

(pakai tul. 16 D 32, As satu sisi = 5. 804 = 4020 mm^2)

Momen kapasitas kolom :

ρ terpasang = 0,026

K = 0,29

Nu, k terpasang = 4263000 N > 4180603 N (OK)

$K \frac{e}{h} = 1,45$

$$\text{Mnak, k} = \frac{1,45}{0,29} \cdot \frac{4263000.\ 700}{0,65} \cdot \frac{1}{1000} = 22954615 \text{ Nm} \quad > 2307768 \text{ Nm}$$

Pn max = 13850054 N > 6431697 N

B. Penulangan lentur kolom lantai satu / dasar

Perhitungan momen rencana kolom di lantai dasar sama dengan di lantai dua. Perbedaan yaitu pada momen rencana di ujung bawah kolom didapat dari momen akibat gempa.

B.1. Perhitungan momen kolom arah x

$$\alpha ka = \frac{21,9}{21,9 + 486,5} = 0,05$$

$\alpha kb = 1$

$$\text{Mu, k-x atas} = \tfrac{3,4}{3,05} \cdot 0,7.\ 1,25.\ 1,3.\ 0,05.\left[\tfrac{6}{5,3} \cdot 739447,2 + 0,3.\ \tfrac{5}{4,275} \cdot 739447,2\right]$$

$$= 59897 \text{ Nm}$$

Mu, k-x bawah = ME x + 0,3. ME y = 908340 Nm

Momen kolom tidak perlu lebih besar dari :

Muk-x atas max = 1,05. (68 + 8,9 + 4. (21,9 + 0,3. 31,4)). 1000 = 212289 Nm

Muk-x bawah max = 3895773 Nm

B.2. Perhitungan momen kolom arah y

$$\alpha ka = \frac{31,4}{31,4 + 520,7} = 0,06$$

$$\alpha kb = 1$$

$$Mu,\ k\text{-}y\ atas = \tfrac{3,4}{3,05}.\ 0,7.\ 1,25.\ 1,3.\ 0,06.\left[\tfrac{5}{4,275}.739447,2 + 0,3.\tfrac{6}{5,3}.739447,2\right]$$

$$= 80482\ Nm$$

Mu, k-y bawah = ME y + 0,3. ME x = 922060 Nm

<u>Momen kolom tidak perlu lebih dari :</u>

Mu, k-y atas = 211449 Nm

Mu, k-y bwh = 3924627 Nm

<u>Cek pengaruh kelangsingan :</u>

Dengan cara yang sama seperti pada perhitungan kolom di lantai dua.

<u>Perhitungan K arah sumbu x :</u>

$$\psi a = \frac{2,36.10^{14}/3400 + 2,36.10^{14}/3600}{1,7.10^{14}/6000} = 4,8$$

$\psi b = 1$ (jepit)

K = 1,7 (untuk kolom unbraced)

$$\frac{K.\ Lu}{r} = \frac{1,7.\ 3050}{0,3.\ 700} = 24,6 \quad > 22$$ (diperhitungkan tekuk)

<u>Pembesaran momen :</u>

$$Cm = 0,6 + 0,4.\ \frac{-65,4}{95,8} = 0,2$$, pakai 0,4

$$\beta d = \frac{1,2.68}{1,2.68 + 1,6.8,9} = 0,85$$

$$(EI) = \frac{2,36.10^{14}}{1+0,85} = 1,3.\ 10^{14}\ Nmm^2$$

$$Pc = \frac{\Pi^2.\ 1,3.\ 10^{14}}{(1,7.\ 3050)^2} = 47724960\ N$$

$$\delta b = \frac{0{,}4}{1-\frac{587520}{0{,}65.\ 47724960}} = 0{,}4 \quad \text{, pakai } \delta b \text{ min} = 1$$

ΣPc kolom exterior lantai dasar = 8. 47724960 = 381799680 N

$$\delta s = \frac{1}{1-\frac{\sum Pu}{\Phi.\sum Pc}} = \frac{1}{1-\frac{4269120}{0{,}65.\ 381799680}} = 1$$

Momen kolom arah x setelah pembesaran (terfaktor) :

$$Mc = \delta b.\ M2b + \delta s.\ M2s$$

$$= 95{,}8 + 455{,}9 = 551{,}7 \text{ kNm}$$

Perhitungan K arah sumbu y :

$$\psi a = \frac{2{,}36.10^{14}/3400+2{,}36.10^{14}/3600}{1{,}7.10^{14}/5000} = 4$$

$$\psi b = 1$$

$K = 1{,}65$, $\frac{1{,}65.3050}{0{,}3.700} = 23{,}9 > 22$ (diperhitungkan tekuk)

$\psi a = \frac{3{,}1.10^{14}/3400+3{,}1.10^{14}/3600}{1{,}7.10^{14}/5000 + 2{,}51.10^{14}/8500} = 2{,}8$ (kolom as A2 interior)

$$\psi b = 1$$

$$K = 1{,}55$$

Pembesaran momen :

$$Cm = 0{,}6 + 0{,}4.\ \frac{-27}{60{,}8} = 0{,}42$$

$$\beta d = \frac{1{,}2.45{,}9}{1{,}2.45{,}96 + 1{,}6.3{,}6} = 0{,}9$$

$$(EI) = \frac{2{,}36.10^{14}}{1+0{,}9} = 1{,}2.\ 10^{14} \text{ Nmm}^2$$

$Pc = \frac{\Pi^2.\ 1{,}2.\ 10^{14}}{(1{,}65.\ 3050)^2} = 46764191$ N (kolom exterior)

$\delta b = \frac{0{,}4}{1-\frac{587520}{0{,}65.\ 46764191}}$ 0,4 , pakai δb min = 1

Kolom interior :

$$(EI) = \frac{3,1.10^{14}}{1+0,9} = 1,6.\ 10^{14}\ \text{Nmm}^2$$

$$Pc = \frac{\Pi^2.1,6.\ 10^{14}}{(1,55.3050)^2} = 70657237\ \text{N}$$

ΣPc kolom = 2. (70657237 + 46764191) = 234842856 N

$$\delta s = \frac{1}{1 - \frac{\sum Pu}{\Phi.\sum Pc}} = \frac{1}{1 - \frac{3842000}{0,65.\ 234842856}} = 1$$

Momen kolom arah y setelah pembesaran :

$Mc = \delta b.\ M2b + \delta s.\ M2s$

$= 60,8 + 713,8 = 774,6$ kNm

Dari perhitungan kolom diatas, momen perlu kolom :

Mu, k-x = 908340 Nm

Mu, k-y = 922060 Nm

B.3. Perhitungan tekan kolom

Untuk kolom lantai satu, jumlah lantai yang dipikul = 9

Rv = 1,1 - 0,025. 9 = 0,875

Ng, k = 1,2. ND, k + 1,6. NL, k

= 1,2. 3082 + 1,6. 356,7 = 4269,1 kN

Tekan maksimum kolom akibat Mnak, b - :

$$Nu, k\text{-}x = 0{,}7.\ 0{,}875.\ 1{,}25.\ (\frac{739447{,}2}{6} + \frac{0{,}3.\ 739447{,}2}{5}) + 1{,}05.\ 4269100$$

$$= 4610901\ N$$

$$Nu, k\text{-}y = 0{,}7.\ 0{,}875.\ 1{,}25.\ (\frac{739447{,}2}{5} + \frac{0{,}3.739447{,}2}{6}) + 1{,}05.\ 4269100$$

$$= 4624110{,}8\ N$$

Tekan minimum kolom akibat Mnak, b + :

$$Nu, k\ x = -\ 0{,}7.\ 0{,}875.\ 1{,}25.\ \left(\frac{404172{,}85}{6} + \frac{0{,}3.\ 402320{,}3}{5}\right) + 1{,}05.\ 4269100$$

$$= 4412520\ N$$

$$Nu, k\ y = -\ 0{,}7.\ 0{,}875.\ 1{,}25.\ \left(\frac{402320{,}3}{5} + \frac{0{,}3.\ 404172{,}85}{6}\right) + 1{,}05.\ 4269100$$

$$= 4405498\ N$$

Tekan kolom tidak perlu lebih dari :

$$Nu, k\text{-}x = 1{,}05.\ (Ng, k + \frac{4}{K}.\ (NE, k\text{-}x + 0{,}3.\ NE, k\text{-}y)) = 13100682\ N$$

$$Nu, k\text{-}y = 1{,}05.\ (Ng, k + \frac{4}{K}.\ (0{,}3.\ NE, k\text{-}x + NE, k\text{-}y)) = 13611654\ N$$

Penulangan lentur kolom arah x :

Dengan cara yang sama seperti pada kolom di lantai dua, didapat :

$\frac{e}{h} = 0{,}18$

$\frac{Nu,\ k}{fc'.\ Ag} = 0{,}31$

$\rho = 1\ \%$

As total perlu = ρ. Ag = 0,01. 700. 700 = 4900 mm^2

(pakai tul. 16 D 32)

Momen kapasitas kolom :

ρ terpasang = $\frac{12864}{700.700}$ = 0,026

K = 0,43

Nu, k terpasang = 7791000 N > Nu perlu

K $\frac{e}{h}$ = 1,1

Mnak, k = 17413846 Nm > Mn perlu

Pn max = 13850054 N > Pn perlu

Penulangan lentur kolom arah y :

$\frac{e}{h}$ = 0,18

K = $\frac{\text{Nu, k}}{\text{fc'. b. h}}$ = 0,31

Diagram interaksi kolom, didapat :

ρ = 1 %

(pakai tul. 16 D 32)

Momen kapasitas kolom :

K = 0,53

K $\frac{e}{h}$ = 0,9

Nu, k terpasang = 7791000 N > Nu perlu

Mnak, k = 17413846 Nm > Mn perlu

Pn max = 13850054 N > Pn perlu

C. Penulangan geser kolom di lantai dua

$$Vu, k\text{-}x = \frac{825516 + 1474588}{2,9} = 795600 \text{ N}$$

$$Vu, k\text{-}y = \frac{869432 + 1500049}{2,9} = 812294 \text{ N}$$

Geser kolom tidak perlu lebih dari :

$Vu, k\text{-}x \max = 1,05. (57,4 + 7,5 + 4. (248 + 0,3. 273.7)). 1000 = 1455867$ N

$Vu, k\text{-}y \max = 1,05. (43,1 + 3,5 + 4. (273,7 + 0,3. 248)). 1000 = 1511328$ N

Geser pada jarak sendi plastis lo :

Daerah sendi plastis kolom (di ujung) tidak boleh kurang dari lo :

- h , untuk Nu < (0,3. Ag. fc')

  4180603 < 4410000

  h = 700 mm
- $\frac{h n}{6} = \frac{2900}{6} = 483$ mm
- 450 mm

Sendi plastis sampai dengan 70 cm dari muka balok.

Syarat jarak sengkang berdasar SKSNI 3.14.4.4 :

- S = 0,25. b

  = 0,25. 700 = 175 mm
- S = 8. D tul lentur

  = 8. 32 = 256 mm
- S = 100 mm

Berdasar SKSNI 3.14.7.2 :

1. Vc di dalam sendi plastis sama dengan nol, sedangkan diluar sendi plastis perhitungan seperti pada SKSNI ayat 3.4.
2. Sengkang merupakan sengkang tertutup, dan memenuhi penulangan pada SKSNI 3.14.4.4.

Perhitungan geser di dalam sendi plastis :

Arah x :

$$\text{Vs perlu} = \frac{\text{Vu, k}}{\Phi} = \frac{795600}{0{,}6} = 1326001\ \text{N}$$

coba tul. D 12, As 1 tul. 113 mm^2 :

$$S = \frac{\text{Av. fy. d}}{\text{Vs}} = \frac{226.\ 400.\ (700 - (60+16+0{,}5.32)}{1326001} = 87{,}4\ \text{mm} \quad \text{(terlalu kecil)}$$

coba lagi dengan 5 D12 :

$$S = \frac{5.\ 113.\ 400.\ 618}{1326001} = 105{,}3\ \text{mm}$$

(Pakai sengkang 5 D12 - 100 mm)

Arah y :

$$\text{Vs perlu} = \frac{812294}{0{,}6} = 1353824\ \text{N}$$

coba tul. 5 D 12, As 1 tul. 113 mm^2 :

$$S = \frac{5.\ 113.\ 400.\ 618}{1353824} = 103{,}2\ \text{mm}$$

(Pakai sengkang 5 D12 - 100 mm)

Perhitungan geser di luar sendi plastis :

Arah x :

$$\text{Vc} = 2.\left(1 + \frac{\text{Nu}}{14.\ \text{Ag}}\right).\frac{\sqrt{fc'}}{6}.\ \text{bw. d} \qquad \text{(SKSNI 3.4.3.2)}$$

$$= 2.\left(1 + \frac{3955744}{14.\ 700.\ 700}\right).\frac{\sqrt{30}}{6}.\ 700.\ 618 = 1245255\ \text{N}$$

$$\text{Vs perlu} = \frac{\text{Vu}}{\Phi} - \text{Vc} = \frac{795600}{0{,}6} - 1245255 = 80746\ \text{N}$$

Coba tul. D 10 :

S perlu = 488,7 mm (perhitungan seperti diatas)

(pakai sengkang D10-100)

Arah y :

Vs perlu = 1353824 - 1245255 = 108569 N

S perlu = 360 mm (pakai sengkang D 10 - 100)

D. Penulangan geser kolom di lantai dasar / satu

$$Vu, k\text{-}x = \frac{59897 + 908340}{3{,}05} = 317455\ N$$

$$Vu, k\text{-}y = \frac{80482 + 922060}{3{,}05} = 328702\ N$$

Geser kolom tidak perlu lebih dari :

$$Vu, k\text{-}x\ max = 1{,}05.\ (41{,}2 + 5{,}4 + 4.\ (286{,}8 + 0{,}3.\ 710{,}5)).\ 1000$$

$$= 2148720\ N$$

$$Vu, k\text{-}y\ \ max = 1{,}05.\ (27{,}6 + 2{,}2 + 4.\ (710{,}5 + 0{,}3.\ 286{,}8)).\ 1000$$

$$= 3376758\ N$$

Geser pada jarak sendi plastis lo :

Daerah sendi plastis kolom (di ujung) tidak boleh kurang dari lo :

- $lo = 1{,}5.\ h$, untuk $Nu > (0{,}3.\ Ag.\ fc')$

  $4624110 > 4410000$

  $lo = 1050$ mm
- $\frac{h\,n}{6} = \frac{3050}{6} = 508$ mm
- 450 mm

Sendi plastis sampai dengan 110 cm dari muka balok.

Perhitungan geser di dalam sendi plastis :

Arah x :

$$Vs\ perlu = \frac{317455}{0{,}6} = 529091\ N$$

coba tul. D 12, As 1 tul. 79 mm^2 :

$$S = \frac{226.\ 400.\ (700 - (60 + 0{,}5.\ 32)}{529091} = 106\ mm$$

(Pakai sengkang D12 - 100 mm)

Arah y :

Vs perlu = 547837 N

coba tul. D 12 :

$$S = \frac{226.\ 400.\ 624}{547837} = 102\ mm$$

(Pakai sengkang D12 - 100 mm)

Perhitungan geser di luar sendi plastis :

Arah x :

$$Vc = 2.\left(1 + \frac{4405498}{14.\ 700.\ 700}\right).\frac{\sqrt{30}}{6}\ .\ 700.\ 624 = 1297036\ N$$

Vs perlu = 529091 - 1297036 = -768754 N

(pakai sengkang D10-100)

Arah y :

Vs perlu = 547837 - 1297036 = -749199 N

(pakai sengkang D10 - 100)

10.3.3. Sambungan balok - kolom

A. Kolom di lantai dua

Arah x :

Mnak, b kn + = 404172,85 Nm

Mnak, b kn - = 739447,2 Nm

$$V\ kol = \frac{0{,}7.\ 1{,}25.\left(\frac{6}{5{,}3}.\ 739447\right)}{\frac{1}{2}.\ (3{,}6 + 3{,}6)} = 203464\ N$$

Tulangan balok 40/70 L=6m (bab IX Perenc. Balok Induk) :

2 lapis tul. D 22, jarak antar lapis 5 cm

tebal beton tertekan a = 75,3 mm

$$z = h - d' - \varnothing tul - \frac{5}{2} - \frac{a}{2}$$

$$= 700 - 52 - 22 - 2{,}5 - 37{,}5 = 586\ mm$$

$$T\ kn = C\ kn = 0{,}7.\ 1{,}25.\ \frac{739447}{0{,}586} = 1104415\ N$$

Vj, h = T kn - V kol = 1104415 - 203464 = 900951 N

$$bj = b\ balok + \frac{1}{2}.\ h\ kolom$$

$= 400 + 350 = 750$ mm , pakai bj = 700 mm

$$Vj,\ h = \frac{Vj,\ h}{bj.\ hc} = \frac{900951}{700.700} = 1{,}84\ MPa$$

Teg. geser joint tidak melebihi (SKSNI 3.14.6.1.2) :

$Vj, h\ max = 1{,}5.\ \sqrt{fc'}\ = 1{,}5.\ \sqrt{30}\ = 8{,}22\ MPa$ (OK)

Geser yang dipikul beton :

$$Vc, h = \frac{2}{3}.\sqrt{\left(\frac{Nu, k}{Ag} - 0, 1.\ fc'\right)}\ .\ bj.\ hc$$

dimana : Nu, k = tekan minimum kolom yang ditinjau

$$= \frac{2}{3}.\sqrt{\left(\frac{3955744}{700.\ 700} - 0, 1.\ 30\right)}\ .\ 700.\ 700 = 735758\ N$$

$Vs, h + Vc, h = Vj, h$

$Vs, h = 900951 - 735758 = 165193\ N$

$$Aj, h\ perlu = \frac{Vs, h}{fy} = \frac{165193}{320} = 513\ mm^2$$

Coba sengkang D 10, As 2 tul. = 157 mm^2

$$n = \frac{513}{157} = 3{,}3$$

(pakai 4 lapis tulangan D 10)

Geser vertikal joint :

$$Vc, v = A'sc.\ \frac{Vj, h}{Asc}.\left(0, 6 + \frac{Nu, k}{Ag.\ fc'}\right)$$

dimana : A'sc dan Asc = luas tulangan lentur tarik dan tekan kolom

$$Vj, h = \frac{bj}{hc}.\ Vj, v$$

dimana : bj = lebar efektif joint

$Vj, v = 900951\ N$

$$Vc, v = 900951.\ (0{,}6 + \frac{3955744}{700.\ 700.\ 30}) = 783015\ N$$

$Vs, v + Vc, v = Vj, v$

$Vs, v = 900951 - 783015 = 117493\ N$

$$Aj, v = \frac{117493}{320} = 367{,}2\ mm^2$$

(Tulangan memanjang tengah terpasang 6 D 32, As = 4825 mm^2)

Arah y :

Mnak, b + = 402320,3 Nm

Mnak, b - = 739447,2 Nm

V kol = 210207 N

2 lapis tul. D 22, jarak antar lapis 5 cm. Tebal beton tertekan a = 75,3 mm

z = 700 - 52 - 22 - 2,5 - 37,5 = 586 mm

$T\ kn = C\ kn = 0{,}7.\ 1{,}25.\ \frac{739447{,}2}{0{,}586} = 1104415\ N$

Vj, h = 1104415 - 210207 = 894209 N

Vj, v = 894209 N

Vs, h + Vc, h = Vj, h

Vs, h = 894209 - 735758 = 158451 N

$Aj,\ h = \frac{Vs,\ h}{fy} = \frac{158451}{320} = 495\ mm^2$

coba sengkang D 10, As 2 tul. = 157 mm^2

$n = \frac{495}{157} = 3{,}1$, pakai 4 lapis D 10

Geser vertikal joint :

Vs, v = 894208 - 783015 = 111194 N

$Aj,\ v = \frac{111194}{320} = 365{,}8\ mm^2$

(Tulangan tengah kolom terpasang 6D32, As = 4825 mm^2)

A. Daktilitas penampang

Daktilitas penampang adalah perbandingan sudut rotasi pada saat kondisi tulangan leleh batas (*ultimate*) terhadap sudut rotasi saat leleh awal (*yield*).

Daktilitas penampang dinyatakan sebagai :

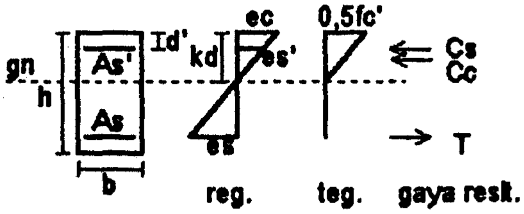
$$\mu = \frac{\varphi u}{\varphi y}$$

A.1. Daktilitas penampang balok

Persamaan :

$$\varepsilon c = \frac{fc'}{Ec} \quad , \varepsilon s' = \frac{fs'}{Es} \quad , \varepsilon s = \frac{fs}{Es}$$

A.1.1. Kondisi leleh awal



Dari diagram regangan didapat :

$$\frac{\varepsilon c}{kd} = \frac{\varepsilon s'}{kd - d'} = \frac{\varepsilon s}{d - kd}$$

Dengan substitusi kedua persamaan diatas menjadi :

$$fs' = \frac{kd - d'}{kd} . n. fc' \quad , fs = \frac{d - kd}{kd} . n. fc'$$

dimana : $n = \frac{Es}{Ec}$

k = koefisien garis netral

Keseimbangan gaya dalam :

$$Cc + Cs' = T$$

dimana : $Cc = 0{,}5.\ fc'.\ b.\ kd$

$$Cs = fs'.\ As' = \frac{kd - d'}{kd}.\ n.\ fc'.\ As'$$

$$T = fs.\ As = \frac{d - kd}{kd}.\ n.\ fc'.\ As$$

Persamaan :

$$0{,}5.\ fc'.\ b.\ kd + As'.\ \frac{kd - d'}{kd}.\ n.\ fc' = As.\ \frac{d - kd}{kd}.\ n.\ fc'$$

$$k^2 + 2.\ k.\ (\rho + \rho')\, n - 2.\ (\rho + \rho'.\tfrac{d'}{d})\, n = 0$$

dimana : $\rho = \frac{As}{b.\ d}$, $\rho' = \frac{As'}{b.\ d}$

Dari persamaan kuadrat diatas dapat dicari harga k :

$$k = \sqrt{(\rho + \rho')^2.\ n^2 + 2.\ n.\left(\rho + \rho'.\tfrac{d'}{d}\right)} - (\rho + \rho')$$

Besar sudut saat tulangan mencapai leleh awal :

$$\varphi y = \frac{esy}{d - kd} \qquad \text{(rad/mm)}$$

A.1.2. Kondisi batas

Saat mencapai batas :

- Tegangan beton tekan 0,85. fc', dan sc 0,003,
- Tulangan tarik selalu leleh.

Untuk mengetahui tulangan tekan leleh atau belum :

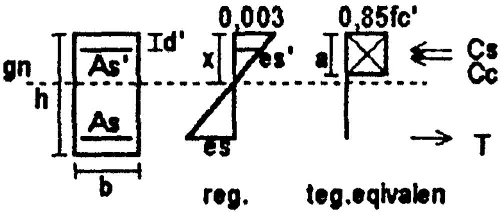
$$\rho - \rho'.\left(1 - \frac{0{,}85.\ fc'}{fy}\right) \geq 0{,}85.\beta 1.\left(\frac{fc'.\ d'}{fy.\ d}\right).\left(\frac{600}{600 - fy}\right)$$

- Tulangan tekan leleh :

$Cc = 0,85.\ fc'.\ a.\ b$

$Cs' = As'.\ fs' = As'.\ fy$

$T = As.\ fy$



Persamaan :

$0,85.\ fc'.\ a.\ b + As'.\ fy = As.\ fy$

akan didapat harga a , $x = \frac{a}{\beta 1}$

- Tulangan tekan belum leleh :

$Cc = 0,85.\ fc'.\ a.\ b$

$Cs' = As'.\ fs' = As'.\ (Es.\ \varepsilon cu.\ \frac{x - d'}{x})$

$T = As.\ fy$

Pers. menjadi :

$0,85.\ fc'.\ a.\ b + As'.\ (Es.\ \varepsilon cu. \frac{x - d'}{x}) = As.\ fy$

didapat harga x.

Sudut saat tulangan mencapai batas :

$\varphi u,b = \frac{\varepsilon cu}{x}$ (rad/mm)

Rotasi sendi plastis penampang kritis balok :

$\theta pb = (\varphi ub - \varphi yb).\ Lpb$ (rad)

dimana : Lpb = panjang sendi plastis balok

$= 0,08.\ lb + 0,022.\ db.\ fy$ (MPa)

lb dan db = panjang efektif dan tinggi efektif balok

Untuk balok dan kolom tipikal $Lpb \approx 0,7.\ d$

A.2. Daktilitas penampang kolom

Persamaan tegangan-regangan sama seperti pada balok :

$$\frac{\varepsilon c}{kd} = \frac{\varepsilon s'}{kd - d'} = \frac{\varepsilon s}{d - kd}$$

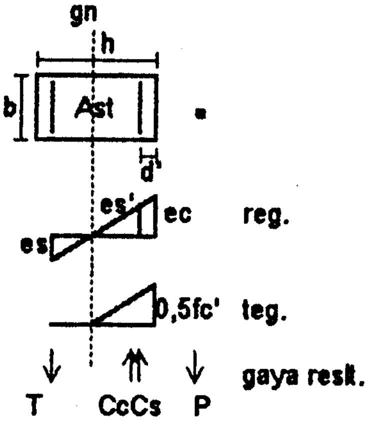
$$fs' = \frac{kd - d'}{kd} .\ n.\ fc'$$

$$fs = \frac{d - kd}{kd} .\ n.\ fc'$$

<u>Pers keseimbangan :</u>

$$P = Cc + Cs - T$$

A.2.1. Saat leleh pertama



$$Cc = 0{,}5.\ fc'.\ b.\ kd$$

$$Cs = fs'.\ 0{,}5.\ Ast = \frac{kd - d'}{kd} .\ n.\ fc'.\ 0{,}5.\ Ast$$

$$T = \frac{d - kd}{kd} .\ n.\ fc'.\ 0{,}5.\ Ast$$

Persamaan :

$$P = 0{,}5.\ fc'.\ b.\ kd + \frac{kd - d'}{kd} .\ n.\ fc'.\ 0{,}5.\ Ast - \frac{d - kd}{kd} .\ n.\ fc'.\ 0{,}5.\ Ast$$

dapat dicari k.

Sudut saat leleh awal :

$$\varphi y,\ c = \frac{fy}{Es.\ d.\ (1 - k)} \quad (rad/mm)$$

A.2.2. Saat batas

$Cc = 0{,}85.\ fc'.\ a.\ b = 0{,}85.\ fc'.\ (\beta 1 . x).\ b$

$Cs = fs'.\ 0{,}5.\ Ast = \frac{x - d'}{x}.\ n.\ fc'.\ 0{,}5.\ Ast$

$T = fy.\ 0{,}5.\ Ast$

Persamaan :

$$P = 0{,}85.\ fc'.\ \beta 1 .\ x.\ b + \frac{x - d'}{x}.\ n.\ fc'.\ 0{,}5.\ Ast - fy.\ 0{,}5.\ Ast$$

dapat dicari x.

Sudut saat batas :

$$\varphi u,c = \frac{\varepsilon cu}{x} \quad \text{(rad/mm)}$$

B. Daktilitas struktur

$$\mu = 1 + \frac{r.\ Lc.\ Lb.\ \theta p,b}{L.\ \Delta y}$$

$$\Delta y = \frac{Lc^2}{6}.\ \sum_{i = 1,2,..r} \frac{\varphi c\ i}{\beta\ i}.[(6.\ \beta\ i.(r - i + 0{,}5) - 3.\ (r - i) - 1)]$$

dimana :

$\varphi y, b$ = kurvatur balok dalam keadaan leleh pertama/awal
$\varphi u, b$ = kurvatur balok saat kondisi batas
$\theta p, b$ = rata-rata rotasi sendi plastis di balok
$\varphi c\ i$ = kurvatur leleh awal kolom pada tingkat ke 1, 2, 3, ..., i
Δy = perpindahan lateral relatif pada tingkat r, pada keadaan leleh pertama, dicapai terhadap tingkat dasar dari struktur
μ = displacement ductility faktor (angka daktilitas struktur)
r = jumlah tingkat
Lc = tinggi tingkat atau panjang kolom
$\beta\ i$ = letak titik belok terhadap kolom pada tingkat tersebut

1. Cek daktilitas penampang balok 40/70 L=5 m

tul. atas As = 3801 mm^2 (bab IX Perenc. Balok Induk)

tul. bawah As' = 1901 mm^2

d' = 50 mm

$\rho = \frac{3801}{400.\ 650} = 0{,}0146$ $\rho' = \frac{1901}{400.\ 650} = 0{,}00731$

Es = 2. 10^5 MPa

Ec = $2400^{1,5}.\ 0{,}043.\ \sqrt{30} = 27691{,}5$ MPa

$n = \dfrac{2.10^5}{27691{,}5} = 7{,}2$

$\varepsilon y = \dfrac{320}{2.\ 10^5} = 0{,}0016$

Pada saat leleh awal :

Cc + Cs = T

Cc = 0,5. 30. 300. k. 650

$Cs = (\dfrac{k.\ 650 - 50}{k.\ 650}.\ 7{,}2.\ 30).\ 1901$

$T = (\dfrac{650 - k.\ 650}{k.\ 650}.\ 7{,}2.\ 30).\ 3801$

didapat harga k :

$$k = \sqrt{(0,0146+0,00731)^2.7,2^2+2.7,2.\left(0,0146+0,00731.\frac{50}{650}\right)} - (0,0146+0,00731).7,2$$

$= 0{,}493 - 0{,}158 = 0{,}335$

$\varphi y = \dfrac{0{,}0016}{650 - 0{,}335.\ 650} = 3{,}7.\ 10^{-6}$ (rad/mm)

Pada saat batas/ultimate :

Anggap tul. tekan belum leleh, x = 88,6 mm (perhit. di bab IX Perenc. Balok Induk)

$$\varepsilon s' = \frac{0{,}003.\ 88{,}6 - 0{,}003.\ 50}{88{,}6} = 0{,}00131 < \varepsilon y \qquad \text{(OK)}$$

$$\varphi u = \frac{0{,}003}{88{,}6} = 3{,}39.\ 10^{-5} \qquad \text{(rad/mm)}$$

Daktilitas penampang (*curvature ductility*) balok :

$$\mu = \frac{\varphi u}{\varphi y} = \frac{3{,}39.\ 10^{-5}}{3{,}7.\ 10^{-6}} = 9{,}16$$

Rotasi sendi plastis yang terjadi :

$$\theta p, b = (3{,}39.\ 10^{-5} - 3{,}7.\ 10^{-6}).\ 0{,}7.\ 650 = 0{,}0137 \qquad \text{(rad)}$$

2. Cek daktilitas struktur

Ambil kolom di as A1 arah y

Mencari β i :

β i dicari berdasar cara Muto di buku Pedoman Perencanaan untuk Struktur ..... 1983, untuk struktur jenis D.

Balok :

$$\text{I balok lantai (tipikal)} = \frac{1}{12}.\ 400.\ 700^3 = 1{,}14.\ 10^{10}\ \text{mm}^4$$

$$k\ 1 = \frac{I, b}{L, b} = \frac{1{,}14.\ 10^{10}}{5000} = 2{,}28.\ 10^6\ \text{mm}^3$$

$$\text{I balok atap} = \frac{1}{12}.\ 300.\ 500^3 = 3{,}13.\ 10^9\ \text{mm}^4$$

$$k\ 2 = \frac{3{,}13.\ 10^9}{5000} = 6{,}26.\ 10^5\ \text{mm}^4$$

Kolom :

$$\text{I kolom lantai (tipikal)} = \frac{1}{12}.\ 700^4 = 2.\ 10^{10}\ \text{mm}^4$$

$$\text{kc lantai 2 s/d atap} = \frac{2.\ 10^{10}}{3650} = 5479452{,}1\ \text{mm}^3$$

$$\text{kc lantai 1} = \frac{2.\ 10^{10}}{3400} = 5882352{,}9\ \text{mm}^3$$

Untuk kolom 10 tingkat :

- Atap : $\bar{k} = \frac{2{,}28.\ 10^6 + 6{,}26.\ 10^5}{2.\ 5479452{,}1} = 0{,}265$
  $\beta 1 = 0{,}1$ (gambar 6.6)
- 9 th : $\bar{k} = \frac{2.\ 2{,}28.10^6}{2.\ 5479452{,}1} = 0{,}416$, $\beta 1 = 0{,}35$
- 8th - 7th : $\beta 1 = 0{,}4$
- 6th - 4th : $\beta 1 = 0{,}45$
- 3th : $\beta 1 = 0{,}5$
- 2nd : $\beta 1 = 0{,}55$
- 1st : $\bar{k} = \frac{2{,}28.\ 10^6}{5882352{,}9} = 0{,}388$, $\beta 1 = 0{,}75$

Mencari φc i kolom :

Tulangan kolom terpasang 16D32, Ast = 12864 mm^2

$$P = 0{,}5.\ fc'.\ b.\ kd + \frac{kd - d'}{kd}.\ n.\ fc'.\ 0{,}5.\ Ast - \frac{d - kd}{kd}.\ n.\ fc'.\ 0{,}5.\ Ast$$

$$4269{,}1.10^3 - 0{,}5.30.700.\ k.600 - \left(\frac{k.\ 600 - 100}{k.\ 600} - \frac{600 - k.\ 600}{k.\ 600}\right).\ 7{,}22.\ 30.\ 0{,}5.12864 = 0$$

didapat $k \approx 0{,}695$

$$\varphi y,\ c = \frac{400}{2.10^5.\ 600.\ (1 - 0{,}695)} = 1{,}09.\ 10^{-5} \quad \text{(rad/mm)}$$

Harga-harga yang lain pada tabel :

i	β i	φy, c	φu, b	φy, b
2	0.55	$9.28.10^{-6}$	$3.39.10^{-5}$	$3.71.10^{-6}$
3	0.5	$7.99.10^{-6}$	$3.39.10^{-5}$	$3.71.10^{-6}$
4	0.45	$7.14.10^{-6}$	$3.39.10^{-5}$	$3.71.10^{-6}$
5	0.45	$6.51.10^{-6}$	$3.39.10^{-5}$	$3.71.10^{-6}$
6	0.45	$6.04.10^{-6}$	$3.39.10^{-5}$	$3.71.10^{-6}$
7	0.4	$5.68.10^{-6}$	$4.21.10^{-5}$	$3.48.10^{-6}$
8	0.4	$5.41.10^{-6}$	$4.21.10^{-5}$	$3.48.10^{-6}$
9	0.35	$5.19.10^{-6}$	$4.21.10^{-5}$	$3.48.10^{-6}$
10	0.1	$5.03.10^{-6}$	$7.59.10^{-5}$	$3.03.10^{-6}$

$$\Delta y = \frac{3400^2}{6} . \frac{1{,}09.10^{-5}}{0{,}75} .((6.\ 0{,}75.(10\text{-}1+0{,}5) - 3.(10\text{-}1)\text{-}1) + \frac{3650^2}{6} . \frac{9{,}28.10^{-6}}{0{,}55} .((6.\ 0{,}55.$$
$$(10\text{-}2+0{,}5) - 3.(10\text{-}2)\text{-}1) + \frac{3650^2}{6} . \frac{7{,}99.10^{-6}}{0{,}5} .((6.\ 0{,}5.(10\text{-}3 + \ldots\ldots\ldots = 72{,}19$$

Rotasi plastis rata-rata balok :

$$\theta p, b = \frac{1}{10} . \{(3{,}39.10^{-5} - 3{,}71.10^{-6}).\ 0{,}7.\ 650.\ 6 + (4{,}21.10^{-5} - 3{,}48.10^{-6}).\ 0{,}7.\ 650.\ 3 +$$
$$(7{,}59.10^{-5} - 3{,}03.10^{-6}).\ 0{,}7.\ 450\} = 0{,}0158 \quad \text{(rad)}$$

Daktilitas struktur :

$$\mu = 1 + \frac{10.\ 3650.\ \left(\frac{2}{3}.5000\right).\ 0{,}0158}{5000.\ 72{,}19} = 6{,}325$$

No kol.	As		lantai	h (m)	hn (m)	alpha x		alpha y		Mu, k-x perlu (Nm)		Mu,k-y perlu (Nm)		Mu, k-x max (Nm)		Mu, k-y max (Nm)	
						ka	kb	ka	kb	atas	bawah	atas	bawah	atas	bawah	atas	bawah
1	A	1	1	3.4	3.05	0.05	1	0.06	1	59896.78	908340	80482.26	922060	212289	3895773	211449	3924627
2		2		3.4	3	0.14	1	0.11	1	233508.71	1171520	246168.78	1183560	603435	5001129	671559	5051907
3	B	1		3.4	3.05	0.04	1	0.06	1	59278.81	908340	78924.08	922060	211974	3895458	212919	3926097
4		2		3.4	3	0.24	1	0.12	1	662516.15	1218890	291687.26	1137620	1382157	5173203	929943	4857699
5	C	1		3.4	3.05	0.04	1	0.06	1	58421.28	908540	78910.06	922120	208824	3894408	211806	3925614
6		2		3.4	3	0.24	1	0.13	1	623607.15	1216500	318164.92	1136630	1364370	5158440	934521	4860891
7	D	1		3.4	3.05	0.04	1	0.05	1	62414.23	906090	67152.21	918200	206745	3882963	194040	3912300
8		2		3.4	2.95	0.09	1	0.13	1	211771.36	1190800	382824.09	1259050	461643	5018475	758310	5405400
9	A	1	2	3.6	2.9	0.53	0.96	0.55	0.94	825516.08	1474588,4	869432.10	1500049.00	1518090	2813832	1604463	2882565
10		2		3.6	2.8	0.51	0.86	0.54	0.89	963118.10	1605252.97	1353155.63	2205595.03	1844430	3544674	2631804	4580478
11	B	1		3.6	2.9	0.53	0.96	0.55	0.94	826701.83	1482413.34	868690.75	1487956.60	1544340	2844576	1651755	2930823
12		2		3.6	2.8	0.52	0.76	0.54	0.88	1623898.39	2399854.47	1560008.82	2538343.61	3373944	4988802	3139878	5068376
13	C	1		3.6	2.9	0.53	0.96	0.55	0.94	827465.56	1483368.28	868299.40	1487972.21	1555197	2856777	1655745	2936745
14		2		3.6	2.8	0.51	0.76	0.54	0.87	1535547.43	2276542.53	1532777.16	2458070.21	3367602	4847640	3148761	4652813
15	D	1		3.6	2.9	0.53	0.96	0.55	0.95	826553.51	1478921.77	868812.26	1501065.64	1523865	2820279	1623258	2898504
16		2		3.6	2.7	0.54	0.91	0.53	0.87	1533794.21	2600610.17	1843424.17	3020753.86	2701545	4115433	3162810	4874226
17	A	1	3	3.6	2.9	0.47	0.61	0.48	0.59	733189.15	942784.42	763300.25	931181.54	1041705	1307985	1084440	1347780
18		2		3.6	2.8	0.47	0.63	0.45	0.60	881665.82	1170670.21	1126312.76	1486065.11	1315860	1675254	1724940	2260440
19	B	1		3.6	2.9	0.47	0.61	0.48	0.59	733237.77	941032.16	756871.70	931877.65	1059450	1330434	1130220	1396500
20		2		3.6	2.8	0.46	0.59	0.46	0.60	1436719.13	1860752.82	1312144.87	1717375.02	2307165	3101343	2097165	2741697
21	C	1		3.6	2.9	0.47	0.61	0.48	0.59	732855.76	941032.16	755254.77	930521.20	1069047	1336839	1127070	1395450
22		2		3.6	2.8	0.46	0.59	0.46	0.60	1358163.26	1762494.69	1288060.05	1687157.06	2311953	3105375	2113608	2759442
23	D	1		3.6	2.9	0.47	0.61	0.48	0.59	732625.55	941284.34	758486.63	931612.18	1044981	1309455	1112160	1374576
24		2		3.6	2.7	0.46	0.60	0.44	0.61	1304163.97	1715469.67	1537592.22	2111876.08	1800330	2334696	2103297	2795247
25	A	1	4	3.6	2.9	0.51	0.53	0.51	0.52	788340.80	815236.50	808021.76	812545.43	1038429	1143975	1062159	1168823
26		2		3.6	2.8	0.51	0.53	0.48	0.55	954808.36	988491.99	1197339.84	1358549.38	1337973	1490811	1738695	2045589
27	B	1		3.6	2.9	0.51	0.53	0.51	0.52	787493.03	815187.88	801708.84	818973.99	1050630	1162350	1117935	1235535
28		2		3.6	2.8	0.48	0.54	0.48	0.54	1502161.86	1714729.29	1376706.33	1557104.46	2180829	2736531	2044203	2481129
29	C	1		3.6	2.9	0.51	0.53	0.51	0.52	786465.22	815569.89	801917.17	820590.92	1063041	1175475	1120056	1237488
30		2		3.6	2.8	0.48	0.54	0.48	0.54	1419367.02	1625832.77	1352815.44	1530953.55	2194290	2751630	2069655	2508219
31	D	1		3.6	2.9	0.51	0.53	0.51	0.52	786288.13	815800.10	806041.09	817359.06	1036854	1146432	1105818	1216278
32		2		3.6	2.7	0.48	0.54	0.47	0.56	1376833.56	1541436.59	1612687.60	1926036.57	1813938	2157372	2088870	2577540

Tabel 10.4.1 Momen rencana kolom

33	A	1	5	3.6	2.9	0.53	0.49	0.55	0.49	827860.72	760084.85	859361.18	767823.92	977991	1002855	994749	1026669
34		2		3.6	2.8	0.55	0.49	0.51	0.52	1027399.05	915349.45	1273139.97	1287522.30	1299270	1348410	1648143	1842519
35	B	1		3.6	2.9	0.53	0.49	0.54	0.49	825619.31	760932.62	850556.98	774136.85	984585	1012725	1057455	1096473
36		2		3.6	2.8	0.52	0.52	0.51	0.52	1647688.56	1649286.56	1466039.80	1492543.00	1980825	2379657	1908879	2220393
37	C	1		3.6	2.9	0.53	0.49	0.54	0.49	820870.68	761960.43	350820.15	773928.52	1002750	1032570	1057476	1096998
38		2		3.6	2.8	0.52	0.52	0.51	0.52	1549195.84	1564629.00	1443428.54	1466198.16	2005605	2404227	1943235	2252775
39	D	1		3.6	2.9	0.53	0.49	0.54	0.49	824178.66	762137.52	843127.63	769804.60	977970	1003002	1048320	1079526
40		2		3.6	2.7	0.50	0.52	0.48	0.53	1435424.54	1468767.01	1668050.98	1850941.19	1742055	1971207	1986810	2346792
41	A	1	6	3.6	2.9	0.57	0.47	0.57	0.45	878454.90	720564.93	895757.79	716484.51	861924	857724	860328	862890
42		2		3.6	2.8	0.55	0.45	0.51	0.49	1032663.98	842758.76	1259617.28	1211722.17	1075347	1139901	1358070	1552866
43	B	1		3.6	2.9	0.57	0.47	0.56	0.46	878089.78	722806.34	879105.00	725288.70	866796	868518	920199	934857
44		2		3.6	2.8	0.51	0.48	0.50	0.49	1598226.10	1503759.86	1446369.44	1403209.52	1511013	1829583	1540539	1821477
45	C	1		3.6	2.9	0.56	0.47	0.56	0.46	872793.67	727554.97	879513.57	725025.54	890715	894537	920451	935739
46		2		3.6	2.8	0.50	0.48	0.50	0.49	1505870.74	1434800.18	1421949.59	1375585.06	1548792	1874670	1577583	1859949
47	D	1		3.6	2.9	0.56	0.47	0.56	0.46	874550.81	724246.99	886181.46	732718.06	867489	868245	933072	943236
48		2		3.6	2.7	0.52	0.50	0.50	0.52	1490501.71	1410176.03	1731210.98	1795577.82	1574034	1753080	1793505	2096031
49	A	1	7	3.6	2.9	0.64	0.43	0.65	0.43	704560.96	668970.75	729174.04	680087.90	764463	682773	763791	687687
50		2		3.6	2.8	0.61	0.45	0.55	0.49	893200.26	837493.83	1216706.16	1225244.86	967344	946722	1206576	1300908
51	B	1		3.6	2.9	0.64	0.43	0.64	0.44	703487.43	670335.87	709436.45	696740.69	766290	689850	825342	760368
52		2		3.6	2.8	0.55	0.49	0.55	0.50	1146618.11	1553222.32	1304767.77	1422879.88	1274994	1473108	1351098	1520988
53	C	1		3.6	2.9	0.64	0.44	0.63	0.44	700572.19	675631.98	705610.18	696332.12	792267	718893	824712	761040
54		2		3.6	2.8	0.55	0.50	0.55	0.50	1105717.41	1478125.29	1297273.71	1397064.02	1316742	1523004	1390977	1562547
55	D	1		3.6	2.9	0.64	0.44	0.64	0.44	699913.19	673874.84	708439.98	689664.23	768831	691131	837312	768138
56		2		3.6	2.7	0.57	0.48	0.55	0.50	1272044.87	1355098.86	1624236.77	1732417.82	1413426	1469916	1611120	1771392
57	A	1	8	3.6	2.9	0.82	0.36	0.85	0.35	896467.73	391422.75	946762.40	386217.72	652932	477456	593943	420525
58		2		3.6	2.8	0.73	0.39	0.64	0.45	1057355.37	562696.76	1415466.41	982724.21	824754	701904	1003800	976500
59	B	1		3.6	2.9	0.82	0.36	0.78	0.36	894115.48	392496.28	874850.63	405955.30	642747	469581	702576	535584
60		2		3.6	2.8	0.68	0.45	0.63	0.45	1400362.46	922212.96	1500765.58	1078542.81	984354	1042524	1104348	1142820
61	C	1		3.6	2.9	0.80	0.36	0.79	0.37	880563.26	395411.52	876809.89	409781.57	869753	496965	700688	538776
62		2		3.6	2.8	0.66	0.45	0.63	0.45	1331015.03	904851.79	1492455.93	1068558.31	1028622	1093302	1146033	1184547
63	D	1		3.6	2.9	0.80	0.36	0.82	0.36	875930.73	396070.52	912012.88	406951.77	646905	474705	715743	553245
64		2		3.6	2.7	0.63	0.43	0.64	0.45	1420871.88	969997.56	1903053.46	1341817.39	1194648	1108842	1368360	1357524

Tabel 10.4.1 Momen rencana kolom

65	A	1	9	3.6	2.9	0.80	0.18	0.66	0.15	875237.87	199515.98	739345.39	168629.35	475965	231861	466053	234591
66		2		3.6	2.8	0.90	0.27	0.79	0.36	1312933.18	398541.64	1745629.85	783963.95	654444	436590	763350	621936
67	B	1		3.6	2.9	0.80	0.18	0.60	0.22	871893.03	201868.23	664698.53	240541.12	471429	232491	526407	304521
68		2		3.6	2.8	0.87	0.32	0.89	0.37	1796718.03	668468.61	2125898.64	882545.00	608286	531510	801171	710871
69	C	1		3.6	2.9	0.82	0.20	0.64	0.21	902875.73	215420.45	719331.34	238581.87	500262	259392	526911	303681
70		2		3.6	2.8	0.88	0.34	0.80	0.37	1769090.91	679554.16	1896215.98	873376.09	654885	583611	847686	757890
71	D	1		3.6	2.9	0.83	0.20	0.71	0.18	910332.26	220052.98	797063.67	203378.87	478401	235053	539721	306957
72		2		3.6	2.7	0.77	0.37	0.86	0.36	1715340.40	821170.56	2553150.57	1063000.70	935991	708435	1071882	894306
73	A	1	roof	3.6	2.9	1	0.20	1	0.34	137732.05	27741.08	139731.72	47109.55	140154	191940	144564	244566
74		2		3.6	2.8	1	0.10	1	0.21	186029.79	18267.45	289317.93	59693.92	253386	175812	326928	265818
75	B	1		3.6	2.9	1	0.20	1	0.40	137732.05	28161.43	139731.72	56461.00	134925	201957	89964	236964
76		2		3.6	2.8	1	0.13	1	0.11	274000.29	36039.22	315709.07	34098.49	148659	122913	265461	211491
77	C	1		3.6	2.9	1	0.18	1	0.36	137732.05	24267.84	139731.72	49616.83	152523	193935	183855	288771
78		2		3.6	2.8	1	0.12	1	0.20	257013.27	30868.43	243992.92	48432.43	190953	153111	346395	305613
79	D	1		3.6	2.9	1	0.17	1	0.29	137732.05	23330.78	139731.72	39878.84	133434	161826	189441	259875
80		2		3.6	2.7	1	0.23	1	0.14	339463.78	79747.05	401222.05	55854.01	311178	279174	425943	376593

Tabel 10.4.1 Momen rencana kolom

65	475965	466053	1	604.2	52.3	43.6	569248.71	738214.60	563121.70	748900.37	909006	883428
66	654444	763350	1	827.2	83.6	56	833074.27	954422.84	923244.49	896190.24	1290240	1209096
67	471429	526407	1	613.76	36.5	38.9	579286.71	748252.60	573159.70	758938.37	846762	853818
68	608288	801171	1	831.24	188.8	88.2	870069.19	965579.37	929560.85	910258.11	1776894	1481130
69	500262	526911	1	629.84	33.9	38.8	596170.71	765136.60	590043.70	775822.37	852600	867006
70	654885	847686	1	899.08	198.1	92.2	938218.67	1039893.89	971215.04	1011067.92	1892226	1580880
71	478401	539721	1	643.64	39.5	43.6	610660.71	779626.60	604533.70	790312.37	896658	908712
72	935991	1071882	1	1100.4	56.5	46	1190563.20	1200147.39	1221008.42	1187721.55	1450680	1419810
73	137732.05	139731.72	1	116.8	7.6	5.2	110749.86	139622.00	109525.88	141370.14	161112	154056
74	186029.79	289317.93	1	118.24	16	14.4	116820.49	137979.78	126233.30	132368.10	209496	204792
75	134925.00	89964.00	1	119.32	10.2	6	113395.86	142268.00	112171.88	144016.14	175686	163338
76	148659.00	265461.00	1	119.56	50.1	24.8	121950.50	143109.80	128742.50	134877.30	367206	292824
77	137732.05	139731.72	1	121.64	9.4	5.8	115831.86	144704.00	114607.88	146452.14	174510	163926
78	190953.00	243992.92	1	123.4	52.7	25.7	124068.13	147212.01	126393.27	139143.35	383292	303912
79	133434.00	139731.72	1	126.36	4.7	5.3	120787.86	149660.00	119563.88	151408.14	159096	160860
80	339463.78	401222.05	1	152.32	11	9.3	169842.55	162922.45	165145.87	171258.28	217854	212856

Tabel 10.4.2 Tekan rencana kolom

33	0.42	0.19	0.01	16*804	12864	4998000	22163076.92	13850054.4	0.43	0.19	0.01	16*804	21371538.46	4998000
34	0.35	0.23	0.01	16*804	12864	5906250	23365384.62	15329054.4	0.44	0.23	0.01	16*804	35048076.92	6075000
35	0.41	0.19	0.01	16*804	12864	4998000	22163076.92	13850054.4	0.42	0.20	0.01	16*804	23112923.08	4998000
36	0.54	0.24	0.02	20*804	16080	4893750	28817307.69	16292568	0.50	0.24	0.017	20*804	27259615.38	5062500
37	0.40	0.20	0.01	16*804	12864	4998000	22163076.92	13850054.4	0.41	0.20	0.01	16*804	18996923.08	5145000
38	0.47	0.26	0.017	20*804	16080	5400000	27259615.38	16292568	0.45	0.26	0.014	20*804	26286057.69	5568750
39	0.40	0.20	0.01	16*804	12864	5145000	22004769.23	13850054.4	0.40	0.20	0.01	16*804	22163076.92	5145000
40	0.37	0.26	0.01	22*804	17688	7492500	29206730.77	19069324.8	0.39	0.26	0.01	22*804	33646153.85	7087500
41	0.53	0.16	0.01	16*804	12864	4116000	22004769.23	13850054.4	0.53	0.16	0.01	16*804	21371538.46	4263000
42	0.43	0.19	0.01	16*804	12864	5231250	25312500	15329054.4	0.53	0.19	0.013	16*804	25312500	4556250
43	0.53	0.16	0.01	16*804	12864	4116000	22004769.23	13850054.4	0.53	0.16	0.01	16*804	21371538.46	4263000
44	0.60	0.20	0.018	20*804	16080	5737500	40889423.08	16292568	0.60	0.19	0.014	20*804	29206730.77	4725000
45	0.52	0.16	0.01	16*804	12864	4263000	21846461.54	13850054.4	0.52	0.16	0.01	16*804	22163076.92	4263000
46	0.56	0.21	0.015	20*804	16080	6243750	38942307.69	16292568	0.54	0.21	0.015	20*804	27259615.38	4893750
47	0.51	0.17	0.01	16*804	12864	4263000	21688153.85	13850054.4	0.51	0.17	0.01	16*804	22163076.92	4263000
48	0.47	0.21	0.01	22*804	17688	6277500	32711538.46	19069324.8	0.47	0.21	0.01	22*804	36450000	6075000
49	0.57	0.12	0.01	16*804	12864	4116000	25329230.77	13850054.4	0.59	0.12	0.01	16*804	22954615.38	3969000
50	0.49	0.14	0.01	16*804	12864	4893750	35048076.92	15329054.4	0.68	0.14	0.01	16*804	25896634.62	3881250
51	0.56	0.12	0.01	16*804	12864	3969000	22163076.92	13850054.4	0.56	0.12	0.01	16*804	22163076.92	3969000
52	0.61	0.15	0.023	20*804	16080	4556250	26286057.69	16292568	0.71	0.14	0.012	20*804	26286057.69	4050000
53	0.54	0.12	0.01	16*804	12864	3822000	21054923.08	13850054.4	0.55	0.13	0.01	16*804	22163076.92	4116000
54	0.55	0.16	0.01	20*804	16080	4050000	23365384.62	16292568	0.66	0.16	0.014	20*804	29206730.77	4387500
55	0.53	0.13	0.01	16*804	12864	4116000	22163076.92	13850054.4	0.54	0.13	0.01	16*804	22954615.38	4116000
56	0.53	0.16	0.01	22*804	17688	5670000	32711538.46	19069324.8	0.56	0.16	0.01	22*804	39253846.15	5670000
57	0.74	0.09	0.01	16*804	12864	1911000	22163076.92	13850054.4	0.67	0.09	0.01	16*804	22163076.92	1617000
58	0.65	0.10	0.01	12864	12864	4050000	26286057.69	15329054.4	0.82	0.10	0.013	12864	38942307.69	2700000
59	0.72	0.09	0.01	16*804	12864	1764000	22954615.38	13850054.4	0.78	0.09	0.01	16*804	22163076.92	1764000
60	0.77	0.10	0.013	20*804	16080	3712500	31153846.15	16292568	0.89	0.10	0.015	20*804	44783653.85	3206250
61	0.73	0.09	0.01	16*804	12864	1764000	22163076.92	13850054.4	0.76	0.09	0.01	16*804	22163076.92	1764000
62	0.74	0.11	0.011	20*804	16080	3881250	31543269.23	16292568	0.84	0.11	0.013	20*804	44783653.85	3206250
63	0.69	0.09	0.01	16*804	12864	1764000	22163076.92	13850054.4	0.76	0.09	0.01	16*804	22163076.92	1764000
64	0.73	0.11	0.011	22*804	17688	4657500	32711538.46	19069324.8	0.70	0.11	0.01	22*804	49628076.92	7897500

Tabel 10.4.3 Penulangan lentur

65	A	1	9	3.6	2.9	0.80	0.18	0.66	0.15	875237.87	199515.98	739345.39	168629.35	475965	231861	466053	234591
66		2		3.6	2.8	0.90	0.27	0.79	0.36	1312933.18	398541.64	1745629.85	783963.95	654444	436590	763350	621936
67	B	1		3.6	2.9	0.80	0.18	0.60	0.22	871893.03	201868.23	664698.53	240541.12	471429	232491	526407	304521
68		2		3.6	2.8	0.87	0.32	0.89	0.37	1796718.03	668468.61	2125898.64	882545.00	608286	531510	801171	710871
69	C	1		3.6	2.9	0.82	0.20	0.64	0.21	902875.73	215420.45	719331.34	238581.87	500262	259392	526911	303681
70		2		3.6	2.8	0.88	0.34	0.80	0.37	1769090.91	679554.16	1896215.98	873376.09	654885	583611	847686	757890
71	D	1		3.6	2.9	0.83	0.20	0.71	0.18	910332.26	220052.98	797063.67	203378.87	478401	235053	539721	306957
72		2		3.6	2.7	0.77	0.37	0.86	0.36	1715340.40	821170.56	2553150.57	1063000.70	935991	708435	1071882	894306
73	A	1	roof	3.6	2.9	1	0.20	1	0.34	137732.05	27741.08	139731.72	47109.55	140154	191940	144564	244566
74		2		3.6	2.8	1	0.10	1	0.21	186029.79	18267.45	289317.93	59693.92	253386	175812	326928	265818
75	B	1		3.6	2.9	1	0.20	1	0.40	137732.05	28161.43	139731.72	56461.00	134925	201957	89964	236964
76		2		3.6	2.8	1	0.13	1	0.11	274000.29	36039.22	315709.07	34098.49	148659	122913	265461	211491
77	C	1		3.6	2.9	1	0.18	1	0.36	137732.05	24267.84	139731.72	49616.83	152523	193935	183855	288771
78		2		3.6	2.8	1	0.12	1	0.20	257013.27	30868.43	243992.92	48432.43	190953	153111	346395	305613
79	D	1		3.6	2.9	1	0.17	1	0.29	137732.05	23330.78	139731.72	39878.84	133434	161826	189441	259875
80		2		3.6	2.7	1	0.23	1	0.14	339463.78	79747.05	401222.05	55854.01	311178	279174	425943	376593

Tabel 10.4.1 Momen rencana kolom

No	perlu (kNm)		Rv	Ng, k	NE, k x	NE, k y	Nu,k-x perlu (N)		Nu, k-y perlu (N)		Nu,k-x max	Nu,k-y max
kol.	Mu, k x	Mu, k y		(kN)	(kN)	(kN)	min	max	min	max	(N)	(N)
1	908340	922060	0.875	4269.12	1538.3	1712.1	4412520.27	4610900.90	4405498.47	4624110.81	13100682	13611654
2	1171520	1183560	0.875	6683.6	1431.7	855.6	6986710.73	7117676.18	7064552.44	7070657.33	14108976	12415242
3	908340	922060	0.875	4327.68	1133.8	1591.4	4474008.27	4672388.90	4466986.47	4685598.81	11311188	12656532
4	1218890	1137620	0.875	7111.04	1873.9	984	7413763.14	7639673.53	7512941.45	7535320.04	16576812	13960506
5	908540	922120	0.875	4381.76	1149.5	1599.6	4530792.27	4729172.90	4523770.47	4742382.81	11444244	12767538
6	1216500	1136630	0.875	7191.36	1857.3	970.2	7483133.91	7738974.76	7547393.36	7669540.14	16574040	13965966
7	906090	918200	0.875	4607.8	1448.7	1699.1	4768134.27	4966514.90	4761112.47	4979724.81	13063596	13799772
8	1190800	1259050	0.875	9017.32	703.7	415	9496186.39	9537599.43	9524017.35	9535374.43	12946626	12097848
9	1474588,4	1500049.00	0.9	3842.88	1333.5	1471.6	3962966.68	4167015.32	3955744.25	4180602.66	11489940	11895954
10	1605252.97	2205595.03	0.9	5931.6	1257.8	715.1	6196223.04	6330930.36	6276288.79	6282568.11	12411966	10816428
11	1482413.34	1487956.60	0.9	3898.08	944.2	1355.6	4020926.68	4224975.32	4013704.25	4238562.66	9766680	10976196
12	2399854.47	2538343.61	0.9	6301.36	1423.2	760.9	6562089.74	6794454.72	6664101.72	6687119.70	13552602	11605440
13	1483368.28	1487972.21	0.9	3951.56	959.8	1363.6	4077080.68	4281129.32	4069858.25	4294716.66	9898434	11085606
14	2276542.53	2458070.21	0.9	6387.12	1401.7	746.1	6636744.93	6899895.52	6702840.37	6828477.05	13533702	11606238
15	1478921.77	1501065.64	0.9	4171.8	1247.5	1461.6	4308332.68	4512381.32	4301110.25	4525968.66	11461506	12090960
16	2600610.17	3020753.86	0.9	7953.08	624.3	336	8379544.68	8422130.67	8408160.53	8419842.10	11396154	10548552
17	942784.42	931181.54	0.925	3469.84	1090.4	1189.6	3569273.09	3778989.75	3561850.04	3792954.52	9721908	10013556
18	1170670.21	1486065.11	0.925	5101.04	1044	555.8	5323247.34	5461696.54	5405537.15	5411990.89	10441200	9005892
19	941032.16	931877.65	0.925	3519.88	731.3	1082.5	3621815.09	3831531.75	3614392.04	3845496.52	8131284	9163812
20	1860752.82	1717375.02	0.925	5217.8	953.3	525	5422842.34	5661661.90	5527687.99	5551345.36	10144050	8884848
21	941032.16	930521.20	0.925	3591.28	746.3	1090.3	3696785.09	3906501.75	3689362.04	3920466.52	8279082	9290442
22	1762494.69	1687157.06	0.925	5564.76	928.5	510.1	5771329.96	6041790.29	5839261.38	5968387.97	10385424	9155328
23	941284.34	931612.18	0.925	3657.96	1010.9	1182.2	3766799.09	3976515.75	3759376.04	3990480.52	9576210	10079832
24	1715469.67	2111876.08	0.925	6937.6	523.1	249.3	7314090.98	7357859.92	7343501.71	7355507.77	9795618	8990646
25	815236.50	812545.43	0.95	3014.32	854	919.4	3088975.50	3304360.17	3081351.82	3318702.37	7910280	8102556
26	988491.99	1358549.38	0.95	4375.8	830.6	409.9	4560857.65	4703048.71	4645371.50	4651999.67	8599584	7362726
27	815187.88	818973.99	0.95	3058.4	537.3	825	3135259.50	3350644.17	3127635.82	3364986.37	6507480	7353318
28	1714729.29	1557104.46	0.95	4462.28	582.7	332.2	4628036.95	4873311.09	4735716.26	4760013.02	7551306	6814836
29	815569.89	820590.92	0.95	3124.56	551.1	832.2	3204727.50	3420112.17	3197103.82	3434454.37	6643980	7470414
30	1625832.77	1530953.55	0.95	4776.8	558.3	318.6	4942034.98	5219805.05	5011802.39	5144418.89	7761936	7057218
31	815800.10	817359.06	0.95	3186.4	783.2	914.3	3269659.50	3485044.17	3262035.82	3499386.37	7787178	8172612
32	1541436.59	1926036.57	0.95	5928.8	420.7	175	6255651.28	6300603.16	6285856.89	6298187.44	8212680	7490322

Tabel 10.4.2 Tekan rencana kolom

33	827860.72	859361.18	0.975	2546.88	635.7	673.7	2596161.90	2817214.60	2588337.60	2831934.22	6193026	6304746
34	1027399.05	1287522.30	0.975	3657.4	630.3	285.5	3805649.96	3951582.89	3892387.86	3899190.45	6847260	5833548
35	825619.31	850556.98	0.975	2585	370.5	594.6	2636187.90	2857240.60	2628363.60	2871960.22	5019546	5678400
36	1649286.56	1492543.00	0.975	3719.88	333.5	193.9	3847007.55	4098736.28	3957520.53	3982456.68	5550888	5140464
37	820870.68	850820.15	0.975	2644.08	382.4	600.9	2698221.90	2919274.60	2690397.60	2933994.22	5139498	5781888
38	1564629.00	1466198.16	0.975	3992.08	317.3	184.3	4116142.01	4401221.82	4187745.40	4323851.81	5756562	5365542
39	824178.66	843127.63	0.975	2698.28	575.4	670.4	2755131.90	2976184.60	2747307.60	2990904.22	6094578	6373878
40	1468767.01	1850941.19	0.975	4937.12	326.8	126.2	5215187.57	5261322.40	5246188.07	5258843.11	6715548	6125784
41	861924.00	860328.00	1	2070.52	440.5	456.9	2093982.31	2320703.03	2085957.39	2335800.07	4599840	4648056
42	1032663.98	1259617.28	1	2944.12	450.2	187.6	3055818.26	3205493.07	3144780.22	3151757.23	5218542	4446498
43	866796.00	879105.00	1	2101.36	232.9	395	2126364.31	2353085.03	2118339.39	2368182.07	3682308	4158882
44	1511013.00	1446369.44	1	2987.76	227.7	119.5	3076772.15	3334955.46	3215694.33	3190118.80	4244058	3925950
45	872793.67	879513.57	1	2152.32	241.9	400.1	2179872:31	2406593.03	2171847.39	2421690.07	3780042	4245150
46	1505870.74	1421949.59	1	3214.2	231.1	118.2	3297431.04	3589820.58	3370870.41	3510466.73	4494462	4162536
47	867489.00	886181.46	1	2197.36	392	455.2	2227164.31	2453885.03	2219139.39	2468982.07	4527180	4712988
48	1490501.71	1795577.82	1	3964.28	246.3	107.6	4194505.87	4241823.64	4226301.26	4239280.78	5332530	4924752
49	704560.96	729174.04	1	1586.28	273.5	274.3	1600432.71	1769398.60	1594305.70	1780084.37	3159912	3162264
50	893200.26	1206576.00	1	2235.32	298	124.8	2311600.27	2432948.84	2401770.49	2374716.24	3755934	3246726
51	703487.43	709436.45	1	1610.6	128	231	1625968.71	1794934.60	1619841.70	1805620.37	2519790	2822610
52	1146618.11	1304767.77	1	2289.12	234.2	106.3	2400843.19	2496353.37	2460334.85	2441032.11	3521154	3145128
53	700572.19	705610.18	1	1650.56	133	234.2	1667926.71	1836892.60	1661799.70	1847578.37	2586780	2884308
54	1105717.41	1297273.71	1	2438.88	249.4	111.7	2555008.67	2656683.89	2588005.04	2627857.92	3749046	3344208
55	699913.19	708439.98	1	1686.92	236.9	273.7	1706104.71	1875070.60	1699977.70	1885756.37	3111108	3219300
56	1272044.87	1611120.00	1	3001.32	174.5	93.8	3186529.20	3196113.39	3216974.42	3183687.55	4002474	3765216
57	652932	593943	1	1098.32	141.5	133.6	1088074.71	1257040.60	1081947.70	1267726.37	1915872	1892646
58	824754	1003800	1	1529.6	176.7	89.6	1570594.27	1691942.84	1660764.49	1633710.24	2461116	2205042
59	642747	702576	1	1113.96	65.1	110.8	1104496.71	1273462.60	1098369.70	1284148.37	1582686	1717044
60	984354	1104348	1	1544.48	244.7	111.1	1618971.19	1714481.37	1678462.85	1659160.11	2789430	2396646
61	669753	700686	1	1143.2	64.2	111.8	1135198.71	1304164.60	1129071.70	1314850.37	1610868	1750812
62	1028622	1146033	1	1667.36	259.3	117.1	1744912.67	1846587.89	1777909.04	1817761.92	2987334	2569266
63	646905	715743	1	1168.52	116.7	133.6	1161784.71	1330750.60	1155657.70	1341436.37	1885422	1935108
64	1194648	1368360	1	2047.04	111	74.2	2184535.20	2194119.39	2214980.42	2181693.55	2709084	2600892

Tabel 10.4.2 Tekan rencana kolom

65	475965	466053	1	604.2	52.3	43.6	569248.71	738214.60	563121.70	748900.37	909006	883428
66	654444	763350	1	827.2	83.6	56	833074.27	954422.84	923244.49	896190.24	1290240	1209096
67	471429	526407	1	613.76	36.5	38.9	579286.71	748252.60	573159.70	758938.37	846762	853818
68	608288	801171	1	831.24	188.8	88.2	870069.19	965579.37	929560.85	910258.11	1776894	1481130
69	500262	526911	1	629.84	33.9	38.8	596170.71	765136.60	590043.70	775822.37	852600	867006
70	654885	847686	1	899.08	198.1	92.2	938218.67	1039893.89	971215.04	1011067.92	1892226	1580880
71	478401	539721	1	643.64	39.5	43.6	610660.71	779626.60	604533.70	790312.37	896658	908712
72	935991	1071882	1	1100.4	56.5	46	1190563.20	1200147.39	1221008.42	1187721.55	1450680	1419810
73	137732.05	139731.72	1	116.8	7.6	5.2	110749.86	139622.00	109525.88	141370.14	161112	154056
74	186029.79	289317.93	1	118.24	16	14.4	116820.49	137979.78	126233.30	132368.10	209496	204792
75	134925.00	89964.00	1	119.32	10.2	6	113395.86	142268.00	112171.88	144016.14	175686	163338
76	148659.00	265461.00	1	119.56	50.1	24.8	121950.50	143109.80	128742.50	134877.30	367206	292824
77	137732.05	139731.72	1	121.64	9.4	5.8	115831.86	144704.00	114607.88	146452.14	174510	163926
78	190953.00	243992.92	1	123.4	52.7	25.7	124068.13	147212.01	126393.27	139143.35	383292	303912
79	133434.00	139731.72	1	126.36	4.7	5.3	120787.86	149660.00	119563.88	151408.14	159096	160860
80	339463.78	401222.05	1	152.32	11	9.3	169842.55	162922.45	165145.87	171258.28	217854	212856

Tabel 10.4.2 Tekan rencana kolom

No	Arah x		ro	As t (mm2)		terpasang			Arah y		ro	pakai	terpasang	
kol.	e/h	K	perlu	pakai	terpasang	Nu, k	Mnak, k-x	Pn	e/h	K	perlu	As t	Mnak, k-y	Nu, k
1	0.18	0.31	0.01	16*804	12864	7791000	17413846.15	13850054.4	0.18	0.31	0.01	16*804	17413846.15	7791000
2	0.22	0.42	0.01	16*804+8*804	19296	10125000	16550480.77	17256081.6	0.22	0.42	0.01	16*804+8*804	14603365.38	9956250
3	0.28	0.32	0.01	16*804	12864	7791000	13456153.85	13850054.4	0.28	0.32	0.01	16*804	14089384.62	7791000
4	0.21	0.45	0.01	20*804+12*804	25728	10968750	19471153.85	19183108.8	0.20	0.45	0.01	20*804+12*804	15576923.08	10968750
5	0.27	0.32	0.01	16*804	12864	7791000	13456153.85	13850054.4	0.28	0.32	0.01	16*804	14247692.31	7791000
6	0.21	0.46	0.01	20*804+12*804	25728	10968750	19471153.85	19183108.8	0.20	0.45	0.01	20*804+12*804	15576923.08	10968750
7	0.26	0.34	0.01	16*804	12864	7791000	13614461.54	13850054.4	0.26	0.34	0.01	16*804	14089384.62	7791000
8	0.17	0.47	0.01	22*804+14*804	28944	13567500	16355769.23	22441622.4	0.15	0.47	0.01	22*804+14*804	19626923.08	13770000
9	0.51	0.28	0.025	16*804	12864	4263000	21371538.46	13850054.4	0.51	0.28	0.025	16*804	22954615.38	4263000
10	0.34	0.38	0.028	16*804+8*804	19296	7256250	26286057.69	17256081.6	0.47	0.32	0.029	16*804+8*804	31153846.15	6581250
11	0.50	0.29	0.025	16*804	12864	4410000	21371538.46	13850054.4	0.50	0.29	0.025	16*804	22163076.92	4410000
12	0.47	0.35	0.04	20*804+12*804	25728	6918750	35048076.92	19183108.8	0.51	0.34	0.04	20*804+12*804	36995192.31	6918750
13	0.49	0.29	0.025	16*804	12864	4410000	21371538.46	13850054.4	0.49	0.29	0.023	16*804	25329230.77	5145000
14	0.44	0.35	0.036	20*804+12*804	25728	7087500	34463942.31	19183108.8	0.48	0.35	0.039	20*804+12*804	37968750	7087500
15	0.47	0.31	0.026	16*804	12864	4704000	21371538.46	13850054.4	0.47	0.31	0.025	16*804	25329230.77	5439000
16	0.41	0.42	0.042	22*804+14*804	28944	8707500	37851923.08	22441622.4	0.40	0.42	0.04	22*804+14*804	49628076.92	8707500
17	0.36	0.26	0.01	16*804	12864	5439000	19788461.54	13850054.4	0.35	0.26	0.01	16*804	20580000	5586000
18	0.29	0.32	0.01	16*804	12864	6750000	19471153.85	15329054.4	0.37	0.32	0.017	16*804	23365384.62	6075000
19	0.35	0.26	0.01	16*804	12864	5439000	15830769.23	13850054.4	0.35	0.26	0.01	16*804	20580000	5586000
20	0.44	0.34	0.028	20*804	16080	5737500	26286057.69	16292568	0.41	0.33	0.024	20*804	34463942.31	7762500
21	0.34	0.27	0.01	16*804	12864	5586000	20580000	13850054.4	0.34	0.27	0.01	16*804	20580000	5880000
22	0.39	0.36	0.026	20*804	16080	6243750	25896634.62	16292568	0.38	0.35	0.024	20*804	34463942.31	8100000
23	0.34	0.27	0.01	16*804	12864	5586000	18996923.08	13850054.4	0.33	0.27	0.01	16*804	20580000	5880000
24	0.31	0.36	0.018	22*804	17688	8100000	23365384.62	19069324.8	0.32	0.36	0.018	22*804	49628076.92	7897500
25	0.35	0.22	0.01	16*804	12864	5439000	19788461.54	13850054.4	0.35	0.23	0.01	16*804	18996923.08	5586000
26	0.28	0.28	0.01	16*804	12864	6750000	19471153.85	15329054.4	0.39	0.28	0.012	16*804	32906250	6918750
27	0.35	0.23	0.01	16*804	12864	5439000	15830769.23	13850054.4	0.35	0.23	0.01	16*804	18996923.08	5586000
28	0.47	0.29	0.023	20*804	16080	5400000	27259615.38	16292568	0.44	0.28	0.018	20*804	35048076.92	7425000
29	0.34	0.23	0.01	16*804	12864	5586000	20580000	13850054.4	0.34	0.23	0.01	16*804	20580000	5586000
30	0.42	0.31	0.022	20*804	16080	5737500	26286057.69	16292568	0.40	0.30	0.015	20*804	35048076.92	7931250
31	0.33	0.24	0.01	16*804	12864	5586000	18996923.08	13850054.4	0.33	0.24	0.01	16*804	20580000	5586000
32	0.33	0.31	0.013	22*804	17688	8100000	23365384.62	19069324.8	0.34	0.31	0.012	22*804	49628076.92	7897500

Tabel 10.4.3 Penulangan lentur

33	0.42	0.19	0.01	16*804	12864	4998000	22163076.92	13850054.4	0.43	0.19	0.01	16*804	21371538.46	4998000
34	0.35	0.23	0.01	16*804	12864	5906250	23365384.62	15329054.4	0.44	0.23	0.01	16*804	35048076.92	6075000
35	0.41	0.19	0.01	16*804	12864	4998000	22163076.92	13850054.4	0.42	0.20	0.01	16*804	23112923.08	4998000
36	0.54	0.24	0.02	20*804	16080	4893750	28817307.69	16292568	0.50	0.24	0.017	20*804	27259615.38	5062500
37	0.40	0.20	0.01	16*804	12864	4998000	22163076.92	13850054.4	0.41	0.20	0.01	16*804	18996923.08	5145000
38	0.47	0.26	0.017	20*804	16080	5400000	27259615.38	16292568	0.45	0.26	0.014	20*804	26286057.69	5568750
39	0.40	0.20	0.01	16*804	12864	5145000	22004769.23	13850054.4	0.40	0.20	0.01	16*804	22163076.92	5145000
40	0.37	0.26	0.01	22*804	17688	7492500	29206730.77	19069324.8	0.39	0.26	0.01	22*804	33646153.85	7087500
41	0.53	0.16	0.01	16*804	12864	4116000	22004769.23	13850054.4	0.53	0.16	0.01	16*804	21371538.46	4263000
42	0.43	0.19	0.01	16*804	12864	5231250	25312500	15329054.4	0.53	0.19	0.013	16*804	25312500	4556250
43	0.53	0.16	0.01	16*804	12864	4116000	22004769.23	13850054.4	0.53	0.16	0.01	16*804	21371538.46	4263000
44	0.60	0.20	0.018	20*804	16080	5737500	40889423.08	16292568	0.60	0.19	0.014	20*804	29206730.77	4725000
45	0.52	0.16	0.01	16*804	12864	4263000	21846461.54	13850054.4	0.52	0.16	0.01	16*804	22163076.92	4263000
46	0.56	0.21	0.015	20*804	16080	6243750	38942307.69	16292568	0.54	0.21	0.015	20*804	27259615.38	4893750
47	0.51	0.17	0.01	16*804	12864	4263000	21688153.85	13850054.4	0.51	0.17	0.01	16*804	22163076.92	4263000
48	0.47	0.21	0.01	22*804	17688	6277500	32711538.46	19069324.8	0.47	0.21	0.01	22*804	36450000	6075000
49	0.57	0.12	0.01	16*804	12864	4116000	25329230.77	13850054.4	0.59	0.12	0.01	16*804	22954615.38	3969000
50	0.49	0.14	0.01	16*804	12864	4893750	35048076.92	15329054.4	0.68	0.14	0.01	16*804	25896634.62	3881250
51	0.56	0.12	0.01	16*804	12864	3969000	22163076.92	13850054.4	0.56	0.12	0.01	16*804	22163076.92	3969000
52	0.61	0.15	0.023	20*804	16080	4556250	26286057.69	16292568	0.71	0.14	0.012	20*804	26286057.69	4050000
53	0.54	0.12	0.01	16*804	12864	3822000	21054923.08	13850054.4	0.55	0.13	0.01	16*804	22163076.92	4116000
54	0.55	0.16	0.01	20*804	16080	4050000	23365384.62	16292568	0.66	0.16	0.014	20*804	29206730.77	4387500
55	0.53	0.13	0.01	16*804	12864	4116000	22163076.92	13850054.4	0.54	0.13	0.01	16*804	22954615.38	4116000
56	0.53	0.16	0.01	22*804	17688	5670000	32711538.46	19069324.8	0.56	0.16	0.01	22*804	39253846.15	5670000
57	0.74	0.09	0.01	16*804	12864	1911000	22163076.92	13850054.4	0.67	0.09	0.01	16*804	22163076.92	1617000
58	0.65	0.10	0.01	12864	12864	4050000	26286057.69	15329054.4	0.82	0.10	0.013	12864	38942307.69	2700000
59	0.72	0.09	0.01	16*804	12864	1764000	22954615.38	13850054.4	0.78	0.09	0.01	16*804	22163076.92	1764000
60	0.77	0.10	0.013	20*804	16080	3712500	31153846.15	16292568	0.89	0.10	0.015	20*804	44783653.85	3206250
61	0.73	0.09	0.01	16*804	12864	1764000	22163076.92	13850054.4	0.76	0.09	0.01	16*804	22163076.92	1764000
62	0.74	0.11	0.011	20*804	16080	3881250	31543269.23	16292568	0.84	0.11	0.013	20*804	44783653.85	3206250
63	0.69	0.09	0.01	16*804	12864	1764000	22163076.92	13850054.4	0.76	0.09	0.01	16*804	22163076.92	1764000
64	0.73	0.11	0.011	22*804	17688	4657500	32711538.46	19069324.8	0.70	0.11	0.01	22*804	49628076.92	7897500

Tabel 10.4.3 Penulangan lentur

65	A	1	9	3.6	2.9	0.80	0.18	0.66	0.15	875237.87	199515.98	739345.39	168629.35	475965	231861	466053	234591
66		2		3.6	2.8	0.90	0.27	0.79	0.36	1312933.18	398541.64	1745629.85	783963.95	654444	436590	763350	621936
67	B	1		3.6	2.9	0.80	0.18	0.60	0.22	871893.03	201868.23	664698.53	240541.12	471429	232491	526407	304521
68		2		3.6	2.8	0.87	0.32	0.89	0.37	1796718.03	668468.61	2125898.64	882545.00	608286	531510	801171	710871
69	C	1		3.6	2.9	0.82	0.20	0.64	0.21	902875.73	215420.45	719331.34	238581.87	500262	259392	526911	303681
70		2		3.6	2.8	0.88	0.34	0.80	0.37	1769090.91	679554.16	1896215.98	873376.09	654885	583611	847686	757890
71	D	1		3.6	2.9	0.83	0.20	0.71	0.18	910332.26	220052.98	797063.67	203378.87	478401	235053	539721	306957
72		2		3.6	2.7	0.77	0.37	0.86	0.36	1715340.40	821170.56	2553150.57	1063000.70	935991	708435	1071882	894306
73	A	1	roof	3.6	2.9	1	0.20	1	0.34	137732.05	27741.08	139731.72	47109.55	140154	191940	144564	244566
74		2		3.6	2.8	1	0.10	1	0.21	186029.79	18267.45	289317.93	59693.92	253386	175812	326928	265818
75	B	1		3.6	2.9	1	0.20	1	0.40	137732.05	28161.43	139731.72	56461.00	134925	201957	89964	236964
76		2		3.6	2.8	1	0.13	1	0.11	274000.29	36039.22	315709.07	34098.49	148659	122913	265461	211491
77	C	1		3.6	2.9	1	0.18	1	0.36	137732.05	24267.84	139731.72	49616.83	152523	193935	183855	288771
78		2		3.6	2.8	1	0.12	1	0.20	257013.27	30868.43	243992.92	48432.43	190953	153111	346395	305613
79	D	1		3.6	2.9	1	0.17	1	0.29	137732.05	23330.78	139731.72	39878.84	133434	161826	189441	259875
80		2		3.6	2.7	1	0.23	1	0.14	339463.78	79747.05	401222.05	55854.01	311178	279174	425943	376593

Tabel 10.4.1 Momen rencana kolom

65	475965	466053	1	604.2	52.3	43.6	569248.71	738214.60	563121.70	748900.37	909006	883428
66	654444	763350	1	827.2	83.6	56	833074.27	954422.84	923244.49	896190.24	1290240	1209096
67	471429	526407	1	613.76	36.5	38.9	579286.71	748252.60	573159.70	758938.37	846762	853818
68	608288	801171	1	831.24	188.8	88.2	870069.19	965579.37	929560.85	910258.11	1776894	1481130
69	500262	526911	1	629.84	33.9	38.8	596170.71	765136.60	590043.70	775822.37	852600	867006
70	654885	847686	1	899.08	198.1	92.2	938218.67	1039893.89	971215.04	1011067.92	1892226	1580880
71	478401	539721	1	643.64	39.5	43.6	610660.71	779626.60	604533.70	790312.37	896658	908712
72	935991	1071882	1	1100.4	56.5	46	1190563.20	1200147.39	1221008.42	1187721.55	1450680	1419810
73	137732.05	139731.72	1	116.8	7.6	5.2	110749.86	139622.00	109525.88	141370.14	161112	154056
74	186029.79	289317.93	1	118.24	16	14.4	116820.49	137979.78	126233.30	132368.10	209496	204792
75	134925.00	89964.00	1	119.32	10.2	6	113395.86	142268.00	112171.88	144016.14	175686	163338
76	148659.00	265461.00	1	119.56	50.1	24.8	121950.50	143109.80	128742.50	134877.30	367206	292824
77	137732.05	139731.72	1	121.64	9.4	5.8	115831.86	144704.00	114607.88	146452.14	174510	163926
78	190953.00	243992.92	1	123.4	52.7	25.7	124068.13	147212.01	126393.27	139143.35	383292	303912
79	133434.00	139731.72	1	126.36	4.7	5.3	120787.86	149660.00	119563.88	151408.14	159096	160860
80	339463.78	401222.05	1	152.32	11	9.3	169842.55	162922.45	165145.87	171258.28	217854	212856

Tabel 10.4.2 Tekan rencana kolom

33	0.42	0.19	0.01	16*804	12864	4998000	22163076.92	13850054.4	0.43	0.19	0.01	16*804	21371538.46	4998000
34	0.35	0.23	0.01	16*804	12864	5906250	23365384.62	15329054.4	0.44	0.23	0.01	16*804	35048076.92	6075000
35	0.41	0.19	0.01	16*804	12864	4998000	22163076.92	13850054.4	0.42	0.20	0.01	16*804	23112923.08	4998000
36	0.54	0.24	0.02	20*804	16080	4893750	28817307.69	16292568	0.50	0.24	0.017	20*804	27259615.38	5062500
37	0.40	0.20	0.01	16*804	12864	4998000	22163076.92	13850054.4	0.41	0.20	0.01	16*804	18996923.08	5145000
38	0.47	0.26	0.017	20*804	16080	5400000	27259615.38	16292568	0.45	0.26	0.014	20*804	26286057.69	5568750
39	0.40	0.20	0.01	16*804	12864	5145000	22004769.23	13850054.4	0.40	0.20	0.01	16*804	22163076.92	5145000
40	0.37	0.26	0.01	22*804	17688	7492500	29206730.77	19069324.8	0.39	0.26	0.01	22*804	33646153.85	7087500
41	0.53	0.16	0.01	16*804	12864	4116000	22004769.23	13850054.4	0.53	0.16	0.01	16*804	21371538.46	4263000
42	0.43	0.19	0.01	16*804	12864	5231250	25312500	15329054.4	0.53	0.19	0.013	16*804	25312500	4556250
43	0.53	0.16	0.01	16*804	12864	4116000	22004769.23	13850054.4	0.53	0.16	0.01	16*804	21371538.46	4263000
44	0.60	0.20	0.018	20*804	16080	5737500	40889423.08	16292568	0.60	0.19	0.014	20*804	29206730.77	4725000
45	0.52	0.16	0.01	16*804	12864	4263000	21846461.54	13850054.4	0.52	0.16	0.01	16*804	22163076.92	4263000
46	0.56	0.21	0.015	20*804	16080	6243750	38942307.69	16292568	0.54	0.21	0.015	20*804	27259615.38	4893750
47	0.51	0.17	0.01	16*804	12864	4263000	21688153.85	13850054.4	0.51	0.17	0.01	16*804	22163076.92	4263000
48	0.47	0.21	0.01	22*804	17688	6277500	32711538.46	19069324.8	0.47	0.21	0.01	22*804	36450000	6075000
49	0.57	0.12	0.01	16*804	12864	4116000	25329230.77	13850054.4	0.59	0.12	0.01	16*804	22954615.38	3969000
50	0.49	0.14	0.01	16*804	12864	4893750	35048076.92	15329054.4	0.68	0.14	0.01	16*804	25896634.62	3881250
51	0.56	0.12	0.01	16*804	12864	3969000	22163076.92	13850054.4	0.56	0.12	0.01	16*804	22163076.92	3969000
52	0.61	0.15	0.023	20*804	16080	4556250	26286057.69	16292568	0.71	0.14	0.012	20*804	26286057.69	4050000
53	0.54	0.12	0.01	16*804	12864	3822000	21054923.08	13850054.4	0.55	0.13	0.01	16*804	22163076.92	4116000
54	0.55	0.16	0.01	20*804	16080	4050000	23365384.62	16292568	0.66	0.16	0.014	20*804	29206730.77	4387500
55	0.53	0.13	0.01	16*804	12864	4116000	22163076.92	13850054.4	0.54	0.13	0.01	16*804	22954615.38	4116000
56	0.53	0.16	0.01	22*804	17688	5670000	32711538.46	19069324.8	0.56	0.16	0.01	22*804	39253846.15	5670000
57	0.74	0.09	0.01	16*804	12864	1911000	22163076.92	13850054.4	0.67	0.09	0.01	16*804	22163076.92	1617000
58	0.65	0.10	0.01	12864	12864	4050000	26286057.69	15329054.4	0.82	0.10	0.013	12864	38942307.69	2700000
59	0.72	0.09	0.01	16*804	12864	1764000	22954615.38	13850054.4	0.78	0.09	0.01	16*804	22163076.92	1764000
60	0.77	0.10	0.013	20*804	16080	3712500	31153846.15	16292568	0.89	0.10	0.015	20*804	44783653.85	3206250
61	0.73	0.09	0.01	16*804	12864	1764000	22163076.92	13850054.4	0.76	0.09	0.01	16*804	22163076.92	1764000
62	0.74	0.11	0.011	20*804	16080	3881250	31543269.23	16292568	0.84	0.11	0.013	20*804	44783653.85	3206250
63	0.69	0.09	0.01	16*804	12864	1764000	22163076.92	13850054.4	0.76	0.09	0.01	16*804	22163076.92	1764000
64	0.73	0.11	0.011	22*804	17688	4657500	32711538.46	19069324.8	0.70	0.11	0.01	22*804	49628076.92	7897500

Tabel 10.4.3 Penulangan lentur

33	0.42	0.19	0.01	16*804	12864	4998000	22163076.92	13850054.4	0.43	0.19	0.01	16*804	21371538.46	4998000
34	0.35	0.23	0.01	16*804	12864	5906250	23365384.62	15329054.4	0.44	0.23	0.01	16*804	35048076.92	6075000
35	0.41	0.19	0.01	16*804	12864	4998000	22163076.92	13850054.4	0.42	0.20	0.01	16*804	23112923.08	4998000
36	0.54	0.24	0.02	20*804	16080	4893750	28817307.69	16292568	0.50	0.24	0.017	20*804	27259615.38	5062500
37	0.40	0.20	0.01	16*804	12864	4998000	22163076.92	13850054.4	0.41	0.20	0.01	16*804	18996923.08	5145000
38	0.47	0.26	0.017	20*804	16080	5400000	27259615.38	16292568	0.45	0.26	0.014	20*804	26286057.69	5568750
39	0.40	0.20	0.01	16*804	12864	5145000	22004769.23	13850054.4	0.40	0.20	0.01	16*804	22163076.92	5145000
40	0.37	0.26	0.01	22*804	17688	7492500	29206730.77	19069324.8	0.39	0.26	0.01	22*804	33646153.85	7087500
41	0.53	0.16	0.01	16*804	12864	4116000	22004769.23	13850054.4	0.53	0.16	0.01	16*804	21371538.46	4263000
42	0.43	0.19	0.01	16*804	12864	5231250	25312500	15329054.4	0.53	0.19	0.013	16*804	25312500	4556250
43	0.53	0.16	0.01	16*804	12864	4116000	22004769.23	13850054.4	0.53	0.16	0.01	16*804	21371538.46	4263000
44	0.60	0.20	0.018	20*804	16080	5737500	40889423.08	16292568	0.60	0.19	0.014	20*804	29206730.77	4725000
45	0.52	0.16	0.01	16*804	12864	4263000	21846461.54	13850054.4	0.52	0.16	0.01	16*804	22163076.92	4263000
46	0.56	0.21	0.015	20*804	16080	6243750	38942307.69	16292568	0.54	0.21	0.015	20*804	27259615.38	4893750
47	0.51	0.17	0.01	16*804	12864	4263000	21688153.85	13850054.4	0.51	0.17	0.01	16*804	22163076.92	4263000
48	0.47	0.21	0.01	22*804	17688	6277500	32711538.46	19069324.8	0.47	0.21	0.01	22*804	36450000	6075000
49	0.57	0.12	0.01	16*804	12864	4116000	25329230.77	13850054.4	0.59	0.12	0.01	16*804	22954615.38	3969000
50	0.49	0.14	0.01	16*804	12864	4893750	35048076.92	15329054.4	0.68	0.14	0.01	16*804	25896634.62	3881250
51	0.56	0.12	0.01	16*804	12864	3969000	22163076.92	13850054.4	0.56	0.12	0.01	16*804	22163076.92	3969000
52	0.61	0.15	0.023	20*804	16080	4556250	26286057.69	16292568	0.71	0.14	0.012	20*804	26286057.69	4050000
53	0.54	0.12	0.01	16*804	12864	3822000	21054923.08	13850054.4	0.55	0.13	0.01	16*804	22163076.92	4116000
54	0.55	0.16	0.01	20*804	16080	4050000	23365384.62	16292568	0.66	0.16	0.014	20*804	29206730.77	4387500
55	0.53	0.13	0.01	16*804	12864	4116000	22163076.92	13850054.4	0.54	0.13	0.01	16*804	22954615.38	4116000
56	0.53	0.16	0.01	22*804	17688	5670000	32711538.46	19069324.8	0.56	0.16	0.01	22*804	39253846.15	5670000
57	0.74	0.09	0.01	16*804	12864	1911000	22163076.92	13850054.4	0.67	0.09	0.01	16*804	22163076.92	1617000
58	0.65	0.10	0.01	12864	12864	4050000	26286057.69	15329054.4	0.82	0.10	0.013	12864	38942307.69	2700000
59	0.72	0.09	0.01	16*804	12864	1764000	22954615.38	13850054.4	0.78	0.09	0.01	16*804	22163076.92	1764000
60	0.77	0.10	0.013	20*804	16080	3712500	31153846.15	16292568	0.89	0.10	0.015	20*804	44783653.85	3206250
61	0.73	0.09	0.01	16*804	12864	1764000	22163076.92	13850054.4	0.76	0.09	0.01	16*804	22163076.92	1764000
62	0.74	0.11	0.011	20*804	16080	3881250	31543269.23	16292568	0.84	0.11	0.013	20*804	44783653.85	3206250
63	0.69	0.09	0.01	16*804	12864	1764000	22163076.92	13850054.4	0.76	0.09	0.01	16*804	22163076.92	1764000
64	0.73	0.11	0.011	22*804	17688	4657500	32711538.46	19069324.8	0.70	0.11	0.01	22*804	49628076.92	7897500

Tabel 10.4.3 Penulangan lentur

65	0.92	0.05	0.01	16*804	12864	2352000	22954615.38	13850054.4	0.89	0.05	0.01	16*804	22163076.92	2499000
66	0.91	0.06	0.01	16*804	12864	2531250	25312500	15329054.4	1.14	0.05	0.01	16*804	23365384.62	2025000
67	0.90	0.05	0.01	16*804	12864	2205000	22163076.92	13850054.4	0.99	0.05	0.01	16*804	18205384.62	1911000
68	0.84	0.06	0.01	20*804	16080	3206250	31153846.15	16292568	1.17	0.05	0.011	20*804	27259615.38	2193750
69	0.93	0.05	0.01	16*804	12864	2352000	22163076.92	13850054.4	0.97	0.05	0.01	16*804	18205384.62	1911000
70	0.84	0.06	0.01	20*804	16080	3206250	27259615.38	16292568	1.12	0.06	0.012	20*804	26286057.69	2193750
71	0.88	0.05	0.01	16*804	12864	2499000	22954615.38	13850054.4	0.98	0.05	0.01	16*804	18205384.62	1911000
72	1.04	0.06	0.01	22*804	17688	2632500	32711538.46	19069324.8	1.00	0.06	0.01	22*804	49628076.92	7897500
73	1.41	0.01	0.01	16*804	12864	882000	9498461.538	13850054.4	1.41	0.01	0.01	16*804	14247692.31	1176000
74	1.93	0.01	0.01	16*804	12864	441000	11873076.92	13850054.4	3.12	0.01	0.01	16*804	10290000	294000
75	1.35	0.01	0.01	16*804	12864	882000	13139538.46	13850054.4	0.89	0.01	0.01	16*804	14247692.31	1176000
76	1.48	0.01	0.01	20*804	16080	441000	12031384.62	14813568	2.81	0.01	0.01	20*804	12664615.38	294000
77	1.36	0.01	0.01	16*804	12864	882000	12664615.38	13850054.4	1.36	0.01	0.01	16*804	11081538.46	882000
78	1.85	0.01	0.01	20*804	16080	441000	12664615.38	14813568	2.51	0.01	0.01	20*804	12664615.38	441000
79	1.27	0.01	0.01	16*804	12864	882000	12664615.38	13850054.4	1.32	0.01	0.01	16*804	11873076.92	882000
80	2.98	0.01	0.01	16*804	12864	535500	7689230.769	15992054.4	2.76	0.01	0.01	16*804	9336923.077	357000

Tabel 10.4.3 Penulangan lentur

No	As		lantai	Vu, k-x	Vu, k-x	di dalam s. plastis				pakai	luar s. plastis					pakai
kol.				perlu (N)	max (N)	Vs perlu	D tul.	kaki	S perlu	S (mm)	Vc	Vs perlu	D tul.	kaki	S perlu	S (mm)
1	A	1	1	317454.68	2148720	529091.14	12	2	105.59	100	1297038.46	-768754.32	10	2	-50.86	100
2		2		468342.90	2073099	780571.50	16	2	137.61	100	1726216.80	-945645.30	10	2	-44.64	100
3	B	1		317252.07	1654905	528753.45	12	2	105.66	100	1304115.79	-775362.34	10	2	-50.37	100
4		2		627135.38	3145989	1045225.64	16	2	102.77	100	1775819.78	-730594.14	10	2	-57.79	100
5	C	1		317036.49	2163168	528394.14	12	2	105.73	100	1310653.53	-782259.39	10	2	-49.93	100
6		2		613369.05	3140046	1022281.75	16	2	105.07	100	1783877.33	-761595.58	10	2	-55.43	100
7	D	1		317542.37	834876	529237.29	12	2	105.56	100	1337979.55	-808742.27	10	2	-48.29	100
8		2		475447.92	2480247	792413.20	16	2	135.55	100	2200637.81	-1408224.61	10	2	-29.98	100
9	A	1	2	795600.43	1455867	1326000.72	12	5	105.33	100	1245254.68	80746.05	10	2	483.71	100
10		2		917275.38	1835190	1528792.31	16	3	105.39	100	1634400.11	-105607.80	10	2	-399.76	100
11	B	1		796246.61	1477455	1327077.69	12	5	105.24	100	1251927.82	75149.87	10	2	519.73	100
12		2		1437054.59	3518151	2395090.99	16	5	112.12	100	1676896.24	718194.74	10	4	117.57	100
13	C	1		796839.25	1481340	1328065.42	12	5	105.17	100	1258393.02	69672.40	10	2	560.59	100
14		2		1361460.70	3518970	2269101.17	16	5	118.34	100	1685567.59	583533.57	10	4	144.70	100
15	D	1		794991.47	1462419	1324985.79	12	5	105.41	100	1285017.88	39967.91	10	2	977.22	100
16		2		1531260.88	2488857	2552101.47	16	5	105.22	100	2070936.53	481164.94	10	3	131.61	100
17	A	1	3	577921.92	785904	963203.20	12	5	145.00	100	1199904.25	-236701.05	10	2	-165.01	100
18		2		732977.15	1009974	1221628.59	16	3	131.89	100	1533002.27	-311373.68	10	2	-135.58	100
19	B	1		577334.46	799218	962224.10	12	5	145.15	100	1205953.60	-243729.49	10	2	-160.25	100
20		2		1177668.56	1893045	1962780.93	16	5	136.81	100	1544570.43	418210.50	10	4	201.90	100
21	C	1		577202.73	804468	962004.55	12	5	145.18	100	1214585.16	-252580.60	10	2	-154.63	100
22		2		1114520.70	1911126	1857534.50	16	5	144.57	100	1585047.95	272486.55	10	4	309.87	100
23	D	1		577210.31	791448	962017.18	12	5	145.18	100	1222646.11	-260628.94	10	2	-149.86	100
24		2		1118382.83	1400868	1863971.38	16	5	144.07	100	1947182.00	-83210.61	10	3	-761.04	100
25	A	1	4	552957.69	724710	921596.15	12	5	151.55	100	1144582.80	-222986.65	10	2	-175.16	100
26		2		694035.84	953316	1156726.40	16	3	139.29	100	1444449.22	-287722.82	10	2	-146.73	100
27	B	1		552648.59	737730	921080.98	12	5	151.63	100	1149911.64	-228830.66	10	2	-170.68	100
28		2		1148889.69	1721538	1914816.16	16	5	140.24	100	1452252.23	462563.93	10	4	182.54	100
29	C	1		552425.90	744240	920709.83	12	5	151.70	100	1157909.74	-237199.90	10	2	-164.66	100
30		2		1087571.35	1746465	1812618.92	16	5	148.15	100	1488723.71	323895.21	10	4	260.69	100
31	D	1		552444.22	731010	920740.36	12	5	151.69	100	1165385.59	-244645.22	10	2	-159.65	100
32		2		1080840.80	1367940	1801401.33	16	5	149.07	100	1824242.15	-22840.82	10	3	-2772.51	100

Tabel 10.4.4.a Penulangan geser

33	A	1	5	547567.44	653016	912612.40	12	5	153.04	100	1087820.34	-175207.94	10	2	-222.92	100
34		2		693838.75	881580	1156397.92	16	3	139.33	100	1356730.37	-200332.45	10	2	-210.74	100
35	B	1		547086.87	666393	911811.45	12	5	153.18	100	1092428.67	-180617.22	10	2	-216.25	100
36		2		1177491.12	1522773	1962485.19	16	5	136.83	100	1361534.13	600951.06	10	4	140.50	100
37	C	1		545803.83	675885	909673.05	12	5	153.54	100	1099570.87	-189897.81	10	2	-205.68	100
38		2		1112080.30	1559019	1853467.17	16	5	144.88	100	1392794.63	460672.54	10	4	183.29	100
39	D	1		547005.58	658413	911675.96	12	5	153.20	100	1106123.12	-194447.15	10	2	-200.86	100
40		2		1075626.50	1278354	1792710.83	16	5	149.79	100	1703390.25	89320.58	10	3	708.98	100
41	A	1	6	551730.97	575064	919551.62	12	5	151.89	100	1029979.54	-110427.92	10	2	-353.69	100
42		2		669793.84	793380	1116323.06	16	3	144.33	100	1269635.95	-153312.89	10	2	-275.37	100
43	B	1		552033.14	587664	920055.24	12	5	151.80	100	1033707.79	-113652.55	10	2	-343.66	100
44		2		1107852.13	1313046	1846420.21	16	5	145.44	100	1272069.78	574350.43	10	4	147.01	100
45	C	1		551844.36	597345	919740.60	12	5	151.86	100	1039868.36	-120127.76	10	2	-325.13	100
46		2		1050239.61	1356936	1750399.36	16	5	153.41	100	1297699.74	452699.61	10	4	186.51	100
47	D	1		551309.59	582540	918849.31	12	5	152.00	100	1045313.25	-126463.94	10	2	-308.84	100
48		2		1074325.09	1160460	1790541.81	16	5	149.97	100	1584836.08	205705.73	10	3	307.85	100
49	A	1	7	473631.62	485520	789386.04	12	3	106.16	100	973373.95	-183987.91	10	2	-212.28	100
50		2		618105.03	686406	1030175.05	16	2	104.27	100	1183193.57	-153018.52	10	2	-275.90	100
51	B	1		473732.17	496545	789553.62	12	3	106.14	100	976314.00	-186760.38	10	2	-209.13	100
52		2		964228.73	1075221	1607047.88	16	3	100.26	100	1193559.31	413488.57	10	2	102.10	100
53	C	1		474553.16	507045	790921.94	12	3	105.95	100	981144.77	-190222.84	10	2	-205.33	100
54		2		922800.96	1124151	1538001.60	16	3	104.76	100	1211465.93	326535.67	10	2	129.29	100
55	D	1		473720.01	492093	789533.35	12	3	106.14	100	985540.34	-196006.99	10	2	-199.27	100
56		2		973016.20	1010205	1621693.66	16	4	132.47	100	1467757.61	153936.05	10	2	274.25	100
57	A	1	8	444100.17	371595	619325.00	12	3	135.31	100	914384.37	-295059.37	10	2	-132.37	100
58		2		578590.05	544236	907060.00	16	2	118.42	100	1097124.27	-190064.27	10	2	-222.12	100
59	B	1		443659.23	381486	635810.00	12	3	131.80	100	916275.09	-280465.09	10	2	-139.26	100
60		2		829491.22	783762	1306270.00	16	3	123.34	100	1102743.35	203526.65	10	2	207.43	100
61	C	1		439991.30	392721	654535.00	12	3	128.03	100	919809.92	-265274.92	10	2	-147.23	100
62		2		798523.86	836535	1330873.11	16	3	121.06	100	1117371.69	213501.41	10	2	197.74	100
63	D	1		438621.12	378504	630840.00	12	3	132.84	100	922870.86	-292030.86	10	2	-133.74	100
64		2		885507.20	808143	1346905.00	16	4	159.50	100	1351374.05	-4469.05	10	2	-9446.67	100

Tabel 10.4.4.a Penulangan geser

65	A	1	9	370604.78	238980	398300.00	12	3	210.40	100	854650.11	-456350.11	10	2	-85.59	100
66		2		611241.01	387933	646555.00	16	2	166.13	100	1011459.88	-364904.88	10	2	-115.69	100
67	B	1		370262.50	249438	415730.00	12	3	201.58	100	855805.82	-440075.82	10	2	-88.75	100
68		2		880423.80	431844	719740.00	16	3	223.86	100	1015756.91	-296016.91	10	2	-142.62	100
69	C	1		385619.37	261240	435400.00	12	3	192.47	100	857749.73	-422349.73	10	2	-92.48	100
70		2		874516.10	489300	815500.00	16	3	197.57	100	1023672.61	-208172.61	10	2	-202.80	100
71	D	1		389788.01	244650	407750.00	12	3	205.52	100	859418.02	-451668.02	10	2	-86.47	100
72		2		939448.50	597828	996380.00	16	4	215.61	100	1235922.25	-239542.25	10	2	-176.24	100
73	A	1	roof	57059.70	47439	79065.00	10	2	493.99	100	802426.03	-723361.03	10	2	-53.99	100
74		2		72963.30	93849	121605.50	10	2	321.18	100	804349.61	-682744.11	10	2	-57.21	100
75	B	1		57204.65	62055	95341.08	10	2	409.66	100	802730.67	-707389.59	10	2	-55.21	100
76		2		110728.39	76020	126700.00	10	2	308.27	100	804638.50	-677938.50	10	2	-57.61	100
77	C	1		55862.03	65688	93103.39	10	2	419.51	100	803011.14	-709907.75	10	2	-55.02	100
78		2		102814.90	101115	168525.00	10	2	231.76	100	804368.03	-635843.03	10	2	-61.43	100
79	D	1		55538.91	42819	71365.00	10	2	547.29	100	803581.74	-732216.74	10	2	-53.34	100
80		2		155263.27	185892	258772.11	10	2	150.93	100	978076.02	-719303.91	10	2	-54.30	100

Tabel 10.4.4.a Penulangan geser

No kol.	Vu, k-y perlu (N)	Vu, k-y max (N)	di dalam s. plastis				pakai S (mm)	luar s. plastis					pakai S (mm)
			Vs perlu	D tul.	kaki	S perlu		Vc	Vs perlu	D tul.	kaki	S perlu	
1	328702.38	3376758	547837.30	12	2	101.98	100	1297036.46	-749199.16	10	2	-52.13	100
2	476576.26	2509962	794293.77	16	2	135.23	100	1726216.80	-931923.03	10	2	-45.30	100
3	328191.50	1704465	546985.83	12	2	102.14	100	1304115.79	-757129.96	10	2	-51.59	100
4	476435.75	2847579	794059.59	16	2	135.27	100	1775819.78	-981760.19	10	2	-43.00	100
5	328206.58	3394482	547010.96	12	2	102.13	100	1310653.53	-763642.57	10	2	-51.15	100
6	484931.64	2846109	808219.40	16	2	132.90	100	1783877.33	-975657.93	10	2	-43.27	100
7	323066.30	861840	538443.83	12	2	103.76	100	1337979.55	-799535.72	10	2	-48.85	100
8	556567.49	2847852	927612.48	16	2	141.80	100	2200637.81	-1273025.33	10	2	-40.61	100
9	812294.32	1511328	1353823.87	12	5	103.17	100	1245254.68	108569.19	10	2	359.75	100
10	1270982.38	2506959	2118303.97	16	4	101.42	100	1634400.11	483903.86	10	3	130.87	100
11	812637.02	1547889	1354395.03	12	5	103.12	100	1251927.82	102467.21	10	2	381.17	100
12	1463697.30	3048045	2439495.49	16	5	110.08	100	1676896.24	762599.25	10	4	110.72	100
13	812507.45	1548960	1354179.09	12	5	103.14	100	1258393.02	95786.07	10	2	407.76	100
14	1425302.63	3043950	2375504.39	16	5	113.04	100	1685567.59	689936.79	10	4	122.38	100
15	817199.28	1528380	1361998.79	12	5	102.55	100	1285017.88	76980.92	10	2	507.37	100
16	1801547.42	2888592	3002579.04	16	5	109.52	100	2070936.53	931642.51	10	4	110.98	100
17	584304.07	809676	973840.11	12	5	143.42	100	1199904.25	-226064.14	10	2	-172.77	100
18	932992.09	1390158	1554986.82	16	4	138.15	100	1533002.27	21984.55	10	3	2880.50	100
19	582327.36	841491	970545.60	12	5	143.91	100	1205953.60	-235407.99	10	2	-165.91	100
20	1081971.39	1686972	1803285.65	16	5	148.91	100	1544570.43	258715.22	10	4	326.36	100
21	581302.06	843192	968836.77	12	5	144.16	100	1214585.16	-245748.39	10	2	-158.93	100
22	1062577.54	1688820	1770962.57	16	5	151.63	100	1585047.95	185914.62	10	4	454.16	100
23	582792.69	835800	971321.15	12	5	143.79	100	1222646.11	-251324.96	10	2	-155.41	100
24	1351654.93	1737750	2252758.21	16	5	145.97	100	1947182.00	305576.22	10	4	338.36	100
25	558816.27	740985	931360.46	12	5	149.96	100	1144582.80	-213222.34	10	2	-183.18	100
26	912817.58	1304121	1521362.63	16	4	141.21	100	1444449.22	76913.41	10	3	823.35	100
27	558856.15	777987	931426.92	12	5	149.95	100	1149911.64	-218484.73	10	2	-178.77	100
28	1047789.57	1572585	1746315.94	16	5	153.77	100	1452252.23	294063.72	10	4	287.13	100
29	559485.55	779520	932475.91	12	5	149.78	100	1157909.74	-225433.82	10	2	-173.26	100
30	1029917.50	1575336	1716529.17	16	5	156.44	100	1488723.71	227805.45	10	4	370.65	100
31	559793.16	776643	932988.59	12	5	149.70	100	1165385.59	-232396.99	10	2	-168.06	100
32	1310638.58	1658496	2184397.64	16	5	150.54	100	1824242.15	360155.49	10	4	287.08	100

Tabel 10.4.4.b Penulangan geser

33	561098.31	664566	935163.85	12	5	149.35	100	1087820.34	-152656.49	10	2	-255.85	100
34	914522.24	1195950	1524203.73	16	4	140.94	100	1356730.37	167473.37	10	3	378.13	100
35	560239.25	705642	933732.08	12	5	149.58	100	1092428.67	-158696.59	10	2	-246.11	100
36	1056636.71	1429869	1761061.19	16	5	152.49	100	1361534.13	399527.06	10	4	211.34	100
37	560258.16	708225	933763.60	12	5	149.58	100	1099570.87	-165807.26	10	2	-235.56	100
38	1039152.39	1434321	1731920.66	16	5	155.05	100	1392794.63	339126.03	10	4	248.98	100
39	556183.53	704760	926972.54	12	5	150.67	100	1106123.12	-179150.57	10	2	-218.02	100
40	1303330.44	1536381	2172217.39	16	5	151.38	100	1703390.25	468827.14	10	4	220.54	100
41	555945.62	582414	926576.03	12	5	150.74	100	1029979.54	-103403.51	10	2	-377.72	100
42	882621.23	1069110	1471035.39	16	4	146.04	100	1269635.95	201399.44	10	3	314.43	100
43	553239.21	624918	922065.34	12	5	151.47	100	1033707.79	-111642.45	10	2	-349.85	100
44	1017706.77	1268778	1696177.95	16	5	158.32	100	1272069.78	424108.17	10	4	199.09	100
45	553289.35	627165	922148.91	12	5	151.46	100	1039868.36	-117719.45	10	2	-331.79	100
46	999119.52	1274259	1665199.19	16	5	161.26	100	1297699.74	367499.45	10	4	229.76	100
47	558241.21	628908	930402.02	12	5	150.12	100	1045313.25	-114911.23	10	2	-339.89	100
48	1306218.07	1388688	2177030.12	16	5	151.05	100	1584836.08	592194.04	10	4	174.60	100
49	485952.39	487809	809920.65	12	3	103.47	100	973373.95	-163453.30	10	2	-238.95	100
50	872125.36	916020	1453542.27	16	3	110.85	100	1183193.57	270348.70	10	2	156.16	100
51	484888.67	529935	808147.78	12	3	103.69	100	976314.00	-168166.22	10	2	-232.26	100
52	974159.88	1076985	1623599.80	16	4	132.32	100	1193559.31	430040.49	10	2	116.20	100
53	483428.38	532308	805713.97	12	3	104.01	100	981144.77	-175430.80	10	2	-222.64	100
54	962263.47	1082991	1603772.46	16	4	133.95	100	1211465.93	392306.53	10	2	107.61	100
55	482104.90	537537	803508.17	12	3	104.29	100	985540.34	-182032.17	10	2	-214.56	100
56	1243205.40	1204938	2008230.00	16	4	131.00	100	1467757.61	540472.39	10	2	143.48	100
57	459648.32	368361	613935.00	12	3	136.50	100	914384.37	-300449.37	10	2	-130.00	100
58	856496.65	715302	1192170.00	16	3	135.15	100	1097124.27	95045.73	10	2	444.18	100
59	441657.22	409101	681835.00	12	3	122.90	100	916275.09	-234440.09	10	2	-166.60	100
60	921181.57	830067	1383445.00	16	4	155.29	100	1102743.35	280701.65	10	2	150.40	100
61	443652.23	411600	686000.00	12	3	122.16	100	919809.92	-233809.92	10	2	-167.05	100
62	914647.94	835842	1393070.00	16	4	154.21	100	1117371.69	275698.31	10	2	153.13	100
63	454815.40	419790	699650.00	12	3	119.78	100	922870.86	-223220.86	10	2	-174.97	100
64	1201804.02	960330	1600550.00	16	4	164.36	100	1351374.05	249175.95	10	2	207.47	100

Tabel 10.4.4.b Penulangan geser

65	313094.74	223503	372505.00	12	3	224.97	100	854650.11	-482145.11	10	2	-81.01	100
66	903426.36	494382	823970.00	16	3	195.54	100	1011459.88	-187489.88	10	2	-225.17	100
67	312151.61	273483	455805.00	12	3	183.85	100	855805.82	-400000.82	10	2	-97.64	100
68	1074444.16	555345	925575.00	16	4	232.10	100	1015756.91	-90181.91	10	2	-468.14	100
69	330314.90	275268	458780.00	12	3	182.66	100	857749.73	-398969.73	10	2	-97.90	100
70	989140.02	560784	934640.00	16	4	229.85	100	1023672.61	-89032.61	10	2	-474.18	100
71	344980.19	279426	465710.00	12	3	179.94	100	859418.02	-393708.02	10	2	-99.20	100
72	1339315.28	710535	1184225.00	16	4	222.14	100	1235922.25	-51697.25	10	2	-1000.01	100
73	64428.02	64848	107380.04	10	2	363.73	100	802426.03	-695045.99	10	2	-56.19	100
74	124647.09	126945	207745.15	10	2	188.01	100	804349.61	-596604.46	10	2	-65.47	100
75	67652.66	124194	112754.44	10	2	346.40	100	802730.67	-689976.23	10	2	-56.61	100
76	124931.27	147714	208218.79	10	2	187.58	100	804638.50	-596419.72	10	2	-65.49	100
77	65292.60	123984	108821.00	10	2	358.92	100	803011.14	-694190.13	10	2	-56.26	100
78	104437.62	148113	174062.71	10	2	224.39	100	804368.03	-630305.32	10	2	-61.97	100
79	61934.68	85680	103224.46	10	2	378.38	100	803581.74	-700357.28	10	2	-55.77	100
80	169287.43	227661	282145.71	10	2	172.03	100	978076.02	-695930.31	10	2	-69.74	100

Tabel 10.4.4.b Penulangan geser

No	Vx kolom	Zkr	Zkn	Ckr=Tkr	Ckn=Tkn	Vj, h	Vo, h	Vs, h	A,j h	pakai tul.			Vj, v	Vo, v	Vs, v	Aj, v	As ter
kol.	(N)	(mm)	(mm)	(N)	(N)	(N)	(N)	(N)	perlu	D.	kaki	n	(N)	(N)	(N)	perlu	pasang
1	209277.51		585.85		1104415.48	895137.97	799553.83	95584.14	298.70	10	2	2	895137.97	805350.06	89787.91	280.59	4824
2	211270.62		585.85		1104415.48	893144.86	1151000.73	-257855.88	-805.80	10	2	2	893144.86	905673.27	-12528.41	-39.15	4824
3	209277.51	585.85		1104415.48		895137.97	807884.31	87253.67	272.67	10	2	2	895137.97	809094.30	86043.68	268.89	4824
4	430294.66	585.85	600.68	1104415.48	957149.38	1631270.20	1196480.58	434789.61	1358.72	10	4	5	1631270.20	1695434.76	-64164.56	-200.51	6432
5	209277.51		585.85		1104415.48	895137.97	815501.90	79636.08	248.86	10	2	2	895137.97	812552.09	82585.89	258.08	4824
6	401670.32	586.87	607.01	1280115.45	582611.89	1461057.02	1203706.14	257350.87	804.22	10	4	5	1461057.02	1524532.60	-63475.58	-198.36	6432
7	209277.51	585.85		1104415.48		895137.97	846599.76	48538.21	151.68	10	2	2	895137.97	827004.73	68133.25	212.92	4824
8	327227.13	585.85	608.71	1104415.48	604227.88	1381416.22	1289183.97	92232.25	288.23	10	2	2	1336854.41	1476662.07	-139807.66	-436.90	6432
9	203464.24		585.85		1104415.48	900951.24	735758.02	165193.22	516.23	10	2	6	900951.24	783015.14	117493.11	368.55	4824
10	205402.00		585.85		1104415.48	899013.48	1061687.69	-162674.21	-508.36	12	2	2	899013.48	869511.09	29502.40	92.19	4824
11	203464.24	585.85		1104415.48		900951.24	744286.41	156664.83	489.58	10	2	6	900951.24	786567.47	114383.77	357.45	4824
12	418342.03	585.85	600.68	1104415.48	957149.38	1643222.83	1103923.65	539299.17	1685.31	12	4	6	1643222.83	1624924.84	18297.98	57.18	6432
13	203464.24		585.85		1104415.48	900951.24	752456.88	148494.36	464.04	10	2	6	900951.24	790009.10	110942.14	346.69	4824
14	390512.81	586.87	607.01	1280115.45	582611.89	1472214.52	1112344.93	359869.60	1124.59	12	4	6	1472214.52	1462333.89	9880.64	30.88	6432
15	203464.24	585.85		1104415.48		900951.24	785208.83	115742.41	361.70	10	2	6	900951.24	804182.35	96768.89	302.40	4824
16	318137.49	585.85	608.71	1104415.48	604227.88	1390505.87	1188945.75	201560.11	629.88	12	2	6	1345650.84	1409701.35	-64050.51	-200.16	6432
17	203464.24		585.85		1104415.48	900951.24	674950.70	226000.54	706.25	10	2	6	900951.24	758873.68	142077.56	443.99	4824
18	205402.00		585.85		1104415.48	899013.48	953381.79	-54368.31	-169.90	12	2	2	899013.48	823003.42	76010.07	237.53	4824
19	203464.24	585.85		1104415.48		900951.24	683374.66	217576.57	679.93	10	2	6	900951.24	762093.94	138857.30	433.93	4824
20	418342.03	585.85	600.68	1104415.48	957149.38	1643222.83	966351.69	676871.14	2115.22	12	4	6	1643222.83	1513989.30	129233.53	403.85	6432
21	203464.24		585.85		1104415.48	900951.24	695217.76	205733.48	642.92	10	2	6	900951.24	766688.79	134262.45	419.57	4824
22	390512.81	586.87	607.01	1280115.45	582611.89	1472214.52	1010424.41	461790.11	1443.09	12	4	6	1472214.52	1386833.06	85381.47	266.82	6432
23	203464.24	585.85		1104415.48		900951.24	706098.59	194852.64	608.91	10	2	6	900951.24	770979.89	129971.35	406.16	4824
24	318137.49	585.85	608.71	1104415.48	604227.88	1390505.87	1084701.75	305804.12	955.64	12	2	6	1345650.84	1336539.89	9110.95	28.47	6432
25	203464.24		585.85		1104415.48	900951.24	592382.16	308569.08	964.28	10	2	6	900951.24	729424.33	171526.91	536.02	4824
26	205402.00		585.85		1104415.48	899013.48	847549.06	51464.42	160.83	12	2	2	899013.48	782387.20	116626.28	364.46	4824
27	203464.24	585.85		1104415.48		900951.24	600829.63	300121.61	937.88	10	2	6	900951.24	732261.04	168690.20	527.16	4824
28	418342.03	585.85	600.68	1104415.48	957149.38	1643222.83	857399.69	785823.13	2455.70	12	4	6	1643222.83	1436594.20	206628.63	645.71	6432
29	203464.24		585.85		1104415.48	900951.24	613290.17	287661.07	898.94	10	2	6	900951.24	736518.68	164432.56	513.85	4824
30	390512.81	586.87	607.01	1280115.45	582611.89	1472214.52	902016.49	570198.04	1781.87	12	4	6	1472214.52	1314483.42	157731.10	492.91	6432
31	203464.24	585.85		1104415.48		900951.24	624712.40	276238.84	863.25	10	2	6	900951.24	740498.31	160452.93	501.42	4824
32	318137.49	585.85	608.71	1104415.48	604227.88	1390505.87	970115.48	420390.38	1313.72	12	2	6	1345650.84	1263860.05	81790.79	255.60	6432

Tabel 10.4.5.a Sambungan balok-kolom

33	203464.24		585.85		1104415.48	900951.24	493506.92	407444.32	1273.26	10	4	6	900951.24	699207.88	201743.35	630.45	4824
34	205402.00		585.85		1104415.48	899013.48	727693.27	171320.22	535.38	16	2	3	899013.48	742153.61	156859.87	490.19	4824
35	203464.24	585.85		1104415.48		900951.24	502260.74	398690.50	1245.91	10	4	6	900951.24	701661.05	199290.19	622.78	4824
36	418342.03	585.85	600.68	1104415.48	957149.38	1643222.83	734763.15	908459.67	2838.94	16	4	4	1643222.83	1360540.55	282682.28	883.38	6432
37	203464.24		585.85		1104415.48	900951.24	515534.17	385417.07	1204.43	10	4	6	900951.24	705463.06	195488.18	610.90	4824
38	390512.81	586.87	607.01	1280115.45	582611.89	1472214.52	779205.05	693009.48	2165.65	16	4	4	1472214.52	1242430.58	229783.94	718.07	6432
39	203464.24	585.85		1104415.48		900951.24	527417.49	373533.75	1167.29	10	4	6	900951.24	708951.03	192000.21	600.00	4824
40	318137.49	585.85	608.71	1104415.48	604227.88	1390505.87	842418.57	548087.30	1712.77	16	4	3	1345650.84	1192414.58	153236.26	478.86	6432
41	203464.24		585.85		1104415.48	900951.24	366253.78	534697.46	1670.93	10	4	6	900951.24	668417.40	232533.84	726.67	4824
42	205402.00		585.85		1104415.48	899013.48	584875.68	314137.80	981.68	16	2	3	899013.48	702206.42	196807.06	615.02	4824
43	203464.24	585.85		1104415.48		900951.24	375757.78	525193.46	1641.23	10	4	6	900951.24	670402.07	230549.17	720.47	4824
44	418342.03	585.85	600.68	1104415.48	957149.38	1643222.83	589336.95	1053885.88	3293.39	16	4	4	1643222.83	1285537.98	357684.85	1117.77	6432
45	203464.24		585.85		1104415.48	900951.24	390956.22	509995.02	1593.73	10	4	6	900951.24	673681.53	227269.71	710.22	4824
46	390512.81	586.87	607.01	1280115.45	582611.89	1472214.52	634415.29	837799.24	2618.12	16	4	4	1472214.52	1171004.32	301210.20	941.28	6432
47	203464.24	585.85		1104415.48		900951.24	403913.25	497037.99	1553.24	10	4	6	900951.24	676580.02	224371.22	701.16	4824
48	318137.49	585.85	608.71	1104415.48	604227.88	1390505.87	694704.70	695801.17	2174.38	16	4	3	1345650.84	1122327.47	223323.37	697.89	6432
49	144013.05		593.20		772021.94	628008.89	164532.73	463476.16	1448.36	10	4	6	628008.89	444916.78	183092.12	572.16	4824
50	145384.60		593.20		772021.94	626637.34	395000.09	231637.26	723.87	16	2	3	626637.34	461821.52	164815.82	515.05	4824
51	144013.05	593.20		772021.94		628008.89	180643.83	628008.89	1962.53	10	4	6	628008.89	446007.72	182001.18	568.75	4824
52	247249.23	593.20	605.14	772021.94	454497.33	979270.03	422298.23	979270.03	3060.22	16	4	4	979270.03	726884.91	252385.12	788.70	6432
53	144013.05		593.20		772021.94	628008.89	204376.40	423632.49	1323.85	10	4	6	628008.89	447800.23	180208.66	563.15	4824
54	237566.58	596.00	608.50	661132.90	474324.17	897890.48	465700.73	432189.75	1350.59	16	4	4	897890.48	674682.02	223208.46	697.53	6432
55	144013.05	593.20		772021.94		628008.89	223794.62	404214.27	1263.17	10	4	6	628008.89	449431.26	178577.63	558.06	4824
56	238135.07	593.20	609.48	772021.94	496490.29	1030377.16	508317.30	522059.86	1631.44	16	4	3	997139.18	780365.89	216773.29	677.42	6432
57	144013.05		593.20		772021.94	628008.89	imaginair	628008.89	1962.53	10	4	7	628008.89	423027.97	204980.92	640.57	4824
58	145384.60		593.20		772021.94	626637.34	imaginair	626637.34	1958.24	16	2	4	626637.34	434304.95	192332.39	601.04	4824
59	144013.05	593.20		772021.94		628008.89	imaginair	628008.89	1962.53	10	4	7	628008.89	423729.55	204279.34	638.37	4824
60	247249.23	593.20	605.14	772021.94	454497.33	979270.03	imaginair	979270.03	3060.22	16	4	4	979270.03	681512.24	297757.79	930.49	6432
61	144013.05		593.20		772021.94	628008.89	imaginair	628008.89	1962.53	10	4	7	628008.89	425041.19	202967.70	634.27	4824
62	237566.58	596.00	608.50	661132.90	474324.17	897890.48	119804.70	778085.78	2431.52	16	4	4	897890.48	631578.17	266312.31	832.23	6432
63	144013.05	593.20		772021.94		628008.89	imaginair	628008.89	1962.53	10	4	7	628008.89	426176.99	201831.90	630.72	4824
64	238135.07	593.20	609.48	772021.94	496490.29	1030377.16	188385.76	841991.39	2631.22	16	4	4	997139.18	729381.61	267757.57	836.74	6432

Tabel 10.4.5.a Sambungan balok-kolom

65	144013.05		593.20		772021.94	628008.89	imaginair	628008.89	1962.53	10	4	7	628008.89	400862.85	227146.04	709.83	4824
66	145384.60		593.20		772021.94	626637.34	imaginair	626637.34	1958.24	16	2	4	626637.34	406917.84	219719.50	686.62	4824
67	144013.05	593.20		772021.94		628008.89	imaginair	628008.89	1962.53	10	4	7	628008.89	401291.69	226717.20	708.49	4824
68	247249.23	593.20	605.14	772021.94	454497.33	979270.03	imaginair	979270.03	3060.22	16	4	4	979270.03	638052.85	341217.19	1066.30	6432
69	144013.05		593.20		772021.94	628008.89	imaginair	628008.89	1962.53	10	4	7	628008.89	402013.00	225995.89	706.24	4824
70	237566.58	596.00	608.50	661132.90	474324.17	897890.48	imaginair	897890.48	2805.91	16	4	4	897890.48	588655.33	309235.15	966.36	6432
71	144013.05	593.20		772021.94		628008.89	imaginair	628008.89	1962.53	10	4	7	628008.89	402632.04	225376.85	704.30	4824
72	238135.07	593.20	609.48	772021.94	496490.29	1030377.16	imaginair	1030377.16	3219.93	16	4	4	997139.18	678805.51	318333.67	994.79	6432
73	47119.85		406.71		184210.14	137090.29	imaginair	137090.29	428.41	10	2	4	137090.29	83275.60	53814.69	168.17	1608
74	47119.85		406.71		184210.14	137090.29	imaginair	137090.29	428.41	10	2	4	137090.29	83203.21	53887.08	168.40	1608
75	47119.85	406.71		184210.14		137090.29	imaginair	137090.29	428.41	10	2	4	137090.29	83300.27	53790.02	168.09	1608
76	85131.80	406.71	407.44	184210.14	128748.10	227826.45	imaginair	227826.45	711.96	10	2	5	227826.45	138342.30	89484.15	279.64	3216
77	47119.85		406.71		184210.14	137090.29	imaginair	137090.29	428.41	10	2	4	137090.29	83322.99	53767.30	168.02	1608
78	87281.77	406.71	407.44	184210.14	128748.10	225676.48	imaginair	225676.48	705.24	10	2	5	225676.48	137065.10	88611.38	276.91	3216
79	47119.85	406.71		184210.14		137090.29	imaginair	137090.29	428.41	10	2	4	137090.29	83369.21	53721.08	167.88	1608
80	100319.21	406.71	505.52	184210.14	172850.76	256741.69	imaginair	256741.69	802.32	10	2	6	231895.72	156198.38	75697.34	236.55	3216

Tabel 10.4.5.a *Sambungan balok-kolom*

No kol.	Vy kolom (N)	Zkr (mm)	Zkn (mm)	Ckr=Tkr (N)	Ckn=Tkn (N)	Vj, h (N)	Vc, h (N)	Vs, h (N)	A,j h perlu	pakai tul.			Vj, v (N)	Vc, v (N)	Vs, v (N)	Aj, v perlu	As ter pasang
										D.	kaki	n					
1	216212.63		585.85		1104415.48	888202.85	799553.83	88649.02	277.03	10	2	2	888202.85	805350.06	82852.79	258.91	4824
2	361381.57	606.08	685.17	1067551.52	1135245.26	1841415.21	1151000.73	690414.48	2157.55	10	4	7	1841415.21	905673.27	935741.94	2924.19	4824
3	216212.63		585.85		1104415.48	888202.85	807884.31	80318.55	251.00	10	2	2	888202.85	809094.30	79108.56	247.21	4824
4	361381.57	606.08	685.17	1067551.52	1135245.26	1841415.21	1196480.58	644934.63	2015.42	10	4	7	1841415.21	1695434.76	145980.45	456.19	6432
5	216212.63		585.85		1104415.48	888202.85	815501.90	72700.95	227.19	10	2	2	888202.85	812552.09	75650.77	236.41	4824
6	361381.57	606.08	685.17	1067551.52	1135245.26	1841415.21	1203706.14	637709.07	1992.84	10	4	7	1841415.21	1524532.60	316882.61	990.26	6432
7	216212.63		585.85		1104415.48	888202.85	846599.76	41603.09	130.01	10	2	2	888202.85	827004.73	61198.12	191.24	4824
8	463826.34	606.08	780.19	1067551.52	1415996.25	2019721.43	1289183.97	730537.46	2282.93	10	4	8	2423665.71	1476662.07	947003.65	2959.39	8040
9	210206.72		585.85		1104415.48	894208.76	735758.02	158450.74	495.16	10	2	6	894208.76	783015.14	111193.62	365.80	4824
10	351343.19	606.08	685.17	1067551.52	1135245.26	1851453.59	1061687.69	789765.89	2468.02	12	4	7	1851453.59	869511.09	981942.50	3068.57	4824
11	210206.72		585.85		1104415.48	894208.76	744286.41	149922.35	468.51	10	2	6	894208.76	786567.47	107641.29	336.38	4824
12	351343.19	606.08	685.17	1067551.52	1135245.26	1851453.59	1103923.65	747529.93	2336.03	12	4	7	1851453.59	1624924.84	226528.74	707.90	6432
13	210206.72		585.85		1104415.48	894208.76	752456.88	141751.88	442.97	10	2	6	894208.76	790009.10	104199.66	325.62	4824
14	351343.19	606.08	685.17	1067551.52	1135245.26	1851453.59	1112344.93	739108.66	2309.71	12	4	7	1851453.59	1462333.89	389119.70	1216.00	6432
15	210206.72		585.85		1104415.48	894208.76	785208.83	108999.93	340.62	10	2	6	894208.76	804182.35	90026.41	281.33	4824
16	450942.27	606.08	780.19	1067551.52	1415996.25	2032605.49	1188945.75	843659.74	2636.44	12	4	8	2439126.59	1409701.35	1029425.24	3216.95	8040
17	210206.72		585.85		1104415.48	894208.76	674950.70	219258.06	685.18	10	2	6	894208.76	758873.68	135335.08	422.92	4824
18	351343.19	606.08	685.17	1067551.52	1135245.26	1851453.59	953381.79	898071.80	2806.47	12	4	7	1851453.59	823003.42	1028450.17	3213.91	4824
19	210206.72		585.85		1104415.48	894208.76	683374.66	210834.09	658.86	10	2	6	894208.76	762093.94	132114.82	412.86	4824
20	351343.19	606.08	685.17	1067551.52	1135245.26	1851453.59	966351.69	885101.90	2765.94	12	4	7	1851453.59	1513989.30	337464.29	1054.58	6432
21	210206.72		585.85		1104415.48	894208.76	695217.76	198991.00	621.85	10	2	6	894208.76	766688.79	127519.97	398.50	4824
22	351343.19	606.08	685.17	1067551.52	1135245.26	1851453.59	1010424.41	841029.18	2628.22	12	4	7	1851453.59	1386833.06	464620.53	1451.94	6432
23	210206.72		585.85		1104415.48	894208.76	706098.59	188110.16	587.84	10	2	6	894208.76	770979.89	123228.87	385.09	4824
24	450942.27	606.08	780.19	1067551.52	1415996.25	2032605.49	1084701.75	947903.75	2962.20	12	4	8	2439126.59	1336539.89	1102586.71	3445.58	8040
25	210206.72		585.85		1104415.48	894208.76	592382.16	301826.60	943.21	10	2	6	894208.76	729424.33	164784.43	514.95	4824
26	351343.19	606.08	685.17	1067551.52	1135245.26	1851453.59	847549.06	1003904.53	3137.20	12	4	7	1851453.59	782387.20	1069066.38	3340.83	4824
27	210206.72		585.85		1104415.48	894208.76	600829.63	293379.13	916.81	10	2	6	894208.76	732261.04	161947.72	506.09	4824
28	351343.19	606.08	685.17	1067551.52	1135245.26	1851453.59	857399.69	994053.89	3106.42	12	4	7	1851453.59	1436594.20	414859.39	1296.44	6432
29	210206.72		585.85		1104415.48	894208.76	613290.17	280918.59	877.87	10	2	6	894208.76	736518.68	157690.08	492.78	4824
30	351343.19	606.08	685.17	1067551.52	1135245.26	1851453.59	902016.49	949437.10	2966.99	12	4	7	1851453.59	1314483.42	536970.17	1678.03	6432
31	210206.72		585.85		1104415.48	894208.76	624712.40	269496.36	842.18	10	2	6	894208.76	740498.31	153710.45	480.35	4824
32	450942.27	606.08	780.19	1067551.52	1415996.25	2032605.49	970115.48	1062490.01	3320.28	12	4	8	2439126.59	1263860.05	1175266.54	3672.71	8040

Tabel 10.4.5.b Sambungan balok-kolom

33	210206.72		585.85		1104415.48	894208.76	493506.92	400701.84	1252.19	10	4	6	894208.76	699207.88	195000.87	609.38	4824
34	351343.19	606.08	685.17	1067551.52	1135245.26	1851453.59	727693.27	1123760.32	3511.75	16	4	5	1851453.59	742153.61	1109299.98	3466.56	4824
35	210206.72		585.85		1104415.48	894208.76	502260.74	391948.02	1224.84	10	4	6	894208.76	701661.05	192547.71	601.71	4824
36	351343.19	606.08	685.17	1067551.52	1135245.26	1851453.59	734763.15	1116690.44	3489.66	16	4	5	1851453.59	1360540.55	490913.04	1534.10	6432
37	210206.72		585.85		1104415.48	894208.76	515534.17	378674.59	1183.36	10	4	6	894208.76	705463.06	188745.70	589.83	4824
38	351343.19	606.08	685.17	1067551.52	1135245.26	1851453.59	779205.05	1072248.54	3350.78	16	4	5	1851453.59	1242430.58	609023.00	1903.20	6432
39	210206.72		585.85		1104415.48	894208.76	527417.49	366791.27	1146.22	10	4	6	894208.76	708951.03	185257.73	578.93	4824
40	450942.27	606.08	780.19	1067551.52	1415996.25	2032605.49	842418.57	1190186.93	3719.33	16	4	5	2439126.59	1192414.58	1246712.02	3895.98	8040
41	210206.72		585.85		1104415.48	894208.76	366253.78	527954.98	1649.86	10	4	6	894208.76	668417.40	225791.36	705.60	4824
42	351343.19	606.08	685.17	1067551.52	1135245.26	1851453.59	584875.68	1266577.90	3958.06	16	4	5	1851453.59	702206.42	1149247.17	3591.40	4824
43	210206.72		585.85		1104415.48	894208.76	375757.78	518450.98	1620.16	10	4	6	894208.76	670402.07	223806.69	699.40	4824
44	351343.19	606.08	685.17	1067551.52	1135245.26	1851453.59	589336.95	1262116.64	3944.11	16	4	5	1851453.59	1285537.98	565915.61	1768.49	6432
45	210206.72		585.85		1104415.48	894208.76	390956.22	503252.54	1572.66	10	4	6	894208.76	673681.53	220527.23	689.15	4824
46	351343.19	606.08	685.17	1067551.52	1135245.26	1851453.59	634415.29	1217038.30	3803.24	16	4	5	1851453.59	1171004.32	680449.27	2126.40	6432
47	210206.72		585.85		1104415.48	894208.76	403913.25	490295.51	1532.17	10	4	6	894208.76	676580.02	217628.74	680.09	4824
48	450942.27	606.08	780.19	1067551.52	1415996.25	2032605.49	694704.70	1337900.80	4180.94	16	4	5	2439126.59	1122327.47	1316799.12	4115.00	8040
49	148785.41		593.20		772021.94	623236.53	164532.73	458703.80	1433.45	10	4	7	623236.53	444916.78	178319.76	557.25	4824
50	321911.98	607.56	685.85	753768.52	1098600.13	1530456.66	395000.09	1135456.57	3548.30	16	4	6	1530456.66	461821.52	1068635.14	3339.48	4824
51	148785.41		593.20		772021.94	623236.53	180643.83	442592.70	1383.10	10	4	7	623236.53	446007.72	177228.81	553.84	4824
52	321911.98	607.56	685.85	753768.52	1098600.13	1530456.66	422298.23	1108158.42	3463.00	16	4	6	1530456.66	726884.91	803571.75	2511.16	6432
53	148785.41		593.20		772021.94	623236.53	204376.40	418860.13	1308.94	10	4	7	623236.53	447800.23	175436.30	548.24	4824
54	321911.98	607.56	685.85	753768.52	1098600.13	1530456.66	465700.73	1064755.93	3327.36	16	4	6	1530456.66	674682.02	855774.64	2674.30	6432
55	148785.41		593.20		772021.94	623236.53	223794.62	399441.91	1248.26	10	4	7	623236.53	449431.26	173805.27	543.14	4824
56	396241.72	607.56	784.23	753768.52	1271879.21	1629406.00	508317.30	1121088.71	3503.40	16	4	6	1955287.20	780365.89	1174921.31	3671.63	8040
57	148785.41		593.20		772021.94	623236.53	imaginair	623236.53	1947.61	10	4	7	623236.53	423027.97	200208.56	625.65	4824
58	321911.98	607.56	685.85	753768.52	1098600.13	1530456.66	imaginair	1530456.66	4782.68	16	4	6	1530456.66	434304.95	1096151.70	3425.47	4824
59	148785.41		593.20		772021.94	623236.53	imaginair	623236.53	1947.61	10	4	7	623236.53	423729.55	199506.98	623.46	4824
60	321911.98	607.56	685.85	753768.52	1098600.13	1530456.66	imaginair	1530456.66	4782.68	16	4	6	1530456.66	681512.24	848944.42	2652.95	6432
61	148785.41		593.20		772021.94	623236.53	imaginair	623236.53	1947.61	10	4	7	623236.53	425041.19	198195.34	619.36	4824
62	321911.98	607.56	685.85	753768.52	1098600.13	1530456.66	119804.70	1410651.95	4408.29	16	4	6	1530456.66	631578.17	898878.49	2809.00	6432
63	148785.41		593.20		772021.94	623236.53	imaginair	623236.53	1947.61	10	4	7	623236.53	426176.99	197059.54	615.81	4824
64	396241.72	607.56	784.23	753768.52	1271879.21	1629406.00	188385.76	1441020.24	4503.19	16	4	6	1955287.20	729381.61	1225905.59	3830.95	8040

Tabel 10.4.5.b *Sambungan balok-kolom*

65	148785.41		593.20		772021.94	623236.53	imaginair	623236.53	1947.61	10	4	7	623236.53	400862.85	222373.68	694.92	4824
66	321911.98	607.56	685.85	753768.52	1098600.13	1530456.66	imaginair	1530456.66	4782.68	16	4	6	1530456.66	406917.84	1123538.82	3511.06	4824
67	148785.41		593.20		772021.94	623236.53	imaginair	623236.53	1947.61	10	4	7	623236.53	401291.69	221944.84	693.58	4824
68	321911.98	607.56	685.85	753768.52	1098600.13	1530456.66	imaginair	1530456.66	4782.68	16	4	6	1530456.66	638052.85	892403.81	2788.76	6432
69	148785.41		593.20		772021.94	623236.53	imaginair	623236.53	1947.61	10	4	7	623236.53	402013.00	221223.53	691.32	4824
70	321911.98	607.56	685.85	753768.52	1098600.13	1530456.66	imaginair	1530456.66	4782.68	16	4	6	1530456.66	588655.33	941801.33	2943.13	6432
71	148785.41		593.20		772021.94	623236.53	imaginair	623236.53	1947.61	10	4	7	623236.53	402632.04	220604.49	689.39	4824
72	396241.72	607.56	784.23	753768.52	1271879.21	1629406.00	imaginair	1629406.00	5091.89	16	4	6	1955287.20	678805.51	1276481.69	3989.01	8040
73	48398.30		406.71		184210.14	135811.84	imaginair	135811.84	424.41	10	2	3	135811.84	83275.60	52536.25	164.18	1608
74	110877.96	407.44	503.87	183883.49	252392.18	325397.71	imaginair	325397.71	1016.87	10	2	7	325397.71	83203.21	242194.50	756.86	1608
75	48398.30		406.71		184210.14	135811.84	imaginair	135811.84	424.41	10	2	3	135811.84	83300.27	52511.57	164.10	1608
76	110877.96	407.44	503.87	183883.49	252392.18	325397.71	imaginair	325397.71	1016.87	10	2	7	325397.71	138342.30	187055.41	584.55	3216
77	48398.30		406.71		184210.14	135811.84	imaginair	135811.84	424.41	10	2	3	135811.84	83322.99	52488.85	164.03	1608
78	79244.51	407.44	503.87	183883.49	148691.75	253330.73	imaginair	253330.73	791.66	10	2	7	253330.73	137065.10	116265.62	363.33	3216
79	48398.30		406.71		184210.14	135811.84	imaginair	135811.84	424.41	10	2	3	135811.84	83369.21	52442.63	163.88	1608
80	135095.60	407.44	500.51	183883.49	334007.83	382795.72	imaginair	382795.72	1196.24	10	4	4	464823.37	156198.38	308624.99	964.45	1608

Tabel 10.4.5.b Sambungan balok-kolom

BAB XI

PERENCANAAN BASEMENT

11.1. PLAT BASEMENT

- Fungsi sebagai tempat parkir kendaraan,
- Jumlah basement satu lantai di lantai dasar.

11.1.1. Desain

- Berdasar data tanah, ketinggian muka air (*water table*) terhadap muka tanah (0.00) :
  - Muka air tertinggi = - 1.20 m
  - Muka air terendah = - 2 m
- Basement direncanakan mempunyai ketinggian - 1,5 m terhadap muka tanah, atau tertanam sebagian ke dalam tanah. Jadi berfungsi sebagai semi basement.
- Plat besement menumpu pada balok sloof, direncanakan jepit elastis,
- Pada perhitungan lentur plat, dianggap plat terletak melayang (tidak menumpu) diatas tanah asli,
- Penulangan plat dengan menggunakan tabel 13.3 momen plat PBI 71.

11.1.2. Beban

Beban yang bekerja pada plat :

1. Gaya tekan keatas air (*uplift water*),
2. Beban kendaraan,
3. Berat sendiri plat basement.

Beban mati

Berat sendiri (t=20 cm) q bs = 0,2. 2400 = 480 kg/m^2

Beban hidup

Berat kendaraan qL = 800 kg/m^2

qu = 1,2. 480 + 1,6. 800 = 1856 kg/m^2

Tekanan keatas *(uplift)* :

- P1 = γw. (h - h1) = 1000. (1,5 - 1,2) = 300 kg/m^2 (mat tertinggi)
- P2 = 0 (mat terendah)

Kombinasi beban :

1. Beban bekerja penuh, saat mat tertinggi

   qu1 = qu - P1 = 1856 - 300 = 1556 kg/m^2
2. Beban bekerja penuh, saat mat terendah

   qu2 = qu = 1856 kg/m^2 (menentukan)
3. Tidak ada beban, saat mat tertinggi

   qu3 = q bs - P1 = 1,2. 480 - 300 = 276 kg/m^2

Perhitungan plat basement tipe 1 :

Dimensi balok sloof induk direncanakan 40x80 cm

d' = 70 mm

ly = 425 - 40 = 385 cm

lx = 400 - 40 = 360 cm

$\frac{ly}{lx} = \frac{385}{360} = 1,1 \; < 2$ (tul. dua arah)

Mlx = -Mtx = 0,001. q. lx^2. X = 0,001. 18560. 3,6^2. 42 = 10103 Nm

Mly = -Mty = 0,001. q. lx^2. X = 0,001. 18560. 3,6^2. 37 = 8900 Nm

Syarat tulangan : 0,00438 $\leq \rho$ ada $\leq$ 0,0166 (Bab II Perencanaan Plat)

Arah sumbu pendek (lx)

Coba pakai tul. D 10 mm :

$$Rn = \frac{10103.1000}{0,8.1000.(200-70-0,5.10)^2} = 0,8 \text{ MPa}$$

$m = 12,55$

$$\rho \text{ perlu} = \frac{1}{12,55}\left(1 - \sqrt{1 - \frac{2.\ 12,55.\ 0,8}{320}}\right) = 0,0036 \quad , \rho \min = 0,00438$$

As perlu = 0,00438. 1000. (200 - 70 - 0,5. 10) = 547,5 mm^2

(Pakai tul. D10 - 130 mm, As = 550 mm^2 , tul. lapis satu)

Arah sumbu panjang (ly)

$$Rn = \frac{8900.1000}{0,8.1000.(200-70-10-0,5.10)^2} = 0,8 \text{ MPa}$$

$$\rho \text{ perlu} = \frac{1}{12,55}\left(1 - \sqrt{1 - \frac{2.\ 12,55.\ 0,8}{320}}\right) = 0,003 \quad , \text{pakai } 0,00438$$

As perlu = 0,00438. 1000. (200 - 70 - 10 - 0,5. 10) = 503,7 mm^2

(Pakai tul. D10 - 130 mm, As = 550 mm^2 , tul. lapis dua)

11.2. DINDING PENAHAN TANAH

Dinding penahan tanah dipasang di seluruh tepi basement, kecuali di tempat masuk (*entrance*) kendaraan. Tebal dinding direncanakan t = 17 cm.

Tekanan tanah aktif (statis) :

$Ka = \tan^2. (45 - \frac{\Phi}{2}) = \tan^2. (45 - \frac{6}{2}) = 0,814$

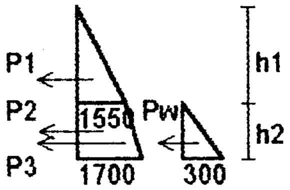
$\sigma 1 = Ka.\ \gamma sat.\ h1 = 0,814.\ 1,59.\ 1,2 = 1,55 \text{ ton/m}^2 = 1550 \text{ kg/m}^2$

$\sigma 2 = Ka.\ (\gamma sat.\ h1 + \gamma'.\ h2)$

$= 0,814.\ (1,59.\ 1,2 + (1,59 - 1).\ 0,3) = 1,7 \text{ ton/m}^2 = 1700 \text{ kg/m}^2$

$\sigma w = \gamma w.\ h2 = 1000.\ 0,3 = 300 \text{ kg/m}^2$

σ tot bawah = $\sigma 2 + \sigma w = 1700 + 300 = 2000 \text{ kg/m}^2$



Tekanan tanah ke samping akibat gempa :

Berdasar referensi Mekanika Tanah jilid 2, Braja Das, didapat gaya aktif pada dinding penahan akibat gempa dengan persamaan Seed Whitman.

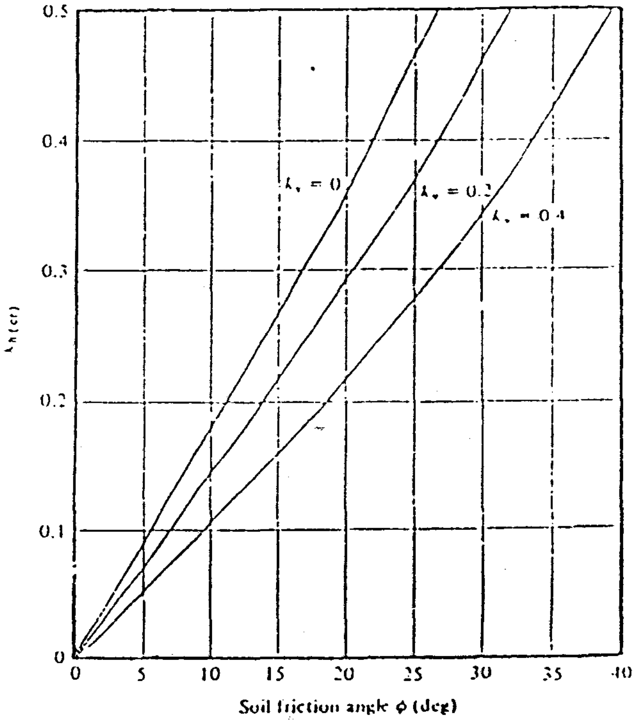
kh dan kv dicari dari grafik,

direncanakan kv = 0,1

$\Phi = 6^{\circ}$, kh = 0,09

δ = sudut geser antara dinding dan tanah

= 18° (table 11.6 Foundation Analysis and Design, Bowles)



GAMBAR 3.1.1 NILAI KRITIS DARI GETARAN HORIZONTAL

$$\bar{\beta} = \tan^{-1}\left(\frac{kh}{1 - kv}\right) = \tan^{-1}\left(\frac{0,09}{1 - 0,1}\right) = 5,71^{0}$$

$$\alpha' = \alpha + \bar{\beta} = 5,71^{0}$$

$$\theta' = \theta + \bar{\beta} = 5,71^{0}$$

$$\mathrm{Ka}\,(\alpha',\theta') = \frac{\cos^2(\Phi - \theta')}{\cos^2\theta'.\ \cos(\delta+\theta').\left[1+\left(\dfrac{\sin(\Phi+\delta).\ \sin\left(\Phi-\alpha'\right)}{\sin\left(\delta+\theta'\right).\ \cos\left(\theta'-\alpha'\right)}\right)^{\frac{1}{2}}\right]^2}$$

$$= \frac{\cos^2(6-5{,}71)}{\cos^2(5{,}71).\ \cos(18+5{,}71).\left[1+\left(\dfrac{\sin\ (6+18).\ \sin\ (6-5{,}71)}{\sin\ (18+5{,}71).\ \cos\ (0)}\right)^{\frac{1}{2}}\right]^2} = 0{,}961$$

$$\frac{\cos^2\theta'}{\cos\bar{\beta}.\ \cos^2\theta} = \frac{\cos^2(5{,}71)}{\cos(5{,}71).\ \cos^2(0)} = 0{,}995 \approx 1$$

<u>Untuk air :</u>

$$\bar{\beta} = 0$$

$$\mathrm{Ka}\,(\alpha',\theta') = \frac{\cos^2(0)}{\cos^2(0).\ \cos(0).\left[1+\left(\dfrac{\sin(0).\ \sin(0)}{\sin(0).\ \cos(0)}\right)^{\frac{1}{2}}\right]^2} = 1$$

$$\frac{\cos^2(0)}{\cos(0).\ \cos^2(0)} = 1$$

$$\sigma\,\mathrm{ae1} = \gamma\mathrm{sat.\ h1}.\ (1-\mathrm{kv}).\ [\mathrm{Ka}(\alpha',\theta')].\ \left(\frac{\cos^2\theta'}{\cos\bar{\beta}\ .\ \cos^2\theta}\right)$$

$$= 1{,}59.\ 1{,}2.\ \ (1 - 0{,}1).\ 0{,}961 = 1650\ \mathrm{kg/m^2}$$

$$\sigma\,\mathrm{ae2} = (\gamma\mathrm{sat.\ h1} + \gamma'.\ \mathrm{h2}).\ (1 - \mathrm{Kv}).\ [\mathrm{Ka}(\alpha',\theta')].\ \left(\frac{\cos^2\theta'}{\cos\bar{\beta}.\ \cos^2\theta}\right)$$

$$= (1{,}59.\ 1{,}2 + 0{,}59.\ 0{,}3).\ (1 - 0{,}1).\ 0{,}961 = 1803\ \mathrm{kg/m^2}$$

$$\sigma\,\mathrm{aeW} = 300\ \mathrm{kg/m^2}$$

Dari perhitungan tekanan tanah diatas, yang menentukan adalah akibat gempa.

Beban luasan (tegangan) tekanan tanah adalah berupa segitiga. Dalam perhitungan dinding atau plat samping, beban dianggap sebagai beban segitiga merata.

Berdasar tabel Bares, dapat dicari momen plat akibat beban segitiga.

Tulangan vertikal :

Dinding terpanjang, b = 6 m

$\gamma = \frac{a}{b} = \frac{1,5}{6} = 0,25$, koefisien tabel 1.90 = 0,1504

q tot = 1803 + 300 = 2103 kg/m^2 = 2103 kg/m/m'

Mu = 0,1504. q. a^2 = 0,1504. 2103. 1,5^2 = 712 kgm/m'

$$Rn = \frac{712.10000}{0,8.1000.(170-70-0,5.10)^2} = 0,9 \text{ MPa}$$

$$\rho \text{ perlu} = \frac{1}{12,55}\left(1 - \sqrt{1 - \frac{2.\ 12,55.\ 0,9}{320}}\right) = 0,003$$, pakai ρ min= 0,00438

As perlu = 0,00438. 1000. (170-70-0,5. 10) = 416,1 mm^2

(pakai tul. vertikal D10 - 150 mm, As = 471 mm^2)

Tul. horisontal :

Mu = 0,0015. q. b^2 = 0,0015. 2103. 6^2 = 114 kgm/m'

Rn = 0,76 MPa

ρ perlu = 0,0021 , pakai ρ min = 0,00438

As perlu = 372,3 mm^2 (pakai tul. horisontal D10 - 200 mm, As = 393 mm^2)

Pengaku/rib :

Pada dinding penahan dipasang rib setiap jarak 3 m.

Akibat tek. tanah statis :

P1 = 0,5. σ1. h1 = 0,5. 1550. 1,2 = 930 kg/m'
P2 = σ1. h2 = 1550. 0,3 = 465 kg/m'
P3 = 0,5. (σ2 - σ1). h2 = 0,5. (1700 - 1550). 0,3 = 22,5 kg/m'
Pw = 0,5. γw. h2^2 = 0,5. 1000. 0,3^2 = 45 kg/m'

P tot = 930 + 465 + 22,5 + 45 = 1462,5 kg/m'

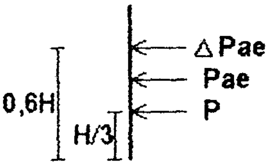
$$M\ tot = P1.\ (h2 + \frac{h1}{3}) + P2.\ \frac{h2}{2} + (P3 + Pw).\ \frac{h2}{3}$$

$$= 930.\ (0,3 + 0,4) + 465.\ 0,15 + 67,5.\ 0,1 = 727,5 \text{ kgm/m'}$$

Akibat gempa :

$$\bar{z} = \frac{Pa.\left(\frac{H}{3}\right) + \Delta Pae.\ (0,6.\ H)}{Pae}$$

dimana : $\bar{z}$ = jarak garis kerja gaya Pae dari dasar



$Pae = Pa + \Delta Pae$

dimana : Pa = gaya aktif akibat tek. tanah statis

ΔPae = penambahan gaya aktif akibat gempa

$Pae1 = 0{,}5.\ \sigma ae1.\ h1 = 0{,}5.\ 1650.\ 1{,}2 = 990\ kg/m'$

$Pae2 = \sigma ae1.\ h2 = 1650.\ 0{,}3 = 495\ kg/m'$

$Pae3 = 0{,}5.\ (\sigma ae2 - \sigma ae1).\ h2 = 0{,}5.\ (1803 - 1650).\ 0{,}3 = 23\ kg/m'$

$PaeW = 45\ kg/m'$

<u>Letak gaya :</u>

$$\bar{z}1 = \frac{930.\left(\frac{1{,}2}{3}\right) + (990-930).\ (0{,}6.1{,}2)}{990} = 0{,}4\ m$$

$$\bar{z}2 = \frac{465.\left(\frac{0{,}3}{2}\right) + (495-465).\ (0{,}5.0{,}3)}{495} = 0{,}15\ m$$

$$\bar{z}3 = \frac{22{,}5.\left(\frac{0{,}3}{3}\right) + (23-22{,}5).\ (0{,}6.0{,}3)}{23} = 0{,}1\ m$$

$\bar{z}W = 0{,}1\ m$

$M\ tot = 990.\ (0{,}4 + 0{,}3) + 495.\ 0{,}15 + (23 + 45).\ 0{,}1 = 774\ kgm/m'$ (menentukan)

Satu rib menahan tekanan samping sepanjang 3 m'

$M\ tot = 774.\ 3 = 2322\ kgm$

<u>Berdasar PBI 71 bab 10 :</u>

$$\bar{\sigma}\ tekan\ beton = \frac{kuat\ bahan}{\gamma p.\ \gamma m.\ \gamma s}$$

dimana : γp = koef. pembebanan tetap = 1,1

$$\gamma m = \frac{1{,}4}{\Phi} = \frac{1{,}4}{0{,}93} = 1{,}5$$

$\gamma s = 1{,}5$

$$\bar{\sigma} = \frac{300}{1{,}1.1{,}5.1{,}5} = 121\ kg/cm^2 \qquad , \bar{fc}' = 12{,}1\ MPa$$

Anggap titik putar di tumpuan :

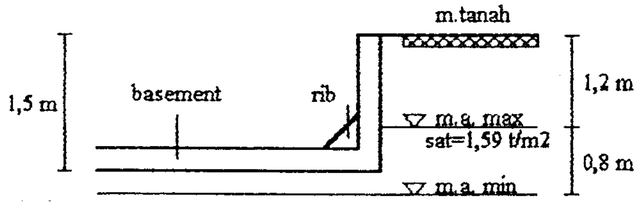
$$f\bar{c}' = \frac{M.\ h}{Ix}$$

$$\frac{1}{12}.\ b.\ h^2 = \frac{2322.\ 10000}{12,1}$$

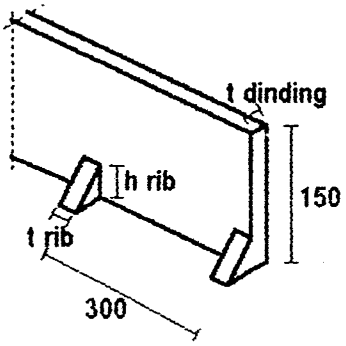
b = tebal rib, direncanakan = 15 cm

$$h = \sqrt{\frac{2322.10000.\ 12}{12,1.\ 150}} = 391 \text{ mm}$$ (pakai tinggi rib = 40 cm)

11.3. Perencanaan plat basement tipe lain pada tabel 11.3.



sket Dinding Basement



sket Dinding basement penahan tanah

tipe plat	qu (N/m2)	ly (cm)	lx	ly/lx	faktor X	Mlx=-Mtx (Nm)	ro		As (mm2)		pasang tul.	faktor X	Mly=-Mty (Nm)	ro		As (mm2)		pasang tul.
							perlu	pakai	perlu	pakai				perlu	pakai	perlu	pakai	
1	18560	385	360	1.07	42	10102.58	2.57E-03	4.38E-03	547.5	550	D10-130	37	8899.89	2.67E-03	4.38E-03	503.7	550	D10-130
2	18560	385	260	1.48	56	7026.07	1.78E-03	4.38E-03	547.5	550	D10-130	37	4642.23	1.38E-03	4.38E-03	503.7	550	D10-130
3	18560	260	210	1.24	46	3765.08	9.47E-04	4.38E-03	547.5	550	D10-130	38	3110.28	9.24E-04	4.38E-03	503.7	550	D10-130
4	18560	360	210	1.71	59	4829.13	1.22E-03	4.38E-03	547.5	550	D10-130	36	2946.59	8.75E-04	4.38E-03	503.7	550	D10-130

Tabel 11.3. Penulangan plat basement

BAB XII

PERENCANAAN PONDASI

12.1. PONDASI

Digunakan pondasi tiang pancang/pile.

Spesifikasi :

- Precast prestressed concrete
- Diameter luar tiang 500 mm (tipe A)
- Tebal beton 90 mm
- Daya dukung rencana 150 ton
- Kuat tekan karakteristik beton min. 500 kgf/cm
- Reinforcement : PC steel bars 9x9,2 mm (deformed)

  Spiral D12 - 50 mm (end)

  D12 - 100 mm (mid)

Perumusan beban yang diterima oleh satu tiang akibat kombinasi beban momen dan aksial, berdasarkan referensi Foundation Analysis and Design, Bowles :

$$Pp = \frac{Q}{n} \pm \frac{My.\,X}{\sum X^2} \pm \frac{Mx.\,Y}{\sum Y^2}$$

dimana : Mx dan My = momen terhadap sumbu x dan y

x, y = jarak terhadap masing-masing tiang (arah x dan y)

$\Sigma X^2, \Sigma Y^2$ = momen inersia tiang group

$I = Io + A.\ d^2$, Io dan A diabaikan

Koreksi data hasil test SPT :

Bila nilai N hasil test SPT > 15, maka harus dikoreksi. Besar koreksi dari perumusan Terzaghi - Peck :

$$N' = 15 + \frac{1}{2}.\,(N - 15)$$

dimana : N' = nilai SPT setelah dikoreksi

Daya dukung tiang :

Daya dukung rencana satu tiang berdasar perumusan Meyerhoff :

$$Pu = P \text{ point bearing} + P \text{ cleef}$$

$$= 40.\,N.\,Ab + \frac{\bar{N}.\,As}{5} \qquad \text{(ton)}$$

dimana : N = Nilai SPT di bawah ujung tiang.

Diambil rata-rata 8. D diatas sampai 4. D dibawah ujung tiang

$\bar{N}$ = Nilai SPT rata-rata sepanjang tiang yang tertanam

Ab = Luas ujung tiang $= \frac{1}{4}.\,\Pi.\,D^2$ (m^2)

As = Luas selimut tiang yang tertanam = $\Pi.\ D.\ L$ (m^2)

Semua nilai N yang dipakai dalam perhitungan adalah N yang telah dikoreksi.

Faktor efisiensi group :

$$\theta = \arctan \tfrac{D}{S}$$

$$\eta = 1 - \theta . \frac{(m - 1). n + (n - 1). m}{90^{o}. m. n}$$

dimana : D = diameter tiang

S = spasi antar tiang

η = faktor efisiensi tiang group

m = jumlah kolom tiang

n = jumlah baris tiang

12.1.1. Perencanaan pondasi di as A1

Pu = 515,08 ton

Muy = 59,35 tm

Mux = 58,81 tm

Berdasar data test tanah, kedalaman tiang direncanakan 40 m dari muka tanah isian (*fiil)*. Tinggi tanah *fill* 2 m.

$$N = \frac{45,5 + 42,5 + 27 + 26,5}{4} = 35,4$$

$$\bar{N} = 13,9$$

$$Ab = \tfrac{1}{4}. \Pi. 0,5^{2} = 0,196 \text{ m}^{2}$$

$$As = \Pi. 0,5 . 38 = 59,69 \text{ m}^{2}$$

$$\text{Pu 1 tiang} = 40. 35,4. 0,196 + \frac{13,9. 59,69}{5} = 443,5 \text{ ton}$$

$$\bar{P} = \frac{Pu}{S F} = \frac{443,5}{3} = 147,8 \text{ ton}$$

Anggap berat poer dan sloof = 5%. Pkolom

= 5%. 515,08 + 515,08 = 540,83 t

$$\text{n pile} = \frac{540,83}{147,8} = 3,7$$

Pertimbangan kombinasi beban momen dan aksial, coba pasang 7 pile.

<u>Spasi antar tiang 150 cm :</u>

$$\theta = \text{arc tan}\,\frac{50}{150} = 18{,}4^0$$
$$\eta = 1 - 18{,}4^o.\ \frac{(3-1).\,2 + (2-1).\,3}{90^0.3.2} = 0{,}76$$

<u>Cek daya dukung tiang group :</u>

$\bar{P}$ 1 dalam group = 0,76. 147,8 = 112,3 t

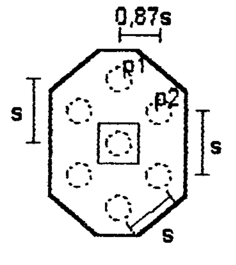
P 7 tiang = 7. 112,3 = 786,1 t > 540,83 t (OK)

<u>Cek aksial 1 tiang :</u>

$$\Sigma X^2 = 4.\ (0{,}87.\ 1{,}5)^2 = 6{,}81\ m^2$$
$$\Sigma Y^2 = 4.\ (0{,}75)^2 + 2.\ (1{,}5)^2 = 6{,}75\ m^2$$

Akibat kombinasi beban aksial dan momen.

$$Pp1\ (max) = \frac{540{,}83}{7} + \frac{58{,}81.\ 1{,}5}{6{,}75} = 90{,}3\ ton\ < 112{,}3\ t$$
$$Pp1\ (min) = \frac{540{,}83}{7} - \frac{58{,}81.1{,}5}{6{,}75} = 64{,}2\ t$$
$$Pp2\ (max) = \frac{540{,}83}{7} + \frac{59{,}35.\ (0{,}87.1{,}5)}{6{,}81} + \frac{58{,}81.\ (0{,}75)}{6{,}75} = 95{,}17\ ton\ < 112{,}3\ t$$
$$Pp2\ (min) = \frac{540{,}83}{7} - \frac{59{,}35.(0{,}87.1{,}5)}{6{,}81} - \frac{58{,}81.(0{,}75)}{6{,}75} = 59{,}4\ t$$



Gaya lateral

Gaya lateral yang diterima tiang menyebabkan tiang mengalami lentur.

Berdasar referensi Pile Foundation Analysis and Design, EH. Davis and H. Polos, kemampuan pile menerima beban lateral berdasar dari :

- Kemampuan masing-masing tiang,
- Kemampuan kelompok tiang/pile group sebagai blok ekivalen, yang meliputi tiang dan tanah diantara tiang/pile.

Menurut NAVFAC DM-7 (1971) gaya lateral yang bekerja pada pondasi terbagi :

1. Tiang pancang dengan poer fleksibel atau terjepit sendi di ujungnya,
2. Tiang pancang dengan poer kaku dan menempel diatas permukaan tanah,
3. Tiang pancang dengan poer kaku dan terletak pada suatu ketinggian.

Cara perhitungan tiang akibat gaya lateral berdasar Buku Pedoman Perencanaan ..... 1983, lampiran B.

Dari deskripsi tanah (data tanah), untuk tanah di permukaan kategori *clay-soft-sand* :

Tegangan tanah ijin lateral = 3500 $kg/m^2/m'$ (tabel B - 1)

Cr = 0,5. Cu = 0,5. 3500 = 1750 kg/m^2

Cek tiang panjang atau pendek :

$H\ total = \sqrt{Hx^2 + Hy^2} = \sqrt{34,61^2 + 35,35^2} = 49,6$ ton

$H\ 1\ tiang = \frac{49,6}{7} = 7,1$ ton

$f = \frac{Ho}{9.\ Cr.\ D} = \frac{7100}{9.\ 1750.\ 0,5} = 0,9$ m

$L1 = f + 1,5.\ D$

$= 0,9 + 1,5.\ 0,5 = 1,65$ m

$L2 = 2,2.\ L1$

$= 2,2.\ 1,65 = 3,63$ m $<$ L tiang (38 m) (termasuk tiang panjang)

Mencari momen pada satu tiang

Akibat gaya lateral akan timbul momen di ujung tiang.

$\frac{Ho}{Cr.\ D} = \frac{7100}{1750.\ 0,5} = 8,1$ (ujung atas ditahan)

Lihat grafik gambar B-3 :

$\frac{Mo}{Cr.\ D^2} = 8,5$

$Mo = 8,5.\ 1,75.\ 0,5^2 = 3,7$ tm

Kekuatan tiang terhadap momen dicari dari grafik brosur PT WIKA.

Untuk pile : tipe A3

D 50 cm

kuat tekan rencana 150 t

kuat momen rencana = 13,5 tm > 3,7 tm (OK)

12.2. POER

Pile cap/poer berfungsi untuk menyatukan seluruh tiang/pile untuk menerima beban di level dasar (geser, aksial, dan momen).

Pada referensi Foundaton Analysis and Design, Bowles, disebutkan persyaratan untuk poer yaitu :

- Momen lentur bekerja pada seluruh penampang,
- Jarak minimum tepi poer dengan muka tiang terluar 150 mm,
- Panjang penanaman tiang ke dalam poer sedikitnya 150 mm (untuk tiang dengan asumsi jepit),
- Jarak min tulangan bawah poer diatas ujung muka tiang 75 mm,
- Tebal minimum poer diatas tulangan bawah 300 mm,
- Harus terdapat tulangan tambahan di tiang ke dalam poer, untuk menjamin bahwa tiang tidak terlepas/tercabut dari poer.

Poer untuk pondasi struktur direncanakan seperti pada point 2 spesifikasi NAVFAC DM-7.

12.2.1. Perencanaan poer di as A1

Direncanakan : t tebal = 100 cm

b lebar = 350 cm

h panjang = 400 cm

d' deking = 150 + 75 + 0,5. 22 = 236 mm

Syarat tulangan :

$$\rho \text{ balance} = \frac{0.85.\ 0.85.\ 30}{400} . \frac{600}{600 + 400} = 0,0325$$

ρ max = 0,75. 0,0325 = 0,0244

Kontrol lendutan : ρ ada $\leq$ 0,5. 0,0244

$\leq$ 0,0122

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

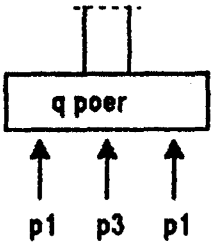
Arah y :

Aksial tiang akibat Mx :

$$Pp1 = \frac{540,83}{7} + \frac{58,81.\ 1,5}{6,75} = 90,33 \text{ t}$$

$$Pp2 = \frac{540,83}{7} + \frac{58,81.\ 0,75}{6,75} = 83,8 \text{ t}$$

dy = 1000 - 236 = 764 mm



Mu = Pp1. L + 2. Pp2. L - 0,5. q. l^2

= 90,33. 1,5 + 2. 83,8. 0,75 - 0,5. (2,4. 3,5). 2^2 = 244,4 tm

$$\text{Mu per m'} = \frac{244,4}{3,5} = 69,8 \text{ tm/m'}$$

$$m = \frac{fy}{0,85.\ fc'} = \frac{400}{0,85.30} = 15,68$$

$$Rn = \frac{69,8.\ 10^7}{0,8.\ 1000.\ 764^2} = 1,5 \text{ MPa}$$

$$\rho \text{ perlu} = \frac{1}{15,68}\left(1 - \sqrt{1 - \frac{2.15,68.1,5}{400}}\right) = 0,0039$$

As bawah = 0,0039. 1000. 764 = 2945,1 mm^2

(pakai D22-100 mm, As = 3801 mm^2)

As atas = 0,4. 2945,1 = 1178 mm^2 (pakai D16 - 100 mm, As = 2011 mm^2)

Arah x :

Aksial akibat My.

$$Pp2 = \frac{540,83}{7} + \frac{59,35.\ 0,87.1,5}{6,81} = 88,63\ t$$

dx = 764 - 22 = 742 mm

$$Mu = 2.\ 88,63.\ (0,87.\ 1,5) - \frac{1}{2}.\ (2,4.\ 4).\ 1,75^2 = 216,3\ tm = 54,2\ tm/m'$$

$$Rn = \frac{54,2.10^7}{0,8.\ 1000.\ 742^2} = 1,2\ MPa$$

$$\rho\ perlu = \frac{1}{15,68}\left(1 - \sqrt{1 - \frac{2.15,68.1,2}{400}}\right) = 0,0032 \quad ,pakai\ 0,0035$$

As bawah = 0,0035. 1000. 742 = 2597 mm^2 (pakai D22 - 100 mm)

As atas = 0,4. 2597 = 1038,8 mm^2 (pakai D16 - 100 mm)

Cek geser pons :

Kegagalan geser pons akan terjadi di perimeter kolom.

Pada umumnya pemasangan tulangan geser akibat geser pons adalah tidak efektif, hal ini antara lain karena pelaksanaan yang sulit dilakukan, oleh karena itu kekuatan poer terhadap geser lebih ditentukan oleh kemampuan beton atau tebal poer.

Kuat geser beton (SKSNI 3.4.11) :

$$Vc = (1 + \frac{2}{\beta c}).\ \frac{\sqrt{fc'}}{6}.\ bo.\ d$$

dimana : $\beta c = \frac{sisi\ panjang}{sisi\ pendek}$ daerah beban terpusat

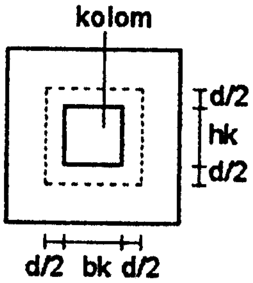
bo = keliling penampang kritis/perimeter kolom

= 2. (b kolom + h kolom) + 4. d

$\beta c = \frac{700}{700} = 1$

bo = 2. (700 + 700) + 4. 742 = 5768 mm

$Vc = (1 + 2).\frac{\sqrt{30}}{6}. 5768. 742 = 11720868$ N



Kuat beton tidak lebih dari :

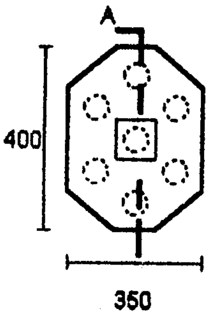
$$Vc\ max = \frac{\sqrt{fc'}}{3}.\ bo.\ d.\ \beta c$$

$$= \frac{\sqrt{30}}{3}. 5768. 742 = 7813912\ N$$, pakai Vc max

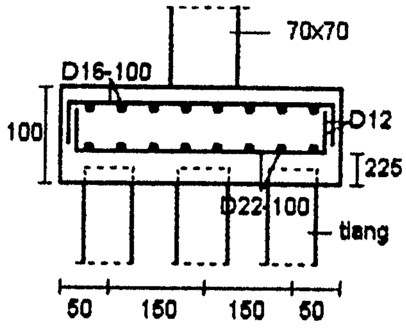
Vu perlu = Pu kolom - Pp = 515,08 - 114,9 = 400,2 ton

$Vs\ perlu = \frac{400{,}2.10^4}{0{,}6} - 7813912 = -1144433$ N (tidak perlu tul. geser)

(tulangan di tengah/sabuk poer pasang tul. praktis D12)



sket Poer di as A1



sket Pot. A

12.3. BALOK SLOOF

Beban aksial

Sloof menerima beban axial tekan dan tarik sebesar 10 % dari Pu maksimum pada pondasi akibat pembebanan dengan gempa (PPTGIUG 3.2.8).

Beban lentur/geser

Beban momen yang bekerja pada sloof yaitu akibat beban-beban yang ada diatas plat basement dan tumpuan plat. Sedangkan momen dari analisa struktur di lantai dasar diterima oleh kolom (jepit kolom - poer).

Pembebanan dari plat basement pada balok sloof sama seperti pada plat lantai yang membebani balok struktur. Beban berupa beban luasan segitiga dan atau luasan trapesium.

Pada referensi Reinforced Conc. Design, Everard dan Tanner, perumusan beban luasan segitiga dan trapesium menjadi q ekivalen :

$$\text{q bentang pendek} = \frac{W.\ S}{3} \qquad \text{(segitiga)}$$

$$\text{q bentang panjang} = \frac{W.\ S}{3} . \frac{(3 - m^2)}{2} \qquad \text{(trapesium)}$$

12.3.1. Perencanaan balok sloof anak L=6 m

Direncanakan : Dimensi 30/60

fy = 400 MPa   fc' = 30 MPa

d' = 70 + 0,5. 16 = 78 mm

Akibat beban luasan trapesium :

$$m = \frac{S}{L} = \frac{2,5}{3} = 0,83$$

$$\text{q satu sisi} = \frac{18560.2,5}{3} . \frac{(3-0,83^2)}{2} = 17872,5 \text{ N/m}$$

$$\text{q dua sisi} = 2.\ 17872,5 + 24000.\ 0,3.\ 0,6 = 40065 \text{ N/m}$$

Momen dan geser balok dicari berdasar sifat tumpuan dengan perumusan pada PBI 71 bab 13.2.

Perhitungan lentur

$M \text{ tump} = \frac{1}{16} . q. lt^2 = \frac{1}{16} . 40065. 5{,}7^2 = 81183 \text{ Nm}$

$Rn = 1{,}2 \text{ MPa}$

$\rho \text{ perlu} = 0{,}0032$, pakai $\rho \min = 0{,}0035$

$As \text{ perlu} = 0{,}0035. 300. (600 - 78) = 548{,}1 \text{ mm}^2$

(pakai 6D16, $As = 1206 \text{ mm}^2$)

Perhitungan geser

$Vu \text{ tump} = \frac{1}{2} . q. l = \frac{1}{2} . 40065. 6 = 114185 \text{ N}$

$Vc = \frac{\sqrt{fc'}}{6} . bw. d$ (SKSNI 3.4.3.1.1)

$= \frac{\sqrt{30}}{6} . 300. 522 = 142956 \text{ N}$

$Vs \text{ perlu} = \frac{114185}{0{,}6} - 142956 = 46946 \text{ N}$

Cek desain geser :

$[\Phi. Vc] < Vu \leq [\Phi. Vc + \Phi. Vs \min]$

$[0{,}6. 142956] < 114185 \leq [0{,}6. 142956 + 0{,}6. \frac{1}{3} . 300. 522]$

$85773 < 114185 \leq 117093$

Coba tul D10 :

$S \text{ perlu} = \frac{157.400.522}{46946} = 698 \text{ mm}$

Syarat jarak geser :

- $S = \frac{d}{2} = \frac{522}{2} = 261 \text{ mm}$
- $S = 600 \text{ mm}$

(pakai sengkang D10 - 200)

Tul. tengah untuk geser dan torsi

(Pasang tul. tengah praktis 2D12)

12.3.2. Perencanaan balok sloof induk L=5 m

Dimensi 40/80 cm

Pu sloof = 10%. 799,4 = 79,94 ton

Cek aksial tarik

$fct = 0,7.\ \sqrt{fc'} = 0,7.\ \sqrt{30} = 3,834$ MPa

$$fr = \frac{Nu}{0,8.\ Ag}$$

$$= \frac{799400}{0,8.\ 400.\ h} = 3,834$$

h perlu = 651,6 mm , h = 80 cm (OK)

Beban :

$$q \text{ satu sisi} = \frac{18560.2,5}{3} = 15467 \text{ N/m}$$

q dua sisi = 2. 15467 + 24000. 0,4. 0,8 = 38614 N/m

Akibat tumpuan sloof anak :

P = 119937,8 + 62160 = 182097,8 N

$$Mo = \frac{1}{4}.\ P.\ L = \frac{1}{4}.\ 182097,8.\ 5 = 227622 \text{ Nm}$$

$$M\ tot = \frac{1}{16}.\ 38614.\ 4,6^2 + \frac{1}{2}.\ 227622 = 164877 \text{ Nm}$$

Penulangan lentur

Dengan diagram interaksi kolom :

fc' = 30 MPa fy = 400 MPa

d' = 70 + 0,5. 25 = 82,5 mm

$\mu = 0,75$

e min = (0,03. 800 + 15) = 39 mm

$$e = \frac{164877}{799400} = 0,21 \text{ m} \qquad > e \text{ min}$$

$$K = \frac{Pu}{fc'.\ Ag} = \frac{799400}{30.\ 400.\ 800} = 0,08$$

Lihat grafik, didapat $\rho < 1$, pakai $\rho = 1\%$

As perlu = 0,01. 400. 800 = 3200 mm^2

(pakai tul. 8D25, Ast = 3927 mm^2)

Perhitungan geser

$Vu = \frac{1}{2}.\ 38614.\ 5 = 96535\ N$

$Vu\ tump\ sloof\ anak = \frac{119937{,}8+62160}{2} = 91049\ N$

$Vu\ perlu = 96535 + 91049 = 187584\ N$

Kuat beton :

$$Vc = 2.\left(1 + \frac{0{,}3.\ Nu}{Ag}\right)\frac{\sqrt{fc'}}{6}.\ bw.\ d \qquad \text{(SKSNI 3.4.3.2.3)}$$

dimana : Nu = negatif untuk aksial tarik

$$Vc = 2.\ \left(1 + \frac{0{,}3.\ (-799400)}{400.\ 800}\right)\frac{\sqrt{30}}{6}.\ 400.\ 717{,}5 = 131302\ N$$

$Vs\ perlu = \frac{187584}{0{,}6} - 131302 = 181335\ N$

Coba tul. D12 :

$S\ perlu = \frac{226.400.717{,}5}{181335} = 357{,}7\ mm$

(pakai D12 - 200 mm)

Tul. tengah untuk geser dan torsi

(Pasang tul. tengah praktis 2D12)

as		**Pu**	**Muy**	**Mux**	**tiang (m)**		**N**		**P satu**	**P ijin**	**Pu+**	**tiang**	**jml**	**m**	**n**	**S**	**P group**	
		(ton)	**(tm)**	**(tm)**	**D**	**L**	**ujung**	**rata2**	**tiang**	**tanah**	**5%. Pu**	**perlu**	**tiang**			**(m)**	**1 pile**	**group**
A	1	515.08	59.35	58.81	0.5	38	35.38	13.93	443.96	147.99	540.83	3.65	7	3	2	1.5	112.69	788.83
	2	681.77	73.51	84.11	0.5	38	35.38	13.93	443.96	147.99	715.86	4.84	9	3	3	1.5	107.65	968.83
B	1	507.82	59.47	59.13	0.5	38	35.38	13.93	443.96	147.99	1071.95	7.24	15	5	3	1.5	103.61	1554.20
	2	759.53	90.74	84.41	0.6	38	35.38	13.93	599.40	199.80	1600.22	10.67	15	5	3	1.5	128.82	1932.30
C	1	513.08	59.53	59.14	0.5	38	35.38	13.93	443.96	147.99	1071.95	7.24	15	5	3	1.5	103.61	1554.20
	2	764.49	90.80	84.44	0.6	38	35.38	13.93	599.40	199.80	1600.22	10.67	15	5	3	1.5	128.82	1932.30
D	1	541.58	59.32	59.16	0.5	38	35.38	13.93	443.96	147.99	568.66	3.84	7	3	2	1.5	112.69	788.83
	2	799.38	72.84	88.19	0.5	38	35.38	13.93	443.96	147.99	839.35	5.67	9	3	3	1.5	107.65	968.83
lift		92.42			0.5	38	35.38	13.93	443.96	147.99	97.04	0.66	1				147.99	

as		**sigma**		**tiang p1 (t)**		**tiang p2 (t)**		**tiang p3 (t)**	
		X^2	**Y^2**	**max.**	**min.**	**max.**	**min.**	**max.**	**min.**
A	1	6.81	6.75	90.33	64.19	95.17	59.36		
	2	13.50	13.50	97.05	62.03	87.71	71.37	88.89	70.19
B	1	13.50	13.50	84.64	58.29	78.07	64.86		
	2	13.50	13.50	126.14	87.22	116.76	96.60		
C	1	13.50	13.50	84.65	58.28	78.08	64.85		
	2	13.50	13.50	126.15	87.21	116.77	96.59		
D	1	6.81	6.75	94.38	68.09	99.17	63.30		
	2	13.50	13.50	105.15	75.37	101.35	85.17	103.06	83.46
lift									

Tabel 12.1 Pondasi tiang

as		poer	poer (cm)			krn Mx		krn My		
		tipe	h	b	t	p1	p2	p1 (ton)	p2	p3
A	1	P1	400	350	100		88.63	90.33	83.80	
	2	P3	400	400	120	87.71	87.71	88.89		88.89
B	1	P2	700	400	100	78.07	78.07	79.35		79.35
	2	P4	700	400	120	116.76	116.76	117.94		117.94
C	1	P2	700	400	100	78.08	78.08	79.35		79.35
	2	P4	700	400	120	116.77	116.77	117.94		117.94
D	1	P1	400	350	100		92.60	94.38	87.81	
	2	P3	400	400	120	101.35	101.35	103.06		103.06
lift		P5	100	100	50					

as		dy	arah y		ro	As (mm2)		dx	arah x		ro	As (mm2)		bo	Vc	Vs
		(mm)	(tm)	(tm/m')	perlu	perlu	pakai	(mm)	(tm)	(tm/m')	perlu	perlu	pakai	(mm)	(N)	perlu (N)
A	1	764	244.39	69.83	3.85E-03	2945.11	D22-100	742	216.63	54.16	3.50E-03	2597.00	D22-100	5768	7813912.25	-1144433.35
	2	964	376.94	94.24	3.25E-03	3374.00	D22-100	942	371.64	92.91	3.50E-03	3297.00	D22-100	6768	11639936.89	-2106592.26
B	1	742	561.51	80.22	4.73E-03	3508.40	D22-100	764	332.12	83.03	3.50E-03	3523.58	D22-100	5768	7813912.25	-1111175.04
	2	937.5	844.22	120.60	4.44E-03	4165.15	D25-100	962.5	502.40	125.60	4.39E-03	4223.17	D25-100	6750	11553522.70	-1061356.03
C	1	742	561.51	80.22	4.73E-03	3508.40	D22-100	764	332.15	83.04	3.50E-03	3523.91	D22-100	5768	7813912.25	-1023508.37
	2	937.5	844.22	120.60	4.44E-03	4165.15	D25-100	962.5	502.43	125.61	4.39E-03	4223.43	D25-100	6750	11553522.70	-978689.36
D	1	764	256.49	73.28	4.05E-03	3095.86	D22-100	742	226.99	56.75	3.50E-03	2597.00	D22-100	5768	7813912.25	-702766.69
	2	964	440.73	110.18	3.82E-03	3682.04	D22-100	942	433.05	108.26	3.93E-03	3705.85	D22-100	7068	14587069.84	-3093558.55
lift		862.5			3.50E-03	3018.75	D22-120	837.5			3.50E-03	2931.25	D22-120	2568	1134618.23	-1760951.57

Tabel 12.2 Poer

portal	sloof	b	h	L	q bs	w	m =	q ek	M tump	ro	As (mm2)		Vc	Vu perlu	D tul.	Vs perlu	S (mm)	
			(cm)		(N/m)	(N/m2)	S/L	(N/m)	(Nm)	perlu	perlu	pakai	(N)	(N)	(mm)	(N)	perlu	pasang
A	anak	30	60	600	4320	18560	0.83	35659.26	81182.88	3.50E-03	548.10	1206	142955.59	199896.30	10	56940.71	575.71	200
A	anak	30	60	500	4320	18560	0.83	30933.33	48671.63	3.50E-03	548.10	1206	142955.59	146888.89	10	3933.30	8334.37	200
B	anak	30	60	600	4320	18560	0.71	37120.00	84149.10	3.50E-03	548.10	1206	142955.59	207200.00	10	64244.41	510.26	200
B	anak	30	60	850	4320	18560	0.71	46432.11	213285.75	8.81E-03	1375.53	1701	142544.80	359494.12	10	216949.32	150.67	100
C	anak	30	60	300	4320	18560	0.71	37120.00	18881.10	3.50E-03	548.10	1206	142955.59	103600.00	10	-39355.59	-832.96	200
D	anak	30	60	800	4320	18560	0.94	49493.33	199412.03	8.19E-03	1279.43	1701	142544.80	358755.56	10	216210.76	151.18	100
D	anak	30	60	850	4320	18560	0.94	52319.08	238025.72	9.92E-03	1549.64	1701	142544.80	401193.46	10	258648.67	126.38	100

Tabel 12.3.1 Balok sloof anak

no	portal	sloof	b	h	L	q be	w	m =	q ek	M tump	M krn tump.	M tot	Pu	e/h	K	pakai	As (mm2)	
				(cm)		(N/m)	(N/m2)	S/L	(N/m)	(Nm)	sloof anak	(Nm)	(t)			ro	perlu	pakai
1	A	induk	40	80	500	7680	18560	0.83	30933.33	51066.13	227622.22	164877.24	79.938	0.26	0.08	0.01	3200	3927
2	B	induk	40	80	600	7680	18560	0.83	35659.26	84944.95	455744.71	312817.30	79.938	0.49	0.08	0.01	3200	3927
3	D	induk	40	80	800	7680	18560	0.94	49493.33	206395.73	481432.16	447111.81	79.938	0.70	0.08	0.01	3200	3927
4	D	induk	40	80	850	7680	18560	0.94	52319.08	246033.72	721593.33	606830.38	79.938	0.95	0.08	0.01	3200	3927

no	Vu krn tump.	Vu	Vu tot	Vc	syarat geser				S =	D tul	Vs perlu	S (mm)	
	sloof anak	induk	(N)	(N)	0.5.phi.Vc	phi.Vc	syarat 3	syarat 4	d/2	(mm)	(N)	perlu	pasang
1	91048.89	96533.33	187582.22	131301.55	39390.46	78780.93	136180.93	393173.68	358.75	12	181335.49	357.69	200
2	151914.90	130017.78	281932.68	131301.55	39390.46	78780.93	136180.93	393173.68	358.75	12	338586.25	191.57	150
3	120358.04	228693.33	349051.37	131301.55	39390.46	78780.93	136180.93	393173.68	358.75	12	450450.74	143.99	100
4	169786.67	254996.08	424782.75	131301.55	39390.46	78780.93	136180.93	393173.68	179.38	12	576669.70	112.48	100

Tabel 12.3.2. Balok sloof induk

```
FINAL PROJECT - ANALYSIS OF UP STAIR (KG-M)
SYSTEM
L=2
JOINT
1         X=0     Y=0
2         X=3.2   Y=1.82
3         X=5
:
RESTRAINTS
1,3,1    R=0,0,0,0,0,0
1,1,0    R=1,1,1,1,1,0
3,3,0    R=0,1,1,1,1,0
:
FRAME
NM=1   NL=3
1     A=1*0.15 I=2.8125E-4,0.0125 E=2.9E9
1     WG=0,-727.5
2     WG=0,-465
3     WG=0,-300
1,1,2  M=1    NSL=1,3
2,2,3  M=1    NSL=2,3
:
COMBO
1     C=1.2,1.6
:
```

```
FINAL PROJECT - ANALYSIS OF DOWN STAIR (KG-M)
SYSTEM
L=2
JOINT
1         X=0     Y=1.82
2         X=3.2   Y=0
3         X=5
:
RESTRAINTS
1,3,1    R=0,0,0,0,0,0
1,1,0    R=1,1,1,1,1,0
3,3,0    R=0,1,1,1,1,0
:
FRAME
NM=1   NL=3
1     A=1*0.15 I=2.8125E-4,0.0125 E=2.9E9
1     WG=0,-727.5
2     WG=0,-465
3     WG=0,-300
1,1,2  M=1    NSL=1,3
2,2,3  M=1    NSL=2,3
:
COMBO
1     C=1.2,1.6
:
```

```
                STRUCTURAL ANALYSIS PROGRAMS

                       VERSION  5.20


                         PROGRAM:SAP90/FILE:tngup.F3F
FINAL PROJECT - ANALYSIS OF UP STAIR (KG-M)
F R A M E   E L E M E N T   F O R C E S
 ELT LOAD   AXIAL DIST      1-2 PLANE         1-3 PLANE
 ID COMB   FORCE ENDI SHEAR   MOMENT SHEAR  MOMENT
  1 -----------------------------------
     1       -551.55
                   .0     2851.50       .00
                  2.8     -.01          3976.82
                  3.7     -911.98       3570.05
  2 -----------------------------------
     1       .00
                   .0     -1049.16      3570.05
                  1.8     -2917.56      .00
```

```
                STRUCTURAL ANALYSIS PROGRAMS

                       VERSION  5.20


                       PROGRAM:SAP90/FILE:tngdown.F3F
FINAL PROJECT - ANALYSIS OF DOWN STAIR (KG-M)
F R A M E   E L E M E N T   F O R C E S
 ELT LOAD   AXIAL DIST      1-2 PLANE         1-3 PLANE
 ID  COMB  FORCE ENDI  SHEAR  MOMENT  SHEAR MOMENT
  1 -----------------------------------
     1       551.55
                   .0     2851.50       .00
                  2.8     -.01          3976.82
                  3.7     -911.98       3570.05
  2 -----------------------------------
     1       .00
                   .0     -1049.16      3570.05
                  1.8     -2917.56      .00
```

```
                    STRUCTURAL ANALYSIS PROGRAMS
                           VERSION 5.20

                                   PROGRAM:SAP90/FILE:tngup.SOL
FINAL PROJECT - ANALYSIS OF UP STAIR (KG-M)


JOINT DISPLACEMENTS


LOAD COMBINATION 1 - DISPLACEMENTS "U" AND ROTATIONS "R"

JOINT    U(X)      U(Y)      U(Z)      R(X)      R(Y)      R(Z)
  1    .000000   .000000   .000000   .000000   .000000   -.009219
  2    .007145   -.012572  .000000   .000000   .000000   .004049
  3    .007145   .000000   .000000   .000000   .000000   .008607


REACTIONS AND APPLIED FORCES


LOAD COMBINATION 1 - FORCES "F" AND MOMENTS "M"

JOINT  F(X)            F(Y)            M(Z)
  1     .0000          3280.4400       .0000
  2  -.3239E-10        -.1482E-10      .0000E+00
  3     .0000          2917.5600       .0000
```

```
                    STRUCTURAL ANALYSIS PROGRAMS
                           VERSION 5.20

                                   PROGRAM:SAP90/FILE:tngdown.SOL
FINAL PROJECT - ANALYSIS OF DOWN STAIR (KG-M)


JOINT DISPLACEMENTS

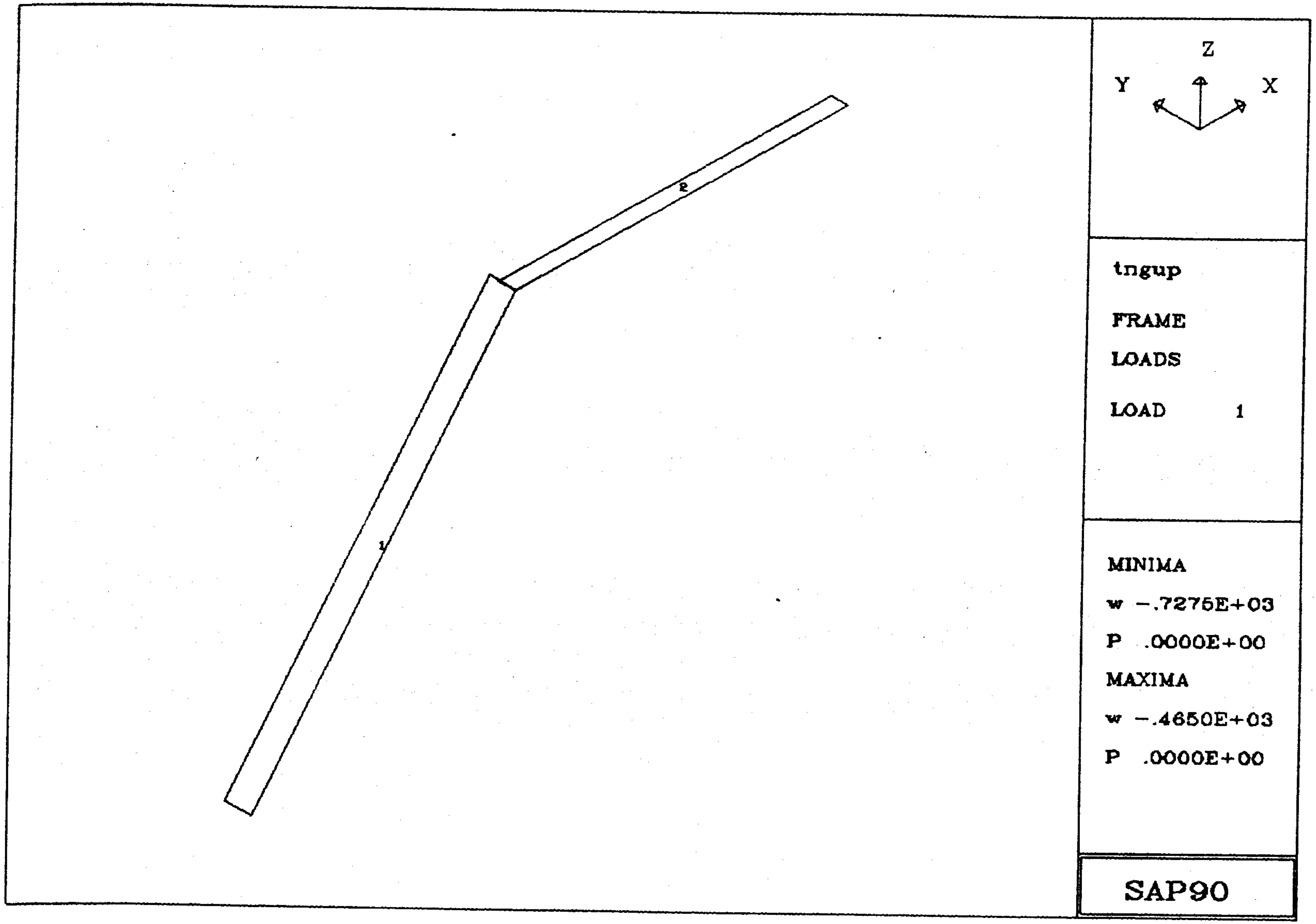

LOAD COMBINATION 1 - DISPLACEMENTS "U" AND ROTATIONS "R"

JOINT    U(X)      U(Y)      U(Z)      R(X)      R(Y)      R(Z)
  1    .000000   .000000   .000000   .000000   .000000   -.009219
  2   -.007145   -.012572  .000000   .000000   .000000   .004049
  3   -.007145   .000000   .000000   .000000   .000000   .008607

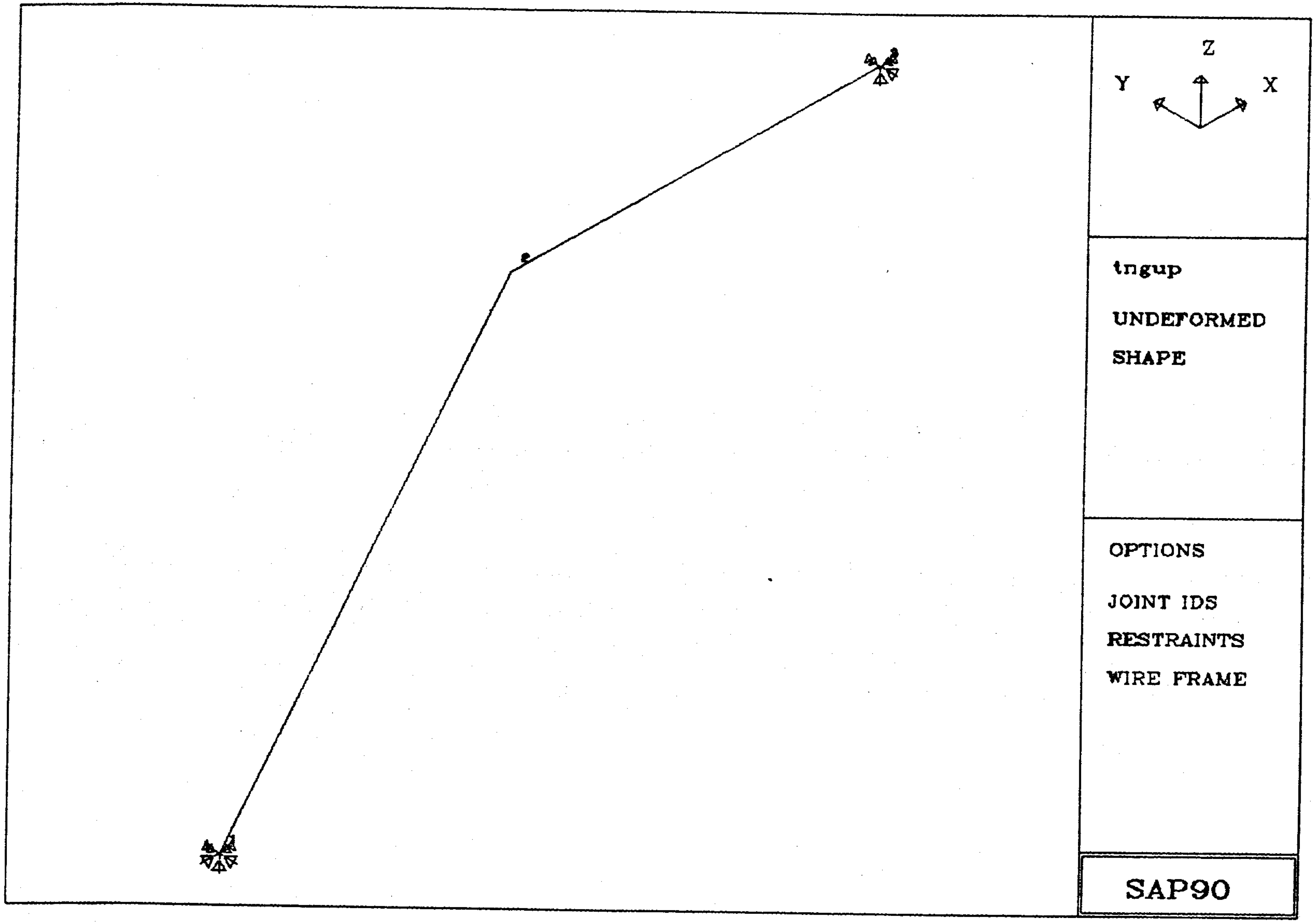

REACTIONS AND APPLIED FORCES


LOAD COMBINATION 1 - FORCES "F" AND MOMENTS "M"

JOINT  F(X)            F(Y)            M(Z)
  1    .0000           3280.4400       .0000
  2    .3239E-10       -.1482E-10      .0000E+00
  3    .0000           2917.5600       .0000
```



Z
Y
X
tngup
FRAME
LOADS
LOAD 1
MINIMA
w −.7275E+03
P .0000E+00
MAXIMA
w −.4650E+03
P .0000E+00
SAP90
1
2



Z
Y
X
tngup
UNDEFORMED
SHAPE
OPTIONS
JOINT IDS
RESTRAINTS
WIRE FRAME
SAP90
3

```
Secondary Floor Beam Analysis,
Units:kN-Meter-Second
$ Control data
2 1 1 0 1 0 1 1 7 0 0 0 0 3 0 0 1 1 1
10.
$ Story data
2ND   3.65
1ST   3.65
$ Frame material data
1 C 2.9E7  24   0.15
$ Column properties
1 1 RECT  0.7  0.7
$ Beam properties
1 1 RECT  0.35  0 0.25
2 1 RECT  0.4   0 0.25
3 1 RECT  0.5   0 0.3
4 1 RECT  0.6   0 0.3
5 1 RECT  0.7   0 0.4
6 1 RECT  0.8   0 0.4
7 1 RECT  0.9   0 0.4
$ Frame control data
SECONDARY FLOOR
1 2 148 247 0 0 0 22
$ Column line orientations
1    2    0
2    5    0
3    8    0
4    11   0.5
5    14   0.5
6    17   0.5
7    25   0.5
8    28   0.5
9    31   0.5
10   34   0
11   37   0
12   40   0
13   0    2
14   2    2
15   5    2
16   8    2
17   11   2
18   14   2
19   17   2
20   25   2
21   28   2
22   31   2
23   34   2
24   37   2
25   40   2
26   42   2
28   2    4.5
29   5    4.5
30   8    4.5
31   11   4.5
32   14   4.5
33   17   4.5
34   25   4.5
35   28   4.5
36   31   4.5
37   34   4.5
38   37   4.5
39   40   4.5
40   42   4.5
41   0    7
42   2    7
43   5    7
44   8    7
45   11   7
46   14   7
47   17   7
48   21   7
49   25   7
50   28   7
51   31   7
52   34   7
53   37   7
54   40   7
55   42   7
56   0    10
57   2    10
58   5    10
59   8    10
60   11   10
61   14   10
62   17   10
63   21   10
64   25   10
65   28   10
66   31   10
67   34   10
68   37   10
69   40   10
70   42   10
71   0    12.5
72   2    12.5
73   5    12.5
74   8    12.5
75   11   12.5
76   14   12.5
77   17   12.5
78   21   12.5
79   25   12.5
80   28   12.5
81   31   12.5
82   34   12.5
83   37   12.5
84   40   12.5
85   42   12.5
86   0    15.5
87   2    15.5
88   5    15.5
89   8    15.5
90   11   15.5
91   14   15.5
92   17   15.5
93   21   15.5
94   25   15.5
95   28   15.5
96   31   15.5
97   34   15.5
98   37   15.5
99   40   15.5
100  42   15.5
101  0    18
102  2    18
103  5    18
104  8    18
105  11   18
106  14   18
107  17   18
108  25   18
109  28   18
110  31   18
111  34   18
112  37   18
113  40   18
114  42   18
115  0    20.5
116  2    20.5
117  5    20.5
118  8    20.5
119  11   20.5
120  14   20.5
121  17   20.5
122  25   20.5
123  28   20.5
124  31   20.5
125  34   20.5
126  37   20.5
127  40   20.5
128  42   20.5
129  2    22.5
130  5    22.5
131  8    22.5
132  11   22
133  14   22
134  17   22
135  25   22
136  28   22
137  31   22
138  34   22.5
139  37   22.5
140  40   22.5
141  18.5 18
142  23.5 18
143  18.5 4.5
144  23.5 4.5
145  18.5 7
146  23.5 7
147  18.5 15.5
148  23.5 15.5
$ Bay connectivities
1    41   56
2    71   86
3    55   70
4    85   100
5    1    2
6    2    3
7    4    5
8    5    6
9    7    8
10   8    9
11   10   11
12   11   12
13   13   27
14   26   40
15   27   41
16   40   55
17   86   101
18   100  114
19   101  115
20   114  128
21   129  130
22   130  131
23   132  133
24   133  134
25   135  136
26   136  137
27   138  139
28   139  140
29   41   42
30   54   55
31   56   57
32   69   70
33   71   72
34   84   85
35   86   87
36   99   100
37   1    14
38   2    15
39   3    16
40   4    17
41   5    18
42   6    19
43   7    20
44   8    21
45   9    22
46   10   23
47   11   24
48   12   25
49   116  129
50   117  130
51   118  131
52   119  132
53   120  133
54   121  134
55   122  135
56   123  136
57   124  137
58   125  138
59   126  139
60   127  140
61   13   14
62   25   26
63   27   28
64   39   40
65   101  102
66   113  114
67   115  116
68   127  128
69   14   15
70   15   16
71   17   18
72   18   19
73   20   21
74   21   22
75   23   24
76   24   25
77   42   43
78   43   44
79   45   46
80   46   47
81   49   50
```

```
83  52  53
84  53  54
85  87  88
86  88  89
87  90  91
88  91  92
89  94  95
90  95  96
91  97  98
92  98  99
93  116  117
94  117  118
95  119  120
96  120  121
97  122  123
98  123  124
99  125  126
100  126  127
101  14  28
102  28  42
103  87  102
104  102  116
105  16  30
106  30  44
107  89  104
108  104  118
109  17  31
110  31  45
111  90  105
112  105  119
113  19  33
114  33  47
115  92  107
116  107  121
117  20  34
118  34  49
119  94  108
120  108  122
121  22  36
122  36  51
123  96  110
124  110  124
125  23  37
126  37  52
127  97  111
128  111  125
129  25  39
130  39  54
131  99  113
132  113  127
```

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134  57  72
135  72  87
136  44  59
137  59  74
138  74  89
139  45  60
140  60  75
141  75  90
142  47  62
143  62  77
144  77  92
145  49  64
146  64  79
147  79  94
148  51  66
149  66  81
150  81  96
151  52  67
152  67  82
153  82  97
154  54  69
155  69  84
156  84  99
157  28  29
158  29  30
159  30  31
160  31  32
161  32  33
162  34  35
163  35  36
164  36  37
165  37  38
166  38  39
167  102  103
168  103  104
169  104  105
170  105  106
171  106  107
172  108  109
173  109  110
174  110  111
175  111  112
176  112  113
177  59  60
178  66  67
179  74  75
180  81  82
181  43  58
182  58  73
183  73  88
```

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185  61  76
186  76  91
187  48  63
188  63  78
189  78  93
190  50  65
191  65  80
192  80  95
193  53  68
194  68  83
195  83  98
196  15  29
197  29  43
198  88  103
199  103  117
200  18  32
201  32  46
202  91  106
203  106  120
204  21  35
205  35  50
206  95  109
207  109  123
208  24  38
209  38  53
210  98  112
211  112  126
212  92  147
213  148  94
214  47  145
215  145  48
216  48  146
217  146  49
218  77  78
219  78  79
220  62  63
221  63  64
222  44  45
223  51  52
224  89  90
225  96  97
226  33  143
227  144  34
228  107  141
229  142  108
230  147  93
231  93  148
232  57  58
233  58  59
234  60  61
```

```
235  61  62
236  64  65
237  65  66
238  67  68
239  68  69
240  72  73
241  73  74
242  75  76
243  76  77
244  79  80
245  80  81
246  82  83
247  83  84
$ Beam span vertical loading
1 0 17.64
2 0 5.76
3 0 15.3
4 0 5
5 0 25.25
6 0 8.25
7 0 18.36
8 0 6
9 0 6.12
10 0 2
11 0 7.16
12 0 2.66
13 0 4.59
14 0 1.5
15 0 7.82
16 0 2.56
17 0 7.22
18 0 2.36
19 0 26.25
20 0 8.58
21 0 13.12
22 0 4.29
$ Column assignments
14  0 2ND 1 1
16  14
17  14
19  14
20  14
22  14
23  14
25  14
42  14
44  14
45  14
47  14
49  14
51  14
```

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52  14
54  14
87  14
89  14
90  14
92  14
94  14
96  14
97  14
99  14
116 14
118 14
119 14
121 14
122 14
124 14
125 14
127 14

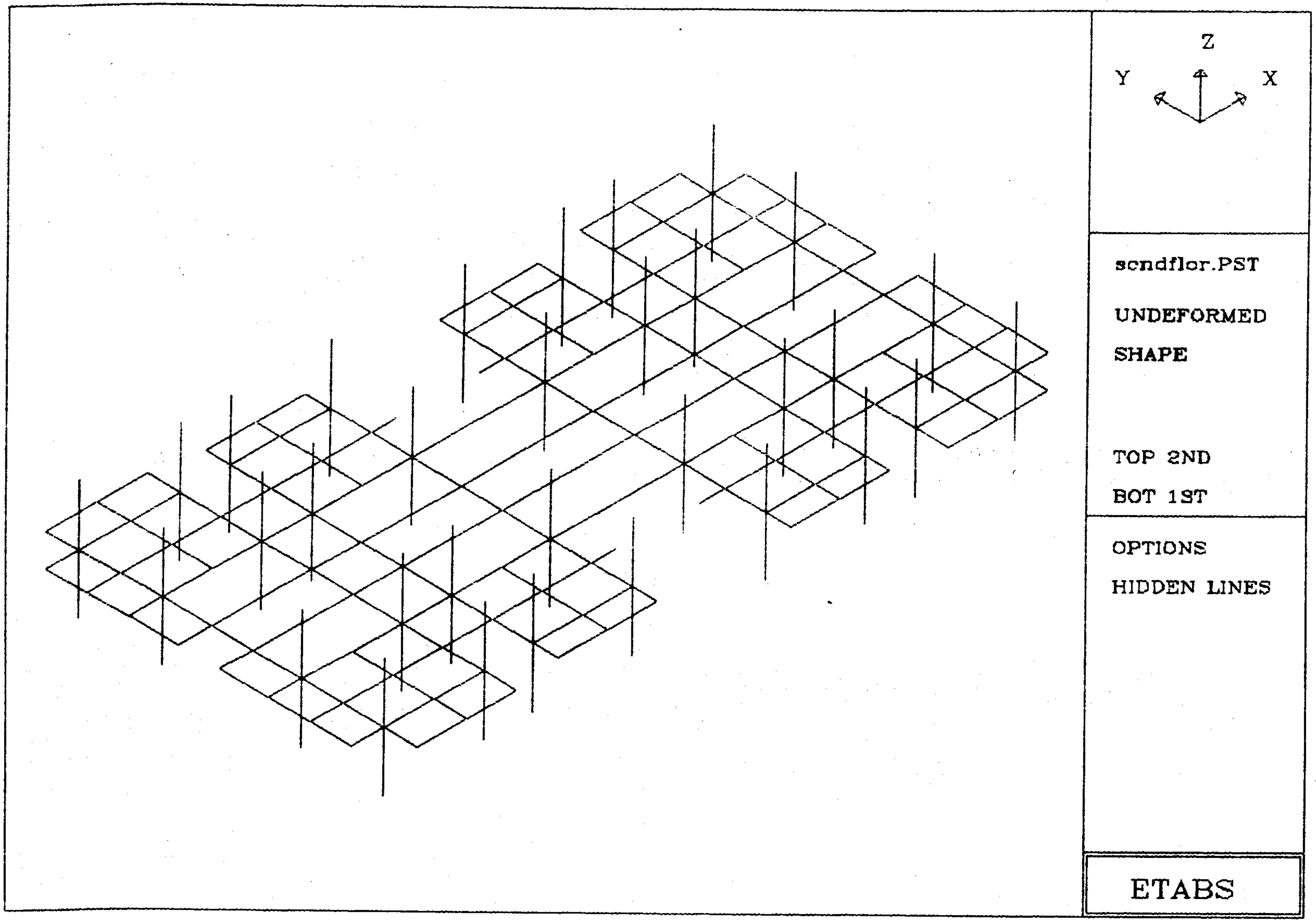
$ Beam assignments
157 0 1ST 3
158 157
160 157
161 157
162 157
163 157
165 157
166 157
167 157
168 157
170 157
171 157
172 157
173 157
175 157
176 157
196 0 1ST 2
197 196
198 196
199 196
200 196
201 196
202 196
203 196
204 196
205 196
206 196
207 196
208 196
209 196
210 196
```

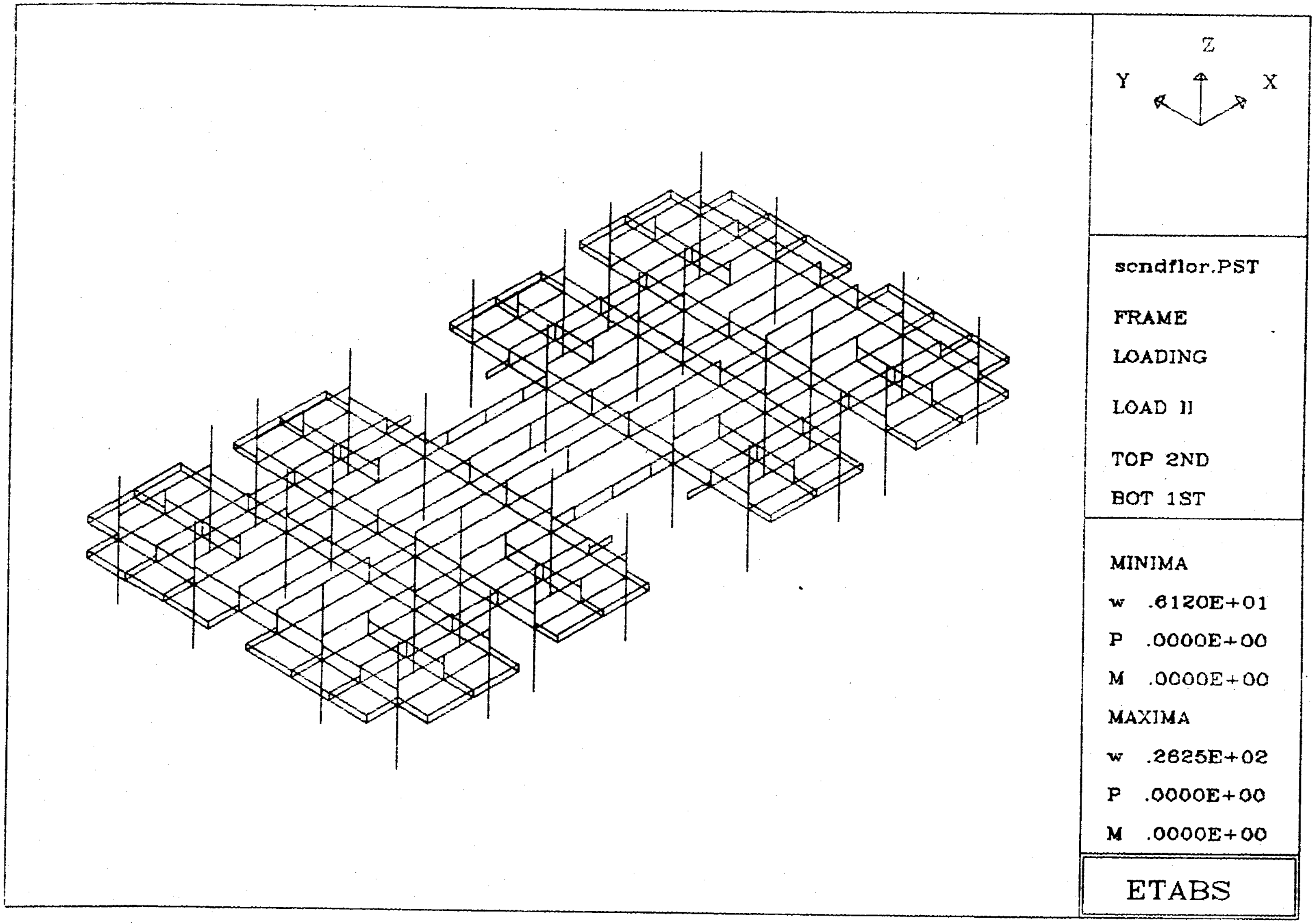
```
211 196
101 0 1ST 7
102 101
103 101
104 101
105 101
106 101
107 101
108 101
109 101
110 101
111 101
112 101
113 101
114 101
115 101
116 101
117 101
118 101
119 101
120 101
121 101
122 101
123 101
124 101
125 101
126 101
127 101
128 101
129 101
130 101
131 101
132 101
232 0 1ST 4
233 232
234 232
235 232
236 232
237 232
238 232
239 232
240 232
241 232
242 232
243 232
244 232
245 232
246 232
247 232
69  0 1ST 6
70  69
71  69
72  69
73  69
74  69
75  69
76  69
77  69
78  69
79  69
80  69
81  69
82  69
83  69
84  69
85  69
86  69
87  69
88  69
89  69
90  69
91  69
92  69
93  69
94  69
95  69
96  69
97  69
98  69
99  69
100 69
133 0 1ST 6
134 133
135 133
136 133
137 133
138 133
139 133
140 133
141 133
148 133
149 133
150 133
151 133
152 133
153 133
154 133
155 133
156 133
40  0 1ST 2
41  40
42  40
43  40
44  40
45  40
52  40
53  40
54  40
55  40
56  40
57  40
29  0 1ST 2
30  29
31  29
32  29
33  29
34  29
35  29
36  29
37  29
38  29
39  29
46  29
47  29
48  29
49  29
50  29
51  29
58  29
59  29
60  29
61  29
62  29
63  29
64  29
65  29
66  29
67  29
68  29
226 0 1ST 1
227 226
228 226
229 226
159 0 1ST 1
164 159
169 159
174 159
177 159
178 159
179 159
180 159
1   0 1ST 1
2   1
3   1
4   1
5   1
6   1
7   1
8   1
9   1
10  1
11  1
12  1
13  1
14  1
15  1
16  1
17  1
18  1
19  1
20  1
21  1
22  1
23  1
24  1
25  1
26  1
27  1
28  1
222 0 1ST 6
223 222
224 222
225 222
218 0 1ST 5
219 218
220 218
221 218
212 0 1ST 6
213 212
214 212
215 212
216 212
217 212
230 212
231 212
142 0 1ST 6
143 142
144 142
145 142
146 142
147 142

$ Beam load assignments
1   0 1ST 0 15 16      $ Lisplank 3 m -
Floor loading
2   1
3   1
4   1
5   1
6   1
7   1
8   1
9   1
10  1
11  1
12  1
21  1
22  1
23  1
24  1
25  1
26  1
27  1
28  1
13  0 1ST 0 17 18      $ Lisplank 2,5 m
14  13
15  13
16  13
17  13
18  13
19  13
20  13
29  0 1ST 0 11 12      $ Consol 2 m
30  29
31  29
32  29
33  29
34  29
35  29
36  29
37  29
38  29
39  29
46  29
47  29
48  29
49  29
50  29
51  29
58  29
59  29
60  29
61  29
62  29
```

```
64 29
65 29
66 29
67 29
68 29
40 0 1ST 0 9 10      $ Consol 1,5 m
41 40
42 40
43 40
44 40
45 40
52 40
53 40
54 40
55 40
56 40
57 40
69 0 1ST 0 5 6       $ Primary beam 6 m
70 69
71 69
72 69
73 69
74 69
75 69
76 69
77 69
78 69
79 69
80 69
81 69
82 69
83 69
84 69
85 69
86 69
87 69
88 69
89 69
91 69
92 69
93 69
94 69
95 69
96 69
97 69
98 69
99 69
100 69
101 0 1ST 0 3 4      $ Primary beam 5 m
102 101
103 101
104 101
105 101
106 101
107 101
108 101
109 101
110 101
111 101
112 101
113 101
114 101
115 101
116 101
117 101
118 101
119 101
120 101
121 101
122 101
123 101
124 101
125 101
126 101
127 101
128 101
130 101
131 101
132 101
133 0 1ST 0 7 8      $ Primary beam 8,5 m
134 133
135 133
136 133
137 133
138 133
139 133
140 133
141 133
142 133
143 133
144 133
145 133
146 133
147 133
148 133
149 133
150 133
151 133
152 133
153 133
154 133
155 133
156 133
157 0 1ST 0 1 2    $ Secondary beam 6 m
158 157
159 157
160 157
161 157
162 157
163 157
164 157
165 157
166 157
167 157
169 157
170 157
171 157
172 157
173 157
174 157
175 157
176 157
159 0 1ST 0 3 4    $ Secondary beam 3 m
164 159
169 159
174 159
177 159
178 159
179 159
180 159
196 0 1ST 0 3 4    $ Secondary beam 5 m
197 196
198 196
199 196
200 196
201 196
202 196
203 196
204 196
205 196
206 196
207 196
208 196
209 196
210 196
211 196
212 0 1ST 0 21 22    $ Primary beam 8 m
213 212
214 212
215 212
216 212
217 212
230 212
231 212
218 0 1ST 0 19 20  $ Scndary beam 8 m
219 218
220 218
221 218
222 0 1ST 0 7 8      $ Primary beam 3 m
223 222
224 222
225 222
226 0 1ST 0 9 10     $ Consol 1,5 m
227 226
228 226
229 226
232 0 1ST 0 5 6   $ Secondary beam 6 m
233 232
234 232
235 232
236 232
237 232
238 232
239 232
240 232
241 232
242 232
243 232
244 232
245 232
246 232
247 232

$ Frame location data
 1 0 0 0 0 /SECONDARY FLOOR
$ Load case data
 1 0 1.2 1.2 1.6
$ End of input data
```


Z
Y
X
scndflor.PST
UNDEFORMED
SHAPE
TOP 2ND
BOT 1ST
OPTIONS
HIDDEN LINES
ETABS



scndflor.PST

FRAME

LOADING

LOAD II

TOP 2ND

BOT 1ST

MINIMA

w .6120E+01

P .0000E+00

M .0000E+00

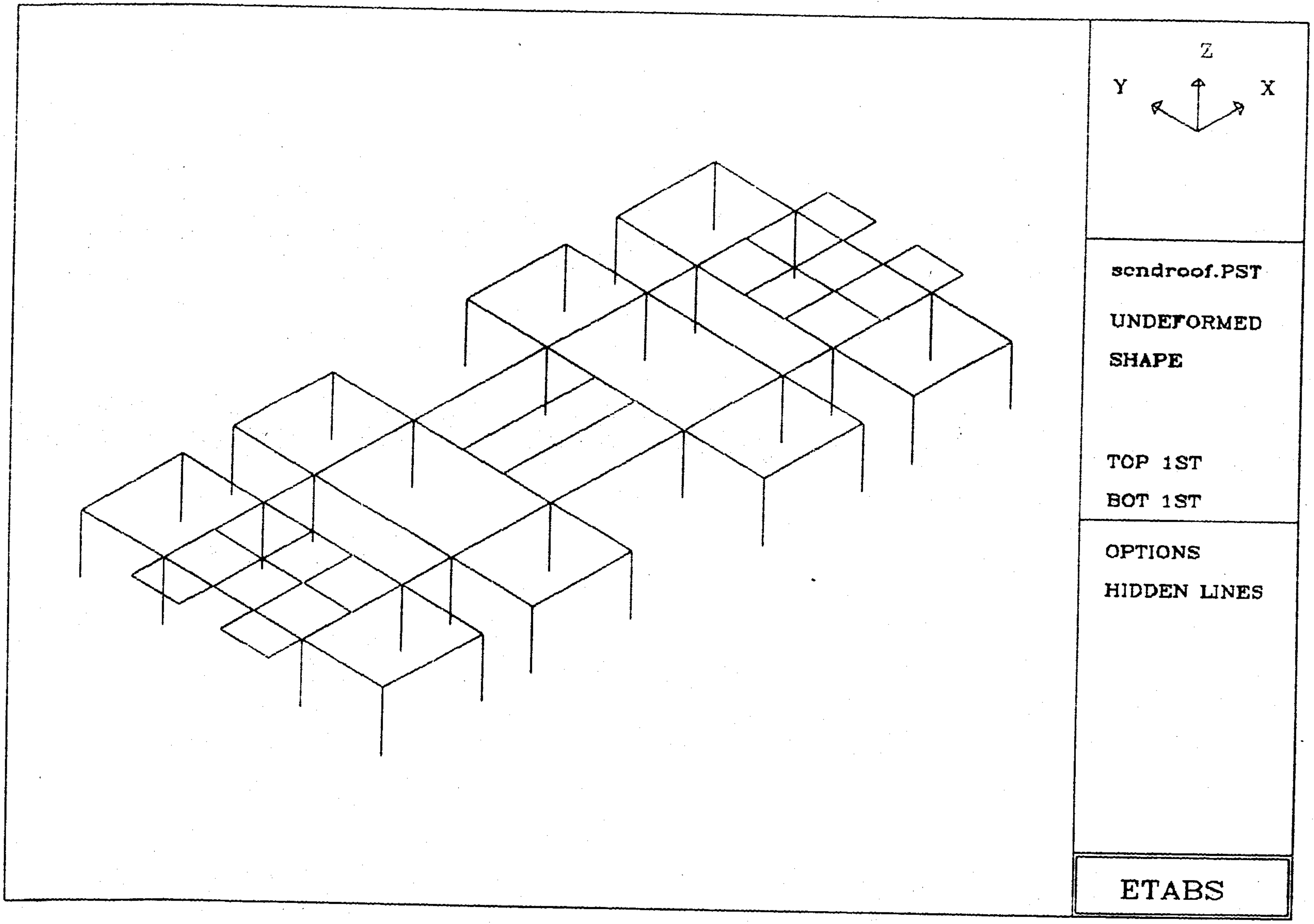
MAXIMA

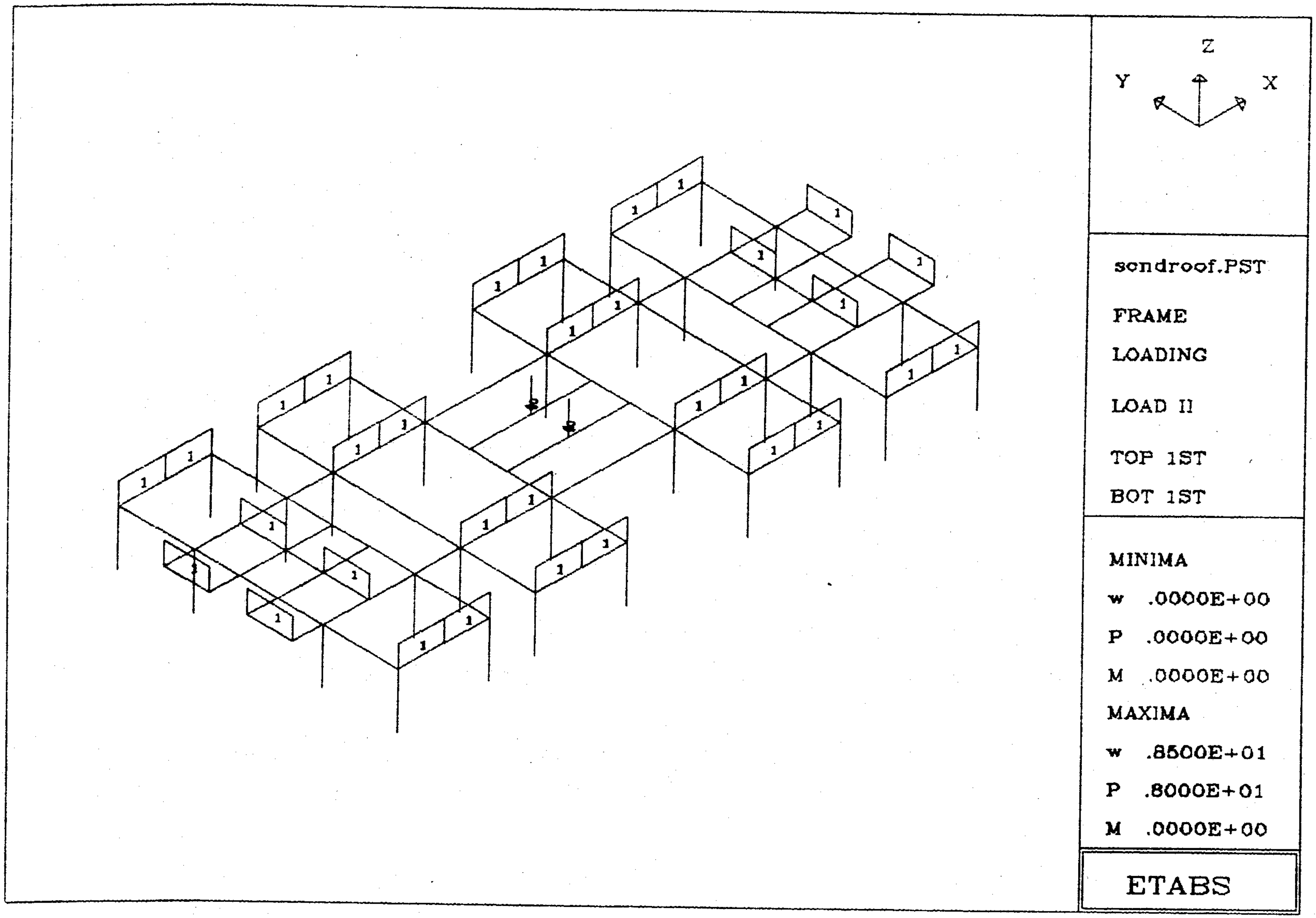
w .2625E+02

P .0000E+00

M .0000E+00

ETABS


Z
Y
X
scndroof.PST
UNDEFORMED
SHAPE
TOP 1ST
BOT 1ST
OPTIONS
HIDDEN LINES
ETABS



```
scndroof.PST

FRAME

LOADING

LOAD II

TOP 1ST

BOT 1ST

MINIMA

w  .0000E+00

P  .0000E+00

M  .0000E+00

MAXIMA

w  .8500E+01

P  .8000E+01

M  .0000E+00

ETABS
```

```
Final Project-Name Static Three Dimensional Frame
Taman Sejahtera Building Structure Analysis,
Units kN-M-Sec
$ Control data
 10 1 1 2 4 7 1 4 5 0 0 0 2 0 1 2 1 1 1
 10 0.0001 0 1
$ Mass data
 1 8 1/10
 0.823  5     11.25  6     18.5
 0.823  37     11.25  6     18.5
 0.773  21    7.5   26    6
 0.773  21    15    26    6
 0.964  14    4.5   6     2.5
 0.964  28    4.5   6     2.5
 0.964  14    18    6     2.5
 0.964  28    18    6     2.5
 2 11 1/10
 5.58  5     11.25  6     22.5
 5.58  9.5   11.25  3     13.5
 5.58  14    11.25  6     21.5
 5.58  21    11.25  8     8.5
 5.58  28    11.25  6     21.5
 5.58  32.5   11.25  3     13.5
 5.58  37    11.25  6     22.5
 5.58  1     6     2     8
 5.58  1     16.5   2     8
 5.58  41    6     2     8
 5.58  41    16.5   2     8
$ Story data
ROOF   3.65   1
9TH    3.65   2
8TH    3.65   2
7TH    3.65   2
6TH    3.65   2
5TH    3.65   2
4TH    3.65   2
3RD    3.65   2
2ND    3.65   2
1ST    3.4    2
$ Frame material data
 1 C 2.9E7  24   0.15          $ Main frame material
$ Column properties
 1 1 RECT  0.7  0.7           $ Main frame column
 2 1 RECT  0.75 0.75           $ Main frame column
 3 1 RECT  0.7  0.85          $ Main frame column
 4 1 RECT  0.75 0.9           $ Main frame column
$ Beam properties
 1 1 RECT  0.5   0 0.3        $ Main frame beam
 2 1 RECT  0.6   0 0.3        $ Main frame beam
 3 1 RECT  0.7   0 0.4        $ Main frame beam
 4 1 RECT  0.8   0 0.4        $ Main frame beam
 5 1 RECT  0.9   0 0.4        $ Main frame beam
$ Frame control data
 MAIN FRAME
 1 10 32 46 0 0 0 16 2
$ Column line orientations
 1    2    2
 2    8    2
 3    11    2
 4    17    2
 5    25    2
 6    31    2
 7    34    2
 8    40    2
 9    2    7
 10    8    7
 11    11    7
 12    17    7
 13    25    7
 14    31    7
 15    34    7
 16    40    7
 17    2    15.5
 18    8    15.5
 19    11    15.5
 20    17    15.5
 21    25    15.5
 22    31    15.5
 23    34    15.5
 24    40    15.5
 25    2    20.5
 26    8    20.5
 27    11    20.5
 28    17    20.5
 29    25    20.5
 30    31    20.5
 31    34    20.5
 32    40    20.5
$ Bay connectivities
 1    1    2
 2    3    4
 3    5    6
 4    7    8
 5    9    10
 6    10    11
 7    11    12
 8    12    13
 9    13    14
 10    14    15
 11    15    16
 12    17    18
 13    18    19
 14    19    20
 15    20    21
 16    21    22
 17    22    23
 18    23    24
 19    25    26
 20    27    28
 21    29    30
 22    31    32
 23    1    9
 24    9    17
 25    17    25
 26    2    10
 27    10    18
 28    18    26
 29    3    11
 30    11    19
 31    19    27
 32    4    12
 33    12    20
 34    20    28
 35    5    13
 36    13    21
 37    21    29
 38    6    14
 39    14    22
 40    22    30
 41    7    15
 42    15    23
 43    23    31
 44    8    16
 45    16    24
 46    24    32
$ Beam span vertical loading
 1   1         $ Roof A point load
 2.5 24.38/1.2
 2   2         $ Roof A point load+secondary beam
 3   54.38/1.2 5.5 54.38/1.2
 3   2 0 24.38/1.2 24.38/1.2         $ Roof B+D point load
 3   4.48/1.2  5.5 4.48/1.2
 4   1         $ Roof C+A point load
 2.5 49.38/1.2
 5   0 8       $ Primary roof beam 6m eq DL
 6   1         $ Primary roof beam 8m point load
 4   12
 7   1 15.3                $ Primary beam 5m point load,eq DL
 2.5 167.06/1.2
 8   1 25.25               $ Primary beam 6m point load,eq DL
```

```
9  2 18.36             $ Primary beam 8.5m point load,eq DL
3  197.65/1.2 5.5 197.65/1.2
10 2 18.36             $ Primary beam 8.5m point load,eq DL
3  345.1/1.2  5.5 345.1/1.2
11 0 5                 $ Primary beam 5m eq LL
12 0 8.25              $ Primary beam 6m eq LL
13 0 6                 $ Primary beam 8.5m, 3m, 8,5m eq LL
14 0 18.36             $ Primary beam 3m eq DL
15 0 40.45             $ Primary beam 8m stair,eq DL
16 0 4.29              $ Primary beam 8m eq LL
$ Column assignments
1  0 ROOF 1 9
2  1
3  1
4  1
5  1
6  1
7  1
8  1
25 1
26 1
27 1
28 1
29 1
30 1
31 1
32 1
9  0 ROOF 1
10 9
11 9
14 9
15 9
16 9
17 9
18 9
19 9
22 9
23 9
24 9
12 0 ROOF 3
13 12
20 12
21 12
9  0 9TH 2 8
10 9
11 9
14 9
15 9
16 9
18 9
19 9
22 9
23 9
24 9
12 0 9TH 4 8
13 12
20 12
21 12

$ Beam assignments
23 0 ROOF 1
25 23
26 23
28 23
29 23
31 23
32 23
34 23
35 23
37 23
38 23
40 23
41 23
43 23
44 23
46 23
1  0 ROOF 1
2  1
3  1
4  1
5  1
7  1
9  1
11 1
12 1
14 1
16 1
18 1
19 1
20 1
21 1
22 1
24 0 ROOF 2
27 24
30 24
39 24
42 24
45 24
6  0 ROOF 1
10 6
13 6
17 6
8  0 ROOF 1
15 8
33 0 ROOF 2
36 33
23 0 9TH 3 8
25 23
26 23
28 23
29 23
31 23
32 23
34 23
35 23
37 23
38 23
40 23
41 23
43 23
44 23
46 23
1  0 9TH 3 8
2  1
3  1
4  1
5  1
7  1
9  1
11 1
12 1
14 1
16 1
18 1
19 1
20 1
21 1
22 1
24 0 9TH 4 8
27 24
30 24
39 24
42 24
45 24
6  0 9TH 4 8
10 6
13 6
17 6
```

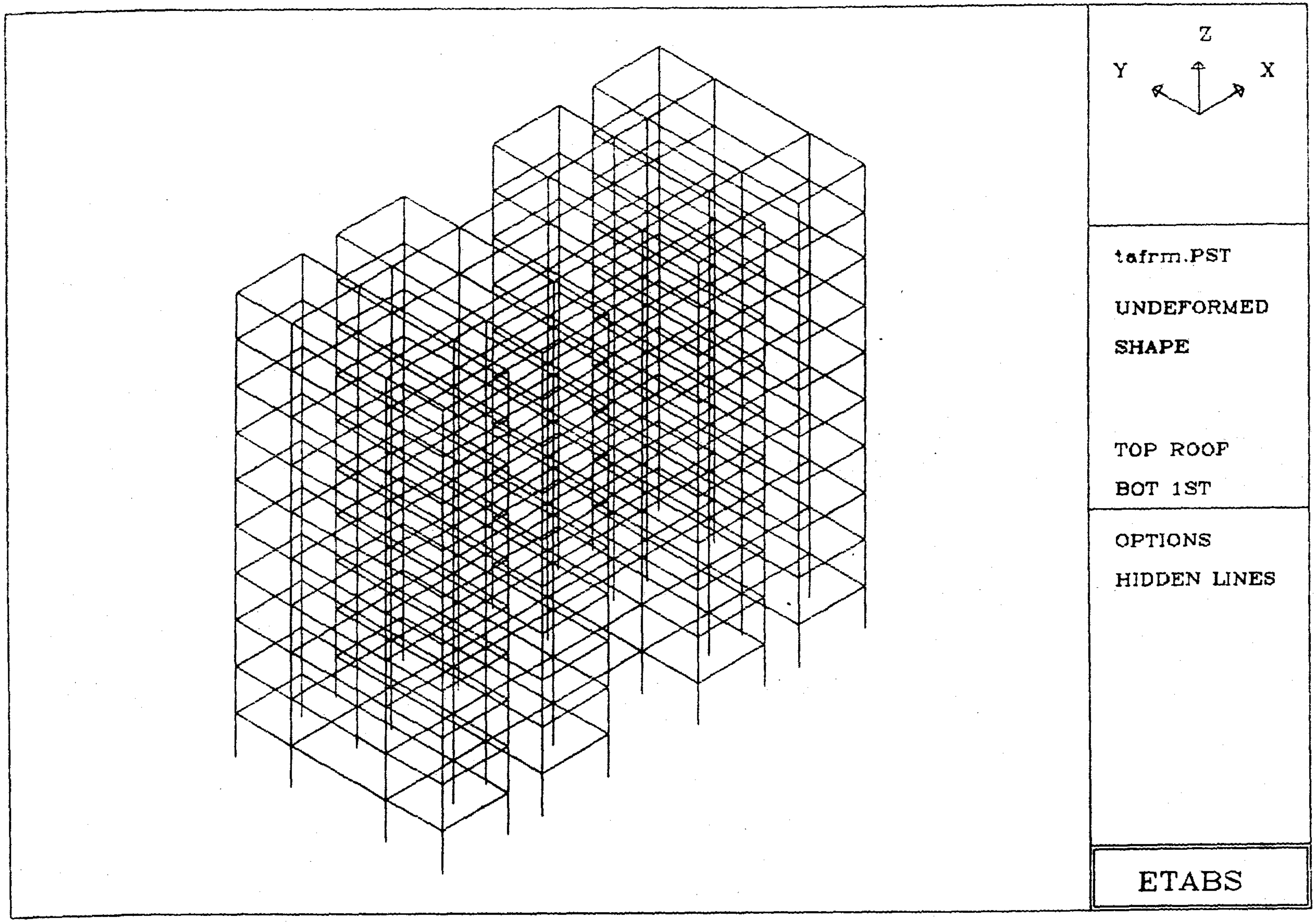
```
 8  0 9TH 5 8
 15  8
 33  0 9TH 5 8
 36  33

$ Beam load assignments
 26  0 ROOF 0 1          $ Roof A loading
 28  26
 41  26
 43  26
 27  0 ROOF 0 2
 30  27
 33  27
 36  27
 39  27
 42  27
 24  0 ROOF 0 3          $ Roof B+D loading
 45  24
 29  0 ROOF 0 4          $ Roof C+A loading
 31  29
 32  29
 34  29
 35  29
 37  29
 38  29
 40  29
 1   0 ROOF 0 5          $ Primary roof beam 6m eq DL
 2   1
 3   1
 4   1
 7   1
 9   1
 14  1
 16  1
 19  1
 20  1
 21  1
 22  1
 8   0 ROOF 0 6          $ Primary roof beam 8m point load
 15  8
 23  0 9TH 0 7 11 5      $ Primary beam 5m - Floor loading
```

```
 25  23
 26  23
 28  23
 29  23
 31  23
 32  23
 34  23
 35  23
 37  23
 38  23
 40  23
 41  23
 43  23
 44  23
 46  23
 1    0 9TH 0 8 12 8     $ Primary beam 6m
 2    1
 3    1
 4    1
 5    1
 7    1
 9    1
 11   1
 12   1
 14   1
 16   1
 18   1
 19   1
 20   1
 21   1
 22   1
 24   0 9TH 0 9 13 8     $ Primary beam 8,5m
 27   24
 30   24
 39   24
 42   24
 45   24
 6    0 9TH 0 14 13 8    $ Primary beam 3m
 10   6
 13   6
 17   6
```

```
 8   0 9TH 0 15 16 8    $ Primary beam 8m
 15  8
 33  0 9TH 0 10 13 8    $ Primary beam 8.5m
 36  33

 $ Frame location data
 1 0 0 0 0 /MAIN FRAME
 $ Response spectrum data
 ELCENTRO RESPONSE SPECTRUM
 2 22 CQC 10 0.05
 0 90
      .0     .3275
      .0263  .3299
      .0278  .3429
      .0345  .3637
      .037   .3410
      .0417  .3458
      .0476  .3516
      .0556  .3546
      .0667  .4455
      .0769  .5053
      .1     .5816
      .1130  .5292
      .1361  .6615
      .2062  .9697
      .2597  .8376
      .3509  .8703
      .4255  .909
      .5605  .5828
      .7407  .4761
      1.1755 .2713
      2.057  .1983
      1000   .0
$ Load case data
 1 0 1 1
 2 0 0 0 1
 3 0 0 0 0 0 0 1  0.3
 4 0 0 0 0 0 0 0 0.3 1
$ End of input data
```



tafrm.PST

UNDEFORMED

SHAPE

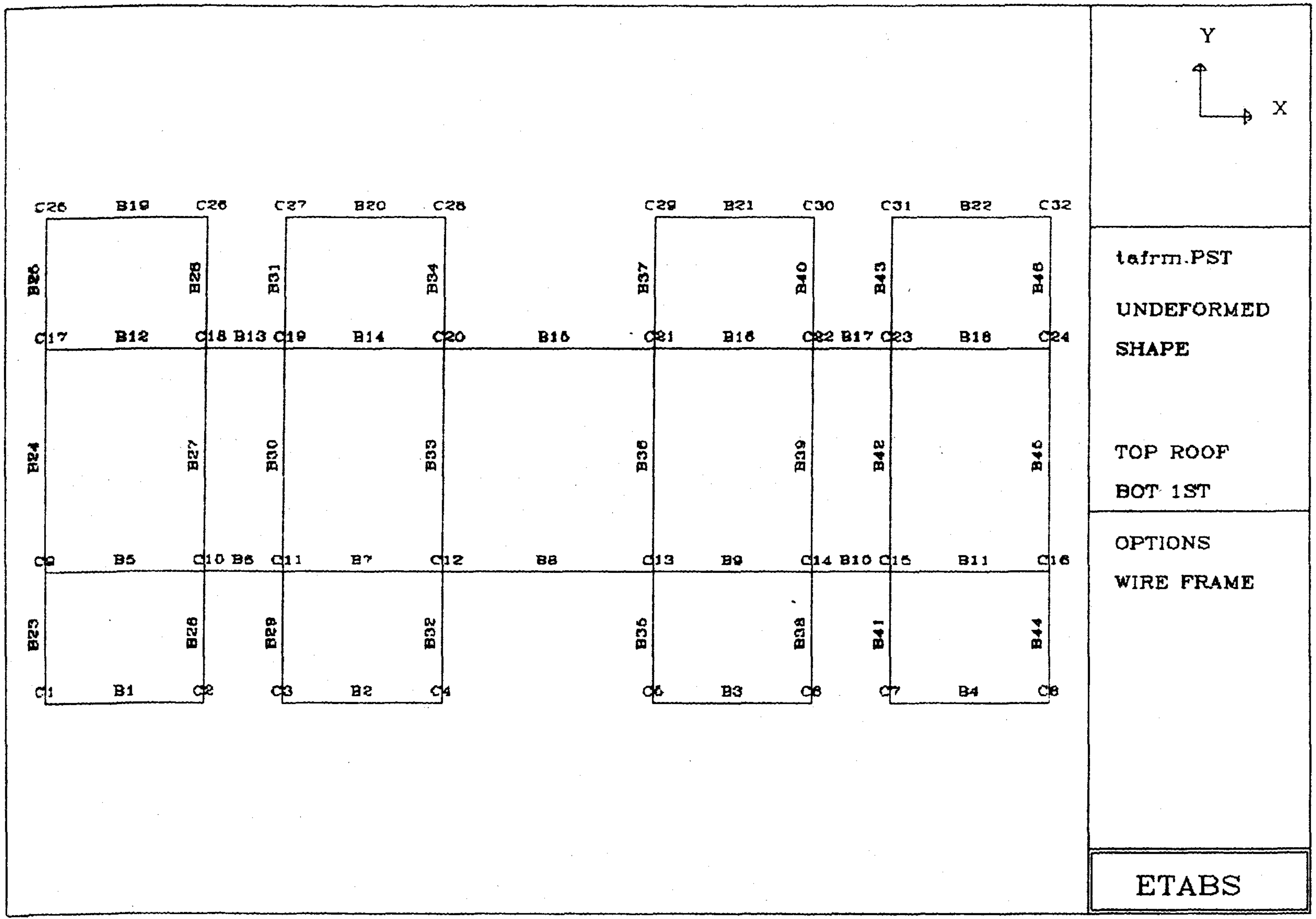
TOP ROOF

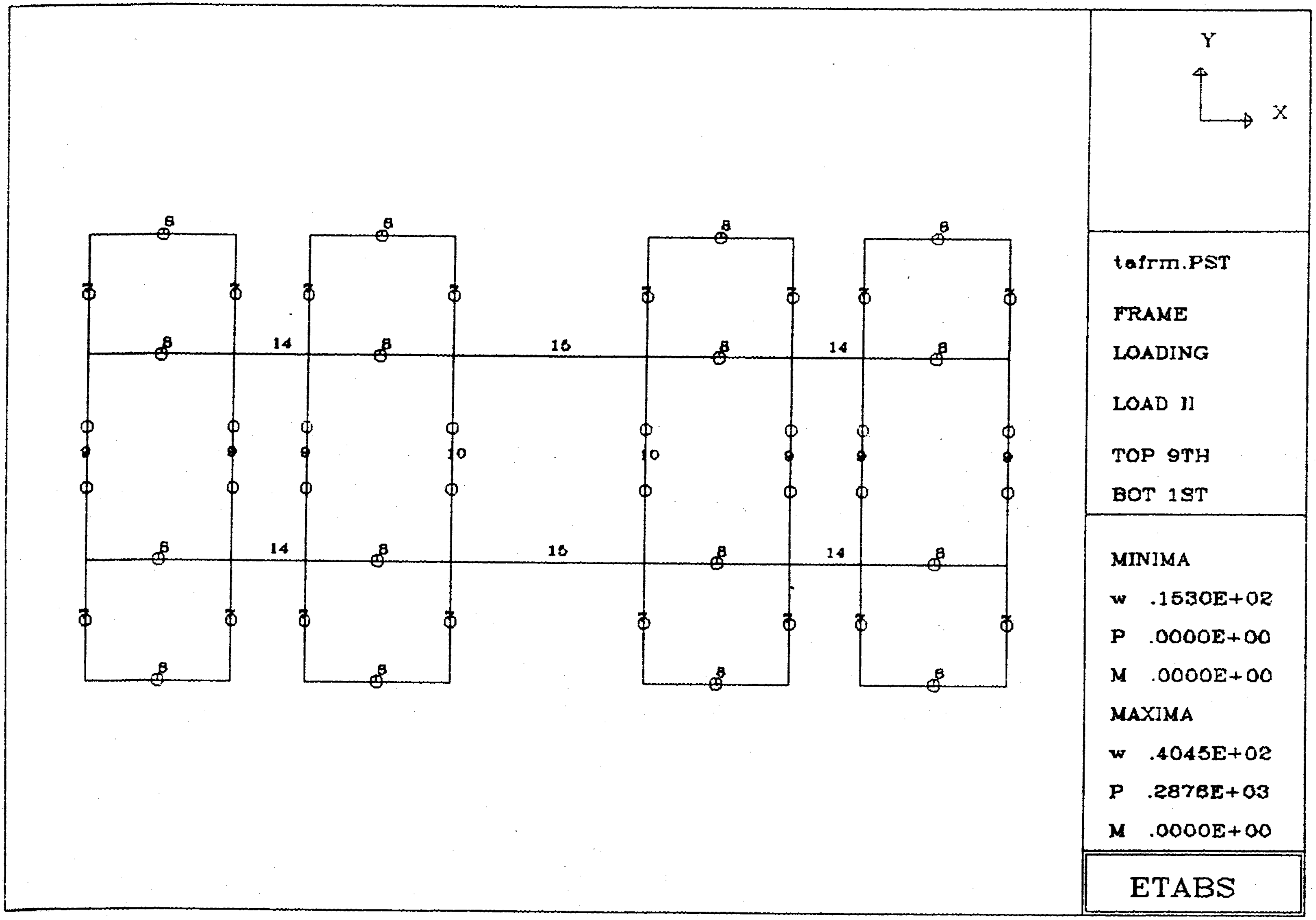
BOT 1ST

OPTIONS

HIDDEN LINES

ETABS


Y
X
C25 B19 C26 C27 B20 C28 C29 B21 C30 C31 B22 C32
B26 B28 B31 B34 B37 B40 B43 B46
C17 B12 C18 B13 C19 B14 C20 B15 C21 B16 C22 B17 C23 B18 C24
B24 B27 B30 B33 B36 B39 B42 B45
C9 B5 C10 B6 C11 B7 C12 B8 C13 B9 C14 B10 C15 B11 C16
B23 B25 B29 B32 B35 B38 B41 B44
C1 B1 C2 C3 B2 C4 C5 B3 C6 C7 B4 C8
tafrm.PST
UNDEFORMED
SHAPE
TOP ROOF
BOT 1ST
OPTIONS
WIRE FRAME
ETABS



tafrm.PST

FRAME

LOADING

LOAD 11

TOP 9TH

BOT 1ST

MINIMA

w .1530E+02

P .0000E+00

M .0000E+00

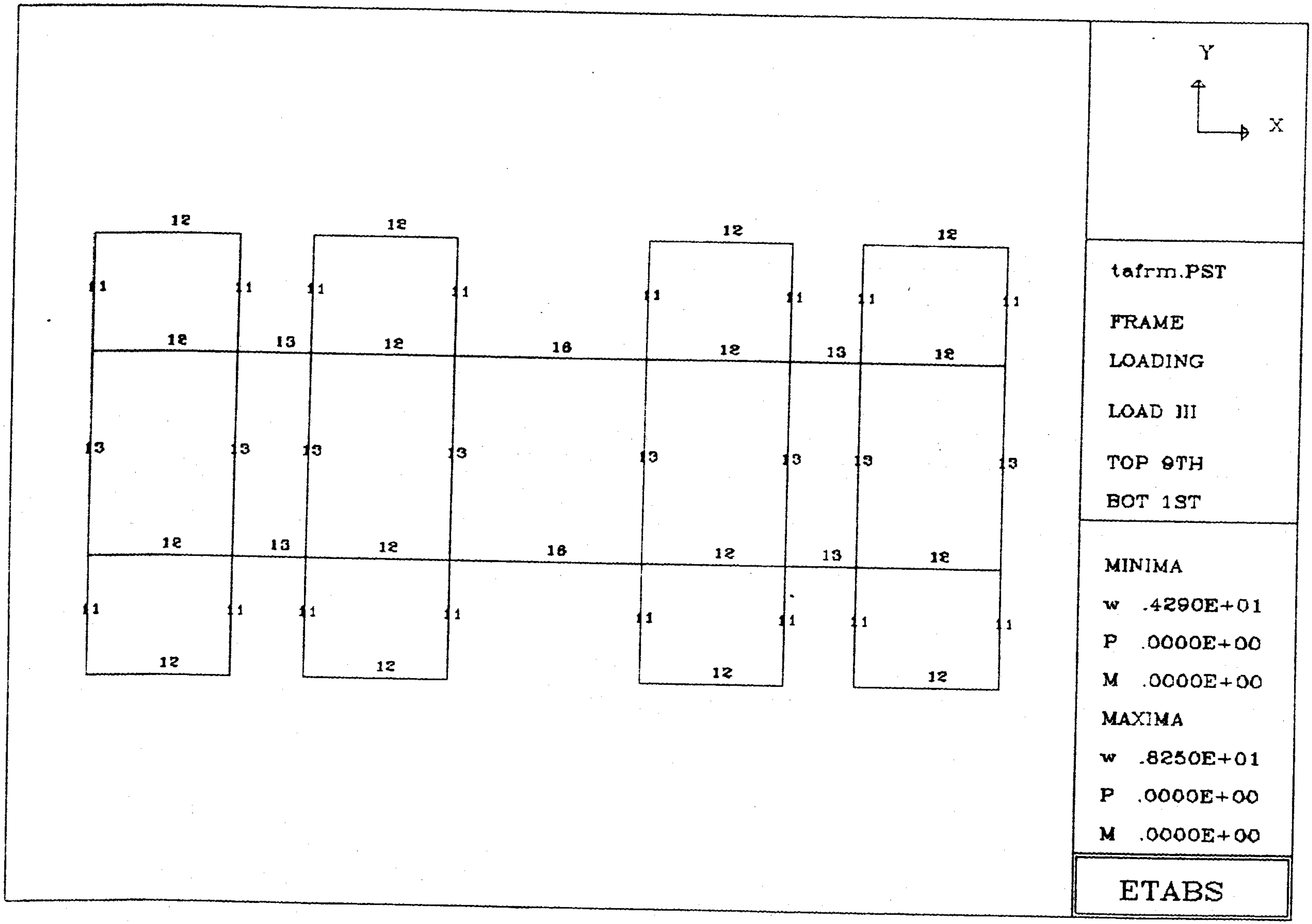
MAXIMA

w .4045E+02

P .2876E+03

M .0000E+00

ETABS



tafrm.PST

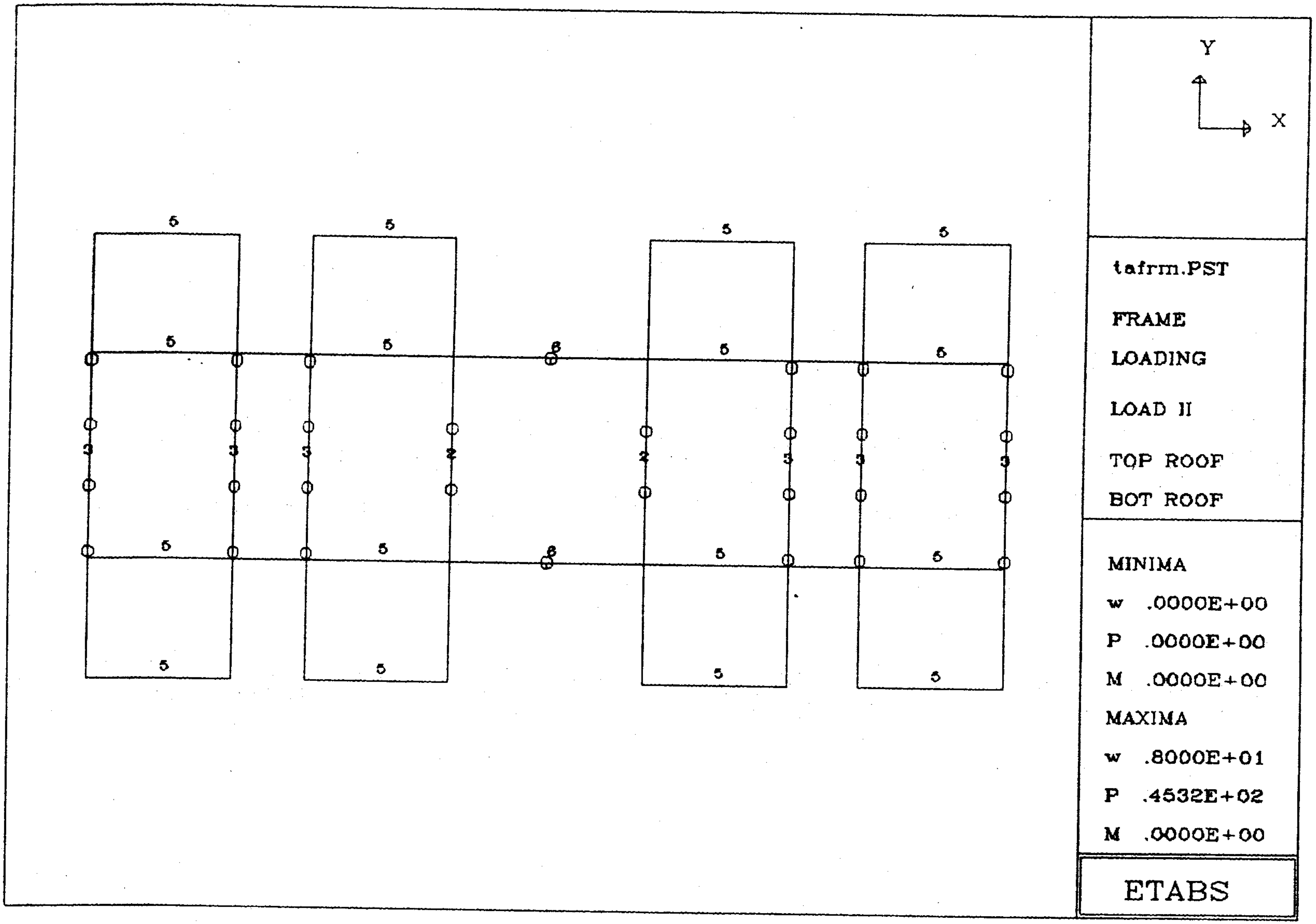
FRAME
LOADING

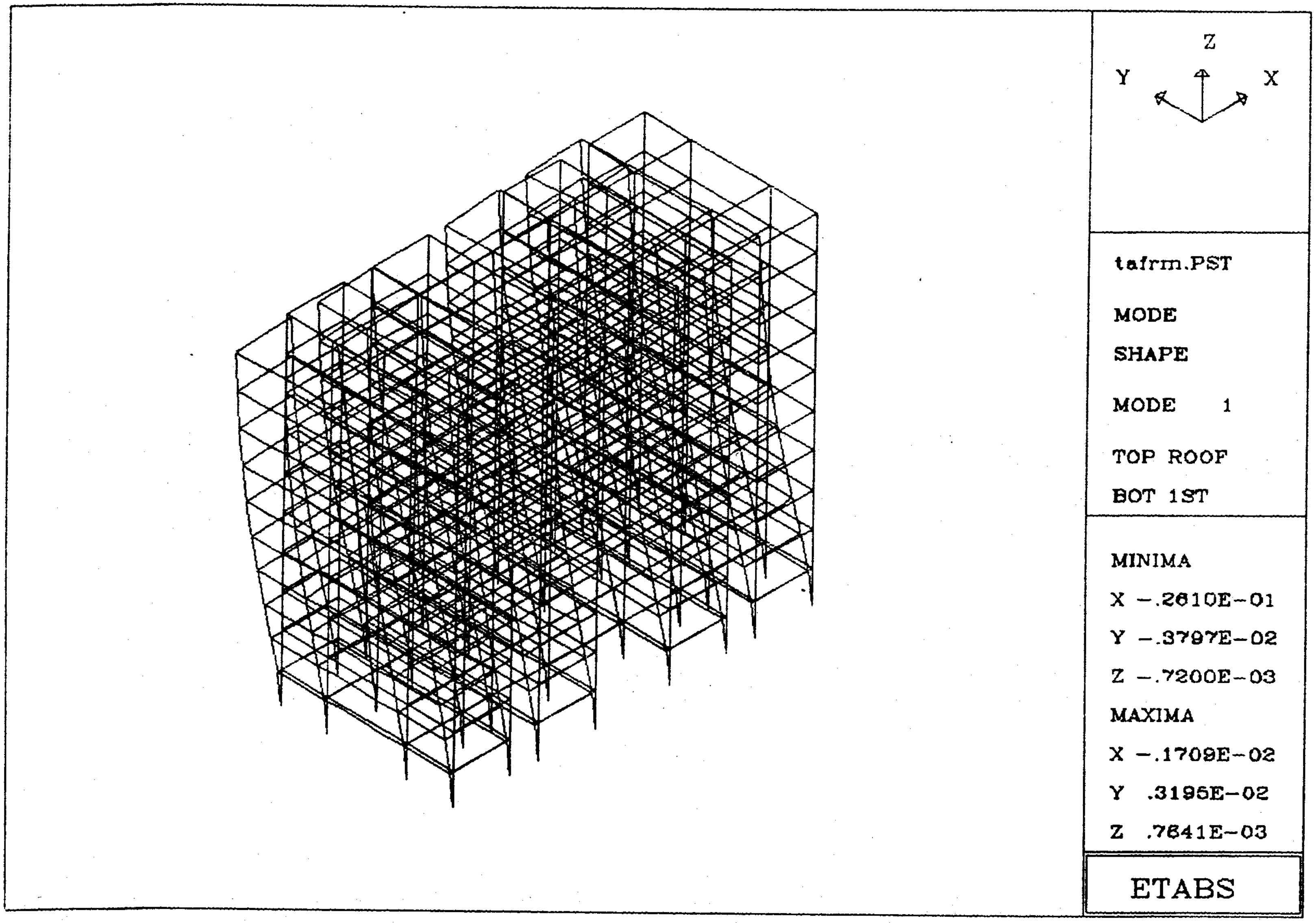
LOAD III

TOP 9TH
BOT 1ST

MINIMA
w .4290E+01
P .0000E+00
M .0000E+00
MAXIMA
w .8250E+01
P .0000E+00
M .0000E+00

ETABS


Y
X
5 5 5 5
5 5 8 5 5
3 3 3 2 2 3 3 3
5 5 8 5 5
5 5 5 5
tafrm.PST
FRAME
LOADING
LOAD II
TOP ROOF
BOT ROOF
MINIMA
w .0000E+00
P .0000E+00
M .0000E+00
MAXIMA
w .8000E+01
P .4532E+02
M .0000E+00
ETABS



tafrm.PST

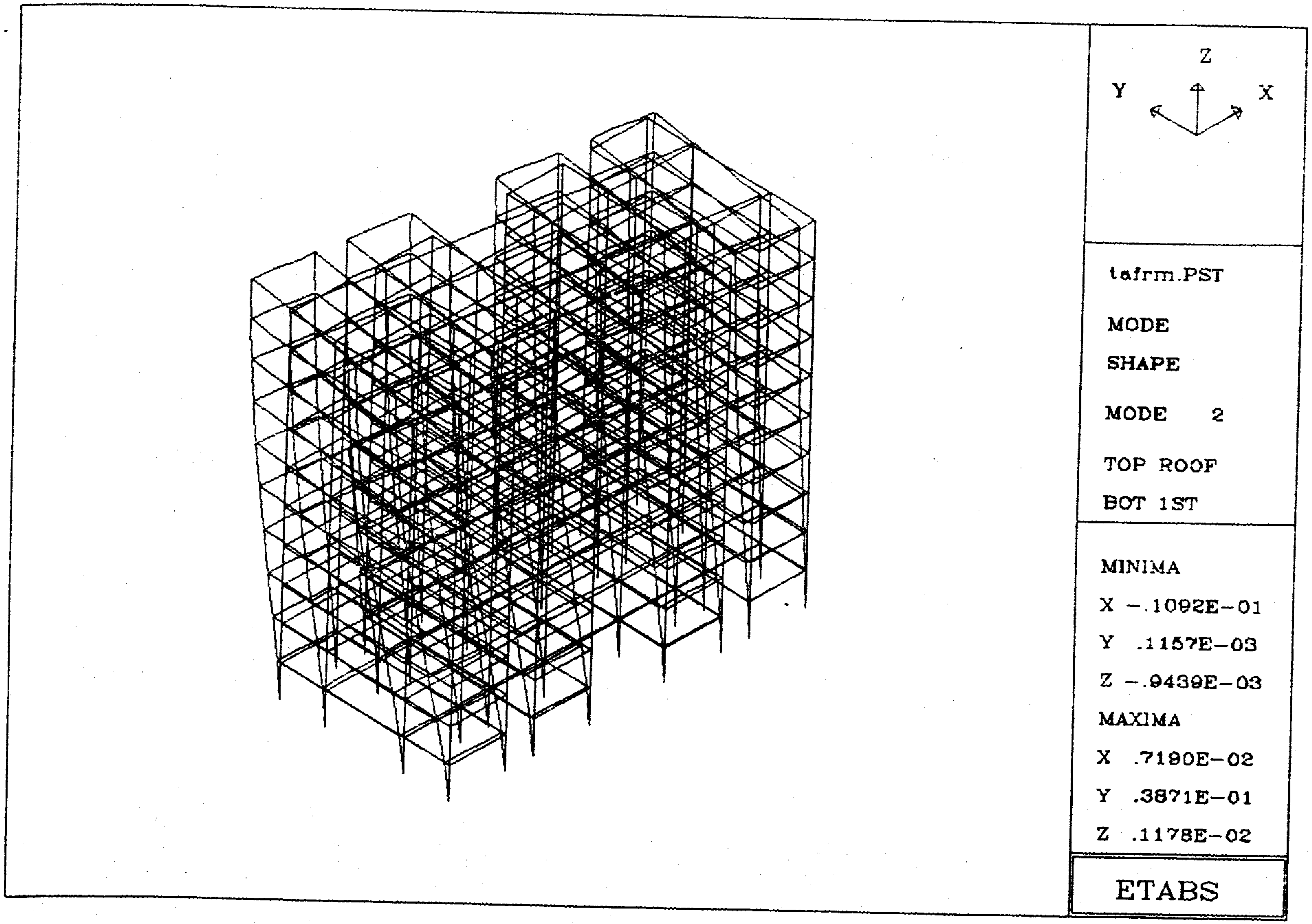
MODE
SHAPE

MODE 1

TOP ROOF
BOT 1ST

MINIMA
X -.2610E-01
Y -.3797E-02
Z -.7200E-03
MAXIMA
X -.1709E-02
Y .3195E-02
Z .7641E-03

ETABS



tafrm.PST

MODE
SHAPE

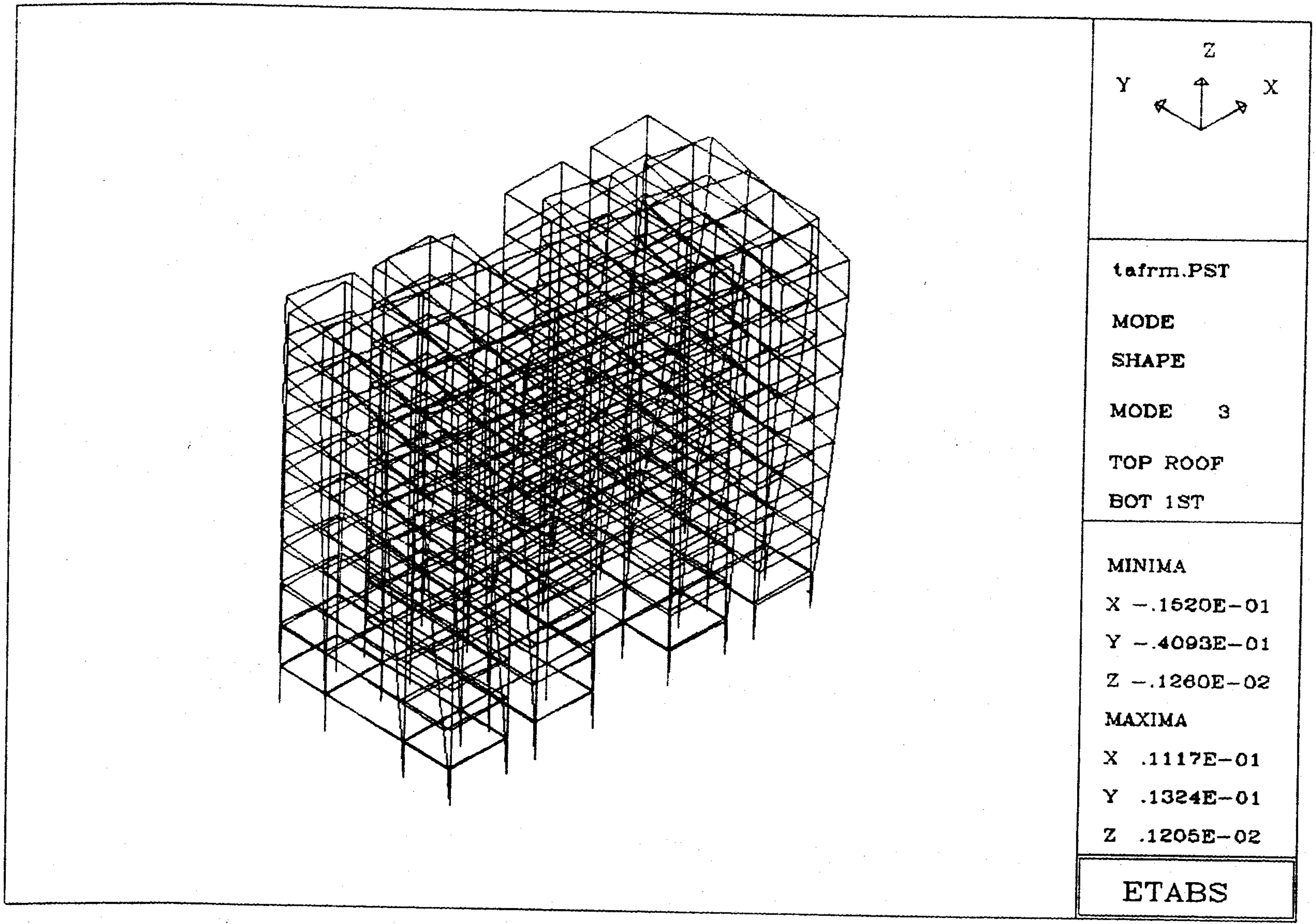
MODE 2

TOP ROOF
BOT 1ST

MINIMA
X -.1092E-01
Y .1157E-03
Z -.9439E-03

MAXIMA
X .7190E-02
Y .3871E-01
Z .1178E-02

ETABS



tafrm.PST

MODE
SHAPE

MODE 3

TOP ROOF
BOT 1ST

MINIMA
X -.1520E-01
Y -.4093E-01
Z -.1260E-02
MAXIMA
X .1117E-01
Y .1324E-01
Z .1205E-02

ETABS

```
              EXTENDED THREE DIMENSIONAL ANALYSIS OF BUILDING SYSTEMS
                                VERSION 5.10
                                     BY
                              ASHRAF HABIBULLAH
                           Copyright (c) 1983-1989
                       COMPUTERS AND STRUCTURES, INC.
                             All rights reserved

etabs                             PAGE 179
                       PROGRAM:ETABS/FILE:tafm.FRM
FINAL PROJECT-NINE STORIES THREE DIMENSIONAL FRAME
TAMAN SEJAHTERA BUILDING STRUCTURE ANALYSIS, UNITS:KN-M-SEC

COLUMN FORCES AT LEVEL 1ST     IN FRAME /MAIN FRAME

COL OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID  ID POINT  MOMENT  SHEAR  MOMENT  SHEAR  FORCE  MOMENT
 1 CASE 1  TOP    67.96  -41.22   45.86  -27.59 -3081.15    .00
      BOTTOM  -43.34           -28.64
 1 CASE 2  TOP     8.85   -5.37    3.61   -2.19  -356.63    .00
      BOTTOM   -5.65            -2.30
 1 CASE 3  TOP    17.52  194.57    4.54   60.84  1536.16    .00
      BOTTOM  593.59           160.77
 1 CASE 4  TOP     5.27   58.39   14.79  202.57  1726.89    .00
      BOTTOM  161.61           588.64

 2 CASE 1  TOP   -67.57   40.99   46.84  -28.19 -3115.29    .00
      BOTTOM   43.10           -29.26
 2 CASE 2  TOP    -8.77    5.32    3.83   -2.33  -364.34    .00
      BOTTOM    5.60            -2.44
 2 CASE 3  TOP    15.76  196.07   16.30   67.97  1132.22    .00
      BOTTOM  540.16           168.25
 2 CASE 4  TOP     4.74   58.84   18.32  204.71  1590.61    .00
      BOTTOM  162.08           537.88

 3 CASE 1  TOP    67.94  -41.21   46.85  -28.19 -3137.59    .00
      BOTTOM  -43.33           -29.27
 3 CASE 2  TOP     8.79   -5.33    3.83   -2.32  -365.11    .00
      BOTTOM   -5.60            -2.44
 3 CASE 3  TOP    15.59  196.27   16.22   67.92  1148.89    .00
      BOTTOM  540.37           168.20
 3 CASE 4  TOP     4.97   59.06   18.34  204.73  1594.57    .00
      BOTTOM  162.30           537.90

 4 CASE 1  TOP   -66.78   40.51   48.36  -29.11 -3226.04    .00
      BOTTOM   42.59           -30.23
 4 CASE 2  TOP    -8.76    5.31    3.80   -2.30  -363.14    .00
      BOTTOM    5.59            -2.42
 4 CASE 3  TOP    16.89  195.13    8.77   63.61  1447.74    .00
      BOTTOM  539.18           163.67
```

```
 4 CASE 4  TOP     5.36   58.72   20.72  206.87  1701.85    .00
      BOTTOM  161.94           540.15

 5 CASE 1  TOP    66.78  -40.51   48.36  -29.11 -3226.04    .00
      BOTTOM  -42.59           -30.23
 5 CASE 2  TOP     8.76   -5.31    3.80   -2.30  -363.14    .00
      BOTTOM   -5.59            -2.42
 5 CASE 3  TOP    16.89  195.14    8.78   63.62  1447.75    .00
      BOTTOM  539.18           163.68
 5 CASE 4  TOP     5.37   58.73   20.72  206.87  1755.86    .00
      BOTTOM  161.95           540.14

 6 CASE 1  TOP   -67.94   41.21   46.85  -28.19 -3137.59    .00
      BOTTOM   43.33           -29.27
 6 CASE 2  TOP    -8.79    5.33    3.83   -2.32  -365.11    .00
      BOTTOM    5.60            -2.44

COL OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID  ID POINT  MOMENT  SHEAR  MOMENT  SHEAR  FORCE  MOMENT
 6 CASE 3  TOP    15.59  196.27   16.21   67.90  1145.89    .00
      BOTTOM  540.38           168.18
 6 CASE 4  TOP     4.98   59.07   18.33  204.70  1584.58    .00
      BOTTOM  162.31           537.85

 7 CASE 1  TOP    67.57  -40.99   46.84  -28.19 -3115.29    .00
      BOTTOM  -43.10           -29.26
 7 CASE 2  TOP     8.77   -5.32    3.83   -2.33  -364.34    .00
      BOTTOM   -5.60            -2.44
 7 CASE 3  TOP    15.76  196.07   16.30   67.96  1122.23    .00
      BOTTOM  540.16           168.25
 7 CASE 4  TOP     4.75   58.84   18.30  204.68  1566.62    .00
      BOTTOM  162.08           537.83

 8 CASE 1  TOP   -67.96   41.22   45.86  -27.59 -3081.15    .00
      BOTTOM   43.34           -28.64
 8 CASE 2  TOP    -8.85    5.37    3.61   -2.19  -356.63    .00
      BOTTOM    5.65            -2.30
 8 CASE 3  TOP    17.52  194.57    4.53   60.82  1526.15    .00
      BOTTOM  538.59           160.74
 8 CASE 4  TOP     5.27   58.39   14.76  202.52  1686.90    .00
      BOTTOM  161.61           535.55

 9 CASE 1  TOP    69.63  -42.01   74.93  -47.63 -4833.03    .00
      BOTTOM  -43.80           -48.91
 9 CASE 2  TOP     9.10   -5.49    8.14   -5.21  -550.77    .00
      BOTTOM   -5.72            -5.40
 9 CASE 3  TOP    63.22  228.32   21.49   95.52  1423.55    .00
      BOTTOM  678.22           227.06
 9 CASE 4  TOP    18.99   68.52   71.32  318.16   844.48    .00
      BOTTOM  203.51           756.60
```

```
10 CASE 1  TOP   -51.95   33.24   75.86  -48.22 -5086.72    .00
    BOTTOM   34.48          -49.52
10 CASE 2  TOP    -6.11    3.91    8.36   -5.35  -609.37    .00
    BOTTOM    4.06           -5.55
10 CASE 3  TOP   189.73  403.53   32.31  102.43  1867.84    .00
    BOTTOM  860.12          234.22
10 CASE 4  TOP    57.05  121.15   74.55  320.22   972.81    .00
    BOTTOM  258.14          758.73

11 CASE 1  TOP    52.08  -33.32   75.82  -48.20 -5111.21    .00
    BOTTOM  -34.56          -49.50
11 CASE 2  TOP     5.90   -3.78    8.33   -5.33  -608.91    .00
    BOTTOM   -3.92           -5.53
11 CASE 3  TOP   189.21  403.22   32.11  102.30  1825.74    .00
    BOTTOM  859.81          234.08
11 CASE 4  TOP    57.62  121.52   74.14  319.95   948.89    .00
    BOTTOM  258.51          758.44

COL OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID   ID POINT  MOMENT   SHEAR  MOMENT   SHEAR   FORCE  MOMENT
12 CASE 1  TOP    17.16  -10.35  116.61  -77.25 -6923.33    .00
    BOTTOM  -10.79          -76.50
12 CASE 2  TOP    -1.25     .76    8.34   -5.57  -698.18    .00
    BOTTOM     .79           -5.57
12 CASE 3  TOP    15.22  322.78   18.75  139.83   720.76    .00
    BOTTOM  864.75          362.00
12 CASE 4  TOP     5.41   97.35   54.35  460.66   387.20    .00
    BOTTOM  259.97         1201.24

13 CASE 1  TOP   -17.16   10.35  116.61  -77.25 -6923.33    .00
    BOTTOM   10.79          -76.50
13 CASE 2  TOP     1.25    -.76    8.34   -5.57  -698.18    .00
    BOTTOM    -.79           -5.57
13 CASE 3  TOP    15.22  322.78   18.76  139.84   720.77    .00
    BOTTOM  864.75          362.02
13 CASE 4  TOP     5.41   97.34   54.37  460.65   387.20    .00
    BOTTOM  259.96         1201.22

14 CASE 1  TOP   -52.08   33.32   75.82  -48.20 -5111.21    .00
    BOTTOM   34.56          -49.50
14 CASE 2  TOP    -5.90    3.78    8.33   -5.33  -608.91    .00
    BOTTOM    3.92           -5.53
14 CASE 3  TOP   189.21  403.22   32.10  102.28  1825.74    .00
    BOTTOM  859.80          234.05
14 CASE 4  TOP    57.61  121.51   74.10  319.92   948.89    .00
    BOTTOM  258.50          758.38

15 CASE 1  TOP    51.95  -33.24   75.86  -48.22 -5086.72    .00
    BOTTOM  -34.48          -49.52
```

```
    BOTTOM   -4.06           -5.55
15 CASE 3  TOP   189.73  403.53   32.31  102.43  1867.84    .00
    BOTTOM  860.12          234.22
15 CASE 4  TOP    57.04  121.13   74.51  320.18   972.81    .00
    BOTTOM  258.11          758.66

16 CASE 1  TOP   -69.63   42.01   74.93  -47.63 -4833.03    .00
    BOTTOM   43.80          -48.91
16 CASE 2  TOP    -9.10    5.49    8.14   -5.21  -550.77    .00
    BOTTOM    5.72           -5.40
16 CASE 3  TOP    63.22  228.32   21.46   95.49  1423.55    .00
    BOTTOM  678.22          227.01
16 CASE 4  TOP    18.99   68.52   71.26  318.09   844.48    .00
    BOTTOM  203.50          756.49

17 CASE 1  TOP    69,63  -42.01  -73.32   47.23 -4805.09    .00
    BOTTOM  -43.80           49.48
17 CASE 2  TOP     9.10   -5.49   -8.14    5.21  -550.77    .00
    BOTTOM   -5.72            5.40

COL OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID   ID POINT  MOMENT   SHEAR  MOMENT   SHEAR   FORCE  MOMENT
17 CASE 3  TOP    63.21  228.33   21.47   95.49  1423.54    .00
    BOTTOM  678.23          227.01
17 CASE 4  TOP    18.98   68.52   71.31  318.16   844.47    .00
    BOTTOM  203.51          756.58

18 CASE 1  TOP   -51.95   33.24  -74.25   47.83 -5058.88    .00
    BOTTOM   34.48           50.10
18 CASE 2  TOP    -6.11    3.91   -8.36    5.35  -609.37    .00
    BOTTOM    4.06            5.55
18 CASE 3  TOP   189.73  403.53   32.30  102.42  1867.84    .00
    BOTTOM  860.12          234.21
18 CASE 4  TOP    57.02  121.12   74.55  320.22   972.81    .00
    BOTTOM  258.09          758.72

19 CASE 1  TOP    52.09  -33.33  -74.22   47.80 -5083.60    .00
    BOTTOM  -34.57           50.08
19 CASE 2  TOP     5.90   -3.78   -8.33    5.33  -608.91    .00
    BOTTOM   -3.92            5.53
19 CASE 3  TOP   189.21  403.22   32.12  102.31  1825.74    .00
    BOTTOM  859.81          234.09
19 CASE 4  TOP    57.60  121.49   74.14  319.96   948.89    .00
    BOTTOM  258.48          758.44

20 CASE 1  TOP    17.18  -10.36 -114.53   77.00 -6895.91    .00
    BOTTOM  -10.80           77.97
20 CASE 2  TOP    -1.25     .76   -8.34    5.57  -698.18    .00
    BOTTOM     .79            5.57
```

```
                                    460.67  387.21    .00
      BOTTOM  259.93          1201.25

 21 CASE 1  TOP  -17.18   10.36 -114.53   77.00 -6895.91    .00
      BOTTOM   10.80            77.97
 21 CASE 2  TOP    1.25    -.76   -8.34    5.57  -698.18    .00
      BOTTOM    -.79             5.57
 21 CASE 3  TOP   15.22  322.79   18.75  139.81   720.76    .00
      BOTTOM  864.77           361.97
 21 CASE 4  TOP    5.43   97.36   54.37  460.64   387.20    .00
      BOTTOM  260.00          1201.20

 22 CASE 1  TOP  -52.09   33.33  -74.22   47.80 -5083.60    .00
      BOTTOM   34.57            50.08
 22 CASE 2  TOP   -5.90    3.78   -8.33    5.33  -608.91    .00
      BOTTOM    3.92             5.53
 22 CASE 3  TOP  189.23  403.24   32.12  102.31  1825.74    .00
      BOTTOM  859.83           234.09
 22 CASE 4  TOP   57.63  121.53   74.11  319.92   948.89    .00
      BOTTOM  258.54           758.39

COL OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID   ID POINT  MOMENT   SHEAR  MOMENT   SHEAR   FORCE  MOMENT
 23 CASE 1  TOP   51.95  -33.24  -74.25   47.83 -5058.88    .00
      BOTTOM  -34.48            50.10
 23 CASE 2  TOP    6.11   -3.91   -8.36    5.35  -609.37    .00
      BOTTOM   -4.06             5.55
 23 CASE 3  TOP  189.74  403.54   32.28  102.40  1867.84    .00
      BOTTOM  860.14           234.17
 23 CASE 4  TOP   57.06  121.16   74.50  320.17   972.81    .00
      BOTTOM  258.16           758.64

 24 CASE 1  TOP  -69.63   42.01  -73.32   47.23 -4805.09    .00
      BOTTOM   43.80            49.48
 24 CASE 2  TOP   -9.10    5.49   -8.14    5.21  -550.77    .00
      BOTTOM    5.72             5.40
 24 CASE 3  TOP   63.21  228.33   21.46   95.48  1423.55    .00
      BOTTOM  678.23           227.00
 24 CASE 4  TOP   19.00   68.53   71.25  318.09   844.48    .00
      BOTTOM  203.52           756.48

 25 CASE 1  TOP   67.96  -41.22  -45.71   27.96 -3083.36    .00
      BOTTOM  -43.34            29.77
 25 CASE 2  TOP    8.85   -5.37   -3.61    2.19  -356.63    .00
      BOTTOM   -5.65             2.30
 25 CASE 3  TOP   17.51  194.58    4.52   60.82  1526.15    .00
      BOTTOM  538.60           160.73
 25 CASE 4  TOP    5.27   58.39   14.78  202.56  1686.90    .00
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 26 CASE 1  TOP  -67.57   40.99  -46.69   28.55 -3117.51    .00
      BOTTOM   43.10            30.39
 26 CASE 2  TOP   -8.77    5.32   -3.83    2.33  -364.34    .00
      BOTTOM    5.60             2.44
 26 CASE 3  TOP   15.75  196.08   16.29   67.96  1122.22    .00
      BOTTOM  540.18           168.24
 26 CASE 4  TOP    4.74   58.84   18.32  204.71  1566.61    .00
      BOTTOM  162.09           537.88

 27 CASE 1  TOP   67.95  -41.22  -46.70   28.55 -3139.93    .00
      BOTTOM  -43.34            30.40
 27 CASE 2  TOP    8.79   -5.33   -3.83    2.32  -365.11    .00
      BOTTOM   -5.60             2.44
 27 CASE 3  TOP   15.57  196.28   16.22   67.92  1145.89    .00
      BOTTOM  540.38           168.21
 27 CASE 4  TOP    4.95   59.05   18.35  204.73  1584.57    .00
      BOTTOM  162.27           537.90

 28 CASE 1  TOP  -66.77   40.50  -48.21   29.47 -3228.90    .00
      BOTTOM   42.59            31.36
 28 CASE 2  TOP   -8.76    5.31   -3.80    2.30  -363.14    .00
      BOTTOM    5.59             2.42

COL OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID   ID POINT  MOMENT   SHEAR  MOMENT   SHEAR   FORCE  MOMENT
 28 CASE 3  TOP   16.87  195.14    8.77   63.61  1447.75    .00
      BOTTOM  539.19           163.68
 28 CASE 4  TOP    5.34   58.70   20.72  206.87  1755.85    .00
      BOTTOM  161.92           540.15

 29 CASE 1  TOP   66.77  -40.50  -48.21   29.47 -3228.90    .00
      BOTTOM  -42.59            31.36
 29 CASE 2  TOP    8.76   -5.31   -3.80    2.30  -363.14    .00
      BOTTOM   -5.59             2.42
 29 CASE 3  TOP   16.88  195.15    8.77   63.60  1447.74    .00
      BOTTOM  539.20           163.66
 29 CASE 4  TOP    5.38   58.74   20.71  206.86  1755.86    .00
      BOTTOM  161.98           540.13

 30 CASE 1  TOP  -67.95   41.22  -46.70   28.55 -3139.93    .00
      BOTTOM   43.34            30.40
 30 CASE 2  TOP   -8.79    5.33   -3.83    2.32  -365.11    .00
      BOTTOM    5.60             2.44
 30 CASE 3  TOP   15.58  196.29   16.22   67.92  1145.89    .00
      BOTTOM  540.40           168.21
 30 CASE 4  TOP    4.99   59.08   18.33  204.71  1584.58    .00
      BOTTOM  162.34           537.86
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 31 CASE 2  TOP     8.77   -5.32   -3.83   2.33  -364.34    .00
     BOTTOM  -5.60          2.44
 31 CASE 3  TOP    15.75  196.08   16.27  67.94  1122.22    .00
     BOTTOM 540.18        168.21
 31 CASE 4  TOP     4.75   58.85   18.29 204.67  1566.62    .00
     BOTTOM 162.10        537.82

 32 CASE 1  TOP   -67.96   41.22  -45.71  27.96 -3083.36    .00
     BOTTOM  43.34         29.77
 32 CASE 2  TOP    -8.85    5.37   -3.61   2.19  -356.63    .00
     BOTTOM   5.65          2.30
 32 CASE 3  TOP    17.51  194.58    4.52  60.81  1526.16    .00
     BOTTOM 538.61        160.72
 32 CASE 4  TOP     5.28   58.40   14.75 202.52  1686.90    .00
     BOTTOM 161.62        535.55

BEAM FORCES AT LEVEL 1ST    IN FRAME /MAIN FRAME

BAY OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID   ID POINT  MOMENT   SHEAR  MOMENT   SHEAR   FORCE  MOMENT
 1 CASE 1 END-I -144.63 -145.83    .00    .00    .00   -.03
      1/4-PT   21.02 -104.21   .00
      1/2-PT  131.53  -62.59   .00
      3/4-PT   21.38  103.94   .00
      END-J -143.91  145.56    .00
 1 CASE 2 END-I  -17.83  -21.89    .00    .00    .00   -.01
      1/4-PT    3.93  -10.96   .00
      1/2-PT   11.22    -.03   .00
      3/4-PT    4.02   10.90   .00
      END-J  -17.67   21.83    .00
 1 CASE 3 END-I  403.90  152.33    .00    .00    .00    .36
      END-J  403.47            .00
 1 CASE 4 END-I  121.19   45.71    .00    .00    .00    .11
      END-J  121.05            .00

 2 CASE 1 END-I -145.24 -146.03    .00    .00    .00   -.05
      1/4-PT   20.68 -104.41   .00
      1/2-PT  131.46  -62.79   .00
      3/4-PT   21.57  103.74   .00
      END-J -143.46  145.36    .00
 2 CASE 2 END-I  -17.72  -21.85    .00    .00    .00    .00
      1/4-PT    3.99  -10.92   .00
      1/2-PT   11.21     .01   .00
      3/4-PT    3.95   10.94   .00
      END-J  -17.79   21.88    .00
 2 CASE 3 END-I  404.65  152.76    .00    .00    .00    .50
      END-J  404.98            .00
 2 CASE 4 END-I  122.33   46.18    .00    .00    .00    .32
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 3 CASE 1 END-I -143.46 -145.36    .00    .00    .00    .05
      1/4-PT   21.57 -103.74   .00
      1/2-PT  131.46   62.79   .00
      3/4-PT   20.68  104.41   .00
      END-J -145.24  146.03    .00
 3 CASE 2 END-I  -17.79  -21.88    .00    .00    .00    .00
      1/4-PT    3.95  -10.94   .00
      1/2-PT   11.21    -.01   .00
      3/4-PT    3.99   10.92   .00
      END-J  -17.72   21.85    .00
 3 CASE 3 END-I  404.98  152.76    .00    .00    .00    .50
      END-J  404.65            .00
 3 CASE 4 END-I  122.43   46.18    .00    .00    .00    .32
      END-J  122.33            .00

 4 CASE 1 END-I -143.91 -145.56    .00    .00    .00    .03
      1/4-PT   21.38 -103.94   .00
      1/2-PT  131.53   62.59   .00
      3/4-PT   21.02  104.21   .00
      END-J -144.63  145.83    .00
 4 CASE 2 END-I  -17.67  -21.83    .00    .00    .00    .01
      1/4-PT    4.02  -10.90   .00
      1/2-PT   11.22     .03   .00
      3/4-PT    3.93   10.96   .00
      END-J  -17.83   21.89    .00

BAY OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID   ID POINT  MOMENT   SHEAR  MOMENT   SHEAR   FORCE  MOMENT
 4 CASE 3 END-I  403.47  152.33    .00    .00    .00    .36
      END-J  403.90            .00
 4 CASE 4 END-I  121.05   45.70    .00    .00    .00    .11
      END-J  121.18            .00

 5 CASE 1 END-I -145.31 -144.73    .00    .00    .00   -.02
      1/4-PT   17.58 -103.50   .00
      1/2-PT  126.37   62.64   .00
      3/4-PT   17.10  103.87   .00
      END-J -146.28  145.09    .00
 5 CASE 2 END-I  -18.01  -21.70    .00    .00    .00   -.01
      1/4-PT    3.36  -10.87   .00
      1/2-PT   10.52    -.04   .00
      3/4-PT    3.46   10.79   .00
      END-J  -17.81   21.62    .00
 5 CASE 3 END-I  415.56  151.21    .00    .00    .00    .26
      END-J  378.29            .00
 5 CASE 4 END-I  124.71   45.38    .00    .00    .00    .08
      END-J  113.52            .00
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6 CASE 1 END-I  -34.94  -29.85    .00    .00    .00    .00
      1/4-PT   -22.17  -15.56    .00
      1/2-PT   -17.43   -1.28    .00
      3/4-PT   -20.73   13.01    .00
      END-J    -32.07   27.30    .00
6 CASE 2 END-I   -5.24   -6.82    .00    .00    .00    .00
      1/4-PT    -2.36   -3.45    .00
      1/2-PT    -1.37    -.07    .00
      3/4-PT    -2.28    3.30    .00
      END-J     -5.08    6.68    .00
6 CASE 3 END-I  676.82  601.71    .00    .00    .00   1.25
      END-J    677.04             .00
6 CASE 4 END-I  203.42  180.70    .00    .00    .00    .40
      END-J    203.19             .00

7 CASE 1 END-I -146.24 -142.89    .00    .00    .00    .12
      1/4-PT    14.25 -101.67    .00
      1/2-PT   120.64   64.48    .00
      3/4-PT     8.96  105.70    .00
      END-J   -156.83  146.93    .00
7 CASE 2 END-I  -17.20  -21.17    .00    .00    .00    .08
      1/4-PT     3.48  -10.34    .00
      1/2-PT     9.95     .48    .00
      3/4-PT     2.21   11.31    .00
      END-J    -19.74   22.14    .00
7 CASE 3 END-I  378.63  149.57    .00    .00    .00    .71
      END-J    406.60             .00
7 CASE 4 END-I  116.32   45.91    .00    .00    .00   1.48
      END-J    124.73             .00

BAY OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID  ID POINT  MOMENT   SHEAR  MOMENT   SHEAR   FORCE  MOMENT
8 CASE 1 END-I -202.72 -168.96    .00    .00    .00    .00
      1/4-PT    26.96  -84.48    .00
      1/2-PT   103.52     .00    .00
      3/4-PT    26.96   84.48    .00
      END-J   -202.72  168.96    .00
8 CASE 2 END-I  -18.90  -15.55    .00    .00    .00    .00
      1/4-PT     2.24   -7.78    .00
      1/2-PT     9.29     .00    .00
      3/4-PT     2.24    7.78    .00
      END-J    -18.90   15.55    .00
8 CASE 3 END-I  322.15   88.86    .00    .00    .00    .06
      END-J    322.15             .00
8 CASE 4 END-I   96.71   26.66    .00    .00    .00    .02
      END-J     96.72             .00

9 CASE 1 END-I -156.83 -146.93    .00    .00    .00   -.12
      1/4-PT     8.96 -105.70    .00
      1/2-PT   120.64  -64.48    .00
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      3/4-PT    14.25  101.67    .00
      END-J   -146.24  142.89    .00
9 CASE 2 END-I  -19.74  -22.14    .00    .00    .00   -.08
      1/4-PT     2.21  -11.31    .00
      1/2-PT     9.95    -.48    .00
      3/4-PT     3.48   10.34    .00
      END-J    -17.20   21.17    .00
9 CASE 3 END-I  406.59  149.57    .00    .00    .00    .71
      END-J    378.63             .00
9 CASE 4 END-I  124.72   45.91    .00    .00    .00   1.48
      END-J    116.31             .00

10 CASE 1 END-I  -32.07  -27.30    .00    .00    .00   -.00
      1/4-PT   -20.73  -13.01    .00
      1/2-PT   -17.43    1.28    .00
      3/4-PT   -22.17   15.56    .00
      END-J    -34.94   29.85    .00
10 CASE 2 END-I   -5.08   -6.68    .00    .00    .00   -.00
      1/4-PT    -2.28   -3.30    .00
      1/2-PT    -1.37     .07    .00
      3/4-PT    -2.36    3.45    .00
      END-J     -5.24    6.82    .00
10 CASE 3 END-I  677.03  601.71    .00    .00    .00   1.25
      END-J    676.82             .00
10 CASE 4 END-I  203.16  180.69    .00    .00    .00    .40
      END-J    203.40             .00

11 CASE 1 END-I -146.28 -145.09    .00    .00    .00    .02
      1/4-PT    17.10 -103.87    .00
      1/2-PT   126.37  -62.64    .00
      3/4-PT    17.58  103.50    .00
      END-J   -145.31  144.73    .00

BAY OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID  ID POINT  MOMENT   SHEAR  MOMENT   SHEAR   FORCE  MOMENT
11 CASE 2 END-I  -17.81  -21.62    .00    .00    .00    .01
      1/4-PT     3.46  -10.79    .00
      1/2-PT    10.52     .04    .00
      3/4-PT     3.36   10.87    .00
      END-J    -18.01   21.70    .00
11 CASE 3 END-I  378.29  151.21    .00    .00    .00    .26
      END-J    415.56             .00
11 CASE 4 END-I  113.51   45.37    .00    .00    .00    .08
      END-J    124.71             .00

12 CASE 1 END-I -145.32 -144.73    .00    .00    .00    .02
      1/4-PT    17.58 -103.50    .00
      1/2-PT   126.37   62.64    .00
      3/4-PT    17.10  103.87    .00
      END-J   -146.28  145.09    .00
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      1/2-PT   10.52    -.04    .00
      3/4-PT    3.46   10.79    .00
      END-J   -17.81   21.62    .00
 12 CASE 3 END-I  415.56  151.21   .00   .00   .00   .26
      END-J  378.29           .00
 12 CASE 4 END-I  124.70   45.37   .00   .00   .00   .08
      END-J  113.51           .00

 13 CASE 1 END-I  -34.95  -29.86   .00   .00   .00  -.00
      1/4-PT  -22.17  -15.57   .00
      1/2-PT  -17.43   -1.28   .00
      3/4-PT  -20.73   13.01   .00
      END-J   -32.07   27.29   .00
 13 CASE 2 END-I   -5.24   -6.82   .00   .00   .00  -.00
      1/4-PT   -2.36   -3.45   .00
      1/2-PT   -1.37    -.07   .00
      3/4-PT   -2.28    3.30   .00
      END-J    -5.08    6.68   .00
 13 CASE 3 END-I  676.82  601.71   .00   .00   .00  1.25
      END-J  677.03           .00
 13 CASE 4 END-I  203.40  180.68   .00   .00   .00   .40
      END-J  203.16           .00

 14 CASE 1 END-I -146.29 -142.91   .00   .00   .00  -.11
      1/4-PT   14.23 -101.68   .00
      1/2-PT  120.64   64.46   .00
      3/4-PT    8.98  105.68   .00
      END-J  -156.78  146.91   .00
 14 CASE 2 END-I  -17.20  -21.17   .00   .00   .00  -.08
      1/4-PT    3.48  -10.34   .00
      1/2-PT    9.95     .48   .00
      3/4-PT    2.21   11.31   .00
      END-J   -19.74   22.14   .00

BAY OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID  ID POINT MOMENT  SHEAR  MOMENT  SHEAR  FORCE  MOMENT
 14 CASE 3 END-I  378.63  149.57   .00   .00   .00   .71
      END-J  406.59           .00
 14 CASE 4 END-I  116.31   45.91   .00   .00   .00  1.48
      END-J  124.72           .00

 15 CASE 1 END-I -202.72 -168.96   .00   .00   .00   .00
      1/4-PT   26.97  -84.48   .00
      1/2-PT  103.53     .00   .00
      3/4-PT   26.97   84.48   .00
      END-J  -202.72  168.96   .00
 15 CASE 2 END-I  -18.90  -15.55   .00   .00   .00   .00
      1/4-PT    2.24   -7.78   .00
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      3/4-PT    2.24    7.78   .00
      END-J   -18.90   15.55   .00
 15 CASE 3 END-I  322.15   88.86   .00   .00   .00   .06
      END-J  322.15           .00
 15 CASE 4 END-I   96.72   26.66   .00   .00   .00   .02
      END-J   96.71           .00

 16 CASE 1 END-I -156.78 -146.91   .00   .00   .00   .11
      1/4-PT    8.98 -105.68   .00
      1/2-PT  120.64  -64.46   .00
      3/4-PT   14.23  101.68   .00
      END-J  -146.29  142.91   .00
 16 CASE 2 END-I  -19.74  -22.14   .00   .00   .00   .08
      1/4-PT    2.21  -11.31   .00
      1/2-PT    9.95    -.48   .00
      3/4-PT    3.48   10.34   .00
      END-J   -17.20   21.17   .00
 16 CASE 3 END-I  406.60  149.57   .00   .00   .00   .71
      END-J  378.63           .00
 16 CASE 4 END-I  124.73   45.91   .00   .00   .00  1.48
      END-J  116.32           .00

 17 CASE 1 END-I  -32.07  -27.29   .00   .00   .00   .00
      1/4-PT  -20.73  -13.01   .00
      1/2-PT  -17.43    1.28   .00
      3/4-PT  -22.17   15.57   .00
      END-J   -34.95   29.86   .00
 17 CASE 2 END-I   -5.08   -6.68   .00   .00   .00   .00
      1/4-PT   -2.28   -3.30   .00
      1/2-PT   -1.37     .07   .00
      3/4-PT   -2.36    3.45   .00
      END-J    -5.24    6.82   .00
 17 CASE 3 END-I  677.04  601.71   .00   .00   .00  1.25
      END-J  676.82           .00
 17 CASE 4 END-I  203.19  180.71   .00   .00   .00   .40
      END-J  203.42           .00

BAY OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID  ID POINT MOMENT  SHEAR  MOMENT  SHEAR  FORCE  MOMENT
 18 CASE 1 END-I -146.28 -145.09   .00   .00   .00  -.02
      1/4-PT   17.10 -103.87   .00
      1/2-PT  126.37  -62.64   .00
      3/4-PT   17.58  103.50   .00
      END-J  -145.32  144.73   .00
 18 CASE 2 END-I  -17.81  -21.62   .00   .00   .00  -.01
      1/4-PT    3.46  -10.79   .00
      1/2-PT   10.52     .04   .00
      3/4-PT    3.36   10.87   .00
      END-J   -18.01   21.70   .00
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18 CASE 4  END-I   113.52   45.38    .00    .00    .00    .08
           END-J   124.72             .00

19 CASE 1  END-I  -144.63  -145.83    .00    .00    .00    .03
           1/4-PT   21.02  -104.21    .00
           1/2-PT  131.53   -62.59    .00
           3/4-PT   21.38   103.94    .00
           END-J  -143.91   145.56    .00
19 CASE 2  END-I   -17.83   -21.89    .00    .00    .00    .01
           1/4-PT    3.93   -10.96    .00
           1/2-PT   11.22     -.03    .00
           3/4-PT    4.02    10.90    .00
           END-J   -17.67    21.83    .00
19 CASE 3  END-I   403.90   152.33    .00    .00    .00    .36
           END-J   403.47             .00
19 CASE 4  END-I   121.18    45.70    .00    .00    .00    .11
           END-J   121.04             .00

20 CASE 1  END-I  -145.24  -146.03    .00    .00    .00    .05
           1/4-PT   20.68  -104.41    .00
           1/2-PT  131.46   -62.80    .00
           3/4-PT   21.58   103.74    .00
           END-J  -143.45   145.36    .00
20 CASE 2  END-I   -17.72   -21.85    .00    .00    .00    .00
           1/4-PT    3.99   -10.92    .00
           1/2-PT   11.21      .01    .00
           3/4-PT    3.95    10.94    .00
           END-J   -17.79    21.88    .00
20 CASE 3  END-I   404.65   152.76    .00    .00    .00    .50
           END-J   404.98             .00
20 CASE 4  END-I   122.32    46.18    .00    .00    .00    .32
           END-J   122.42             .00

21 CASE 1  END-I  -143.45  -145.36    .00    .00    .00   -.05
           1/4-PT   21.58  -103.74    .00
           1/2-PT  131.46    62.80    .00
           3/4-PT   20.68   104.41    .00
           END-J  -145.24   146.03    .00

BAY OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID  ID POINT   MOMENT   SHEAR  MOMENT   SHEAR   FORCE  MOMENT
21 CASE 2  END-I   -17.79   -21.88    .00    .00    .00    .00
           1/4-PT    3.95   -10.94    .00
           1/2-PT   11.21     -.01    .00
           3/4-PT    3.99    10.92    .00
           END-J   -17.72    21.85    .00
21 CASE 3  END-I   404.99   152.76    .00    .00    .00    .50
           END-J   404.66             .00
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           END-J   122.34             .00

22 CASE 1  END-I  -143.91  -145.56    .00    .00    .00   -.03
           1/4-PT   21.38  -103.94    .00
           1/2-PT  131.53    62.59    .00
           3/4-PT   21.02   104.21    .00
           END-J  -144.63   145.83    .00
22 CASE 2  END-I   -17.67   -21.83    .00    .00    .00   -.01
           1/4-PT    4.02   -10.90    .00
           1/2-PT   11.22      .03    .00
           3/4-PT    3.93    10.96    .00
           END-J   -17.83    21.89    .00
22 CASE 3  END-I   403.47   152.34    .00    .00    .00    .36
           END-J   403.91             .00
22 CASE 4  END-I   121.06    45.71    .00    .00    .00    .11
           END-J   121.19             .00

23 CASE 1  END-I   -97.64  -110.08    .00    .00    .00   -.53
           1/4-PT    7.75   -87.14    .00
           1/2-PT   88.63   -64.21    .00
           3/4-PT   -2.06    97.95    .00
           END-J  -118.99   120.88    .00
23 CASE 2  END-I    -7.27   -10.39    .00    .00    .00   -.07
           1/4-PT     .98    -5.05    .00
           1/2-PT    3.52      .29    .00
           3/4-PT     .35     5.64    .00
           END-J    -8.53    10.98    .00
23 CASE 3  END-I   130.68    60.00    .00    .00    .00   1.09
           END-J   125.82             .00
23 CASE 4  END-I   434.71   199.58    .00    .00    .00    .33
           END-J   418.50             .00

24 CASE 1  END-I  -313.20  -212.60    .00    .00    .00    .00
           1/4-PT   51.03  -163.39    .00
           1/2-PT  174.08     2.49    .00
           3/4-PT   47.10   160.04    .00
           END-J  -310.65   209.25    .00
24 CASE 2  END-I   -28.88   -23.25    .00    .00    .00    .00
           1/4-PT    4.91   -11.63    .00
           1/2-PT   16.17      .00    .00
           3/4-PT    4.91    11.63    .00
           END-J   -28.88    23.25    .00

BAY OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID  ID POINT   MOMENT   SHEAR  MOMENT   SHEAR   FORCE  MOMENT
24 CASE 3  END-I   119.19    30.76    .00    .00    .00    .00
           END-J   119.21             .00
24 CASE 4  END-I   397.29   102.53    .00    .00    .00    .00
           END-J   397.30             .00
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         1/4-PT   -1.44   -97.47    .00
         1/2-PT   88.74    64.68    .00
         3/4-PT    7.35    87.62    .00
          END-J  -98.55   110.55     .00
  25 CASE 2 END-I   -8.53  -10.98    .00    .00    .00    .07
         1/4-PT     .35    -5.64    .00
         1/2-PT    3.52    -.29     .00
         3/4-PT     .98    5.05     .00
          END-J   -7.27   10.39      .00
  25 CASE 3 END-I  125.80   59.99    .00    .00    .00   1.09
          END-J  130.66              .00
  25 CASE 4 END-I  418.50  199.58    .00    .00    .00    .33
          END-J  434.70              .00

  26 CASE 1 END-I -100.69 -111.51    .00    .00    .00   1.01
        1/4-PT    6.23   -88.58     .00
        1/2-PT   88.65   -65.64     .00
        3/4-PT    -.50    96.51     .00
         END-J -115.90   119.44      .00
  26 CASE 2 END-I   -7.98  -10.73    .00    .00    .00    .15
        1/4-PT     .63    -5.38     .00
        1/2-PT    3.53    -.04      .00
        3/4-PT     .71    5.30      .00
         END-J   -7.81   10.65       .00
  26 CASE 3 END-I  166.70   76.98    .00    .00    .00   6.49
         END-J  162.38               .00
  26 CASE 4 END-I  445.57  204.70    .00    .00    .00   1.95
         END-J  429.53               .00

  27 CASE 1 END-I -313.07 -212.60    .00    .00    .00    .00
        1/4-PT   51.16  -163.39     .00
        1/2-PT  174.22     2.49     .00
        3/4-PT   47.23   160.04     .00
         END-J -310.52   209.25      .00
  27 CASE 2 END-I  -28.85  -23.25    .00    .00    .00    .00
        1/4-PT    4.94   -11.63     .00
        1/2-PT   16.20      .00     .00
        3/4-PT    4.94    11.63     .00
         END-J  -28.85    23.25      .00
  27 CASE 3 END-I  120.71   30.75    .00    .00    .00    .00
         END-J  120.71               .00
  27 CASE 4 END-I  397.67  102.50    .00    .00    .00    .01
         END-J  397.67               .00

BAY OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID   ID POINT  MOMENT   SHEAR  MOMENT   SHEAR   FORCE   MOMENT
28 CASE 1 END-I -114.77 -118.97    .00    .00    .00  -1.01
       1/4-PT     .12   -96.03     .00
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         3/4-PT    5.83    89.06    .00
          END-J -101.60   111.99     .00
  28 CASE 2 END-I   -7.81  -10.65    .00    .00    .00   -.15
         1/4-PT     .71    -5.30    .00
         1/2-PT    3.53      .04    .00
         3/4-PT     .63     5.38    .00
          END-J   -7.98    10.73     .00
  28 CASE 3 END-I  162.38   76.98    .00    .00    .00   6.49
          END-J  166.71              .00
  28 CASE 4 END-I  429.53  204.70    .00    .00    .00   1.95
          END-J  445.57              .00

  29 CASE 1 END-I -100.68 -111.51    .00    .00    .00  -1.02
        1/4-PT    6.24   -88.57     .00
        1/2-PT   88.65   -65.64     .00
        3/4-PT    -.50    96.51     .00
         END-J -115.91   119.45      .00
  29 CASE 2 END-I   -7.96  -10.72    .00    .00    .00   -.16
        1/4-PT     .64    -5.38     .00
        1/2-PT    3.53    -.03      .00
        3/4-PT     .71    5.31      .00
         END-J   -7.82   10.65       .00
  29 CASE 3 END-I  166.49   76.88    .00    .00    .00   6.46
         END-J  162.18               .00
  29 CASE 4 END-I  445.52  204.69    .00    .00    .00   1.95
         END-J  429.55               .00

  30 CASE 1 END-I -313.08 -212.60    .00    .00    .00    .00
        1/4-PT   51.16  -163.39     .00
        1/2-PT  174.21     2.49     .00
        3/4-PT   47.23   160.04     .00
         END-J -310.52   209.25      .00
  30 CASE 2 END-I  -28.85  -23.25    .00    .00    .00    .00
        1/4-PT    4.93   -11.63     .00
        1/2-PT   16.19      .00     .00
        3/4-PT    4.93    11.63     .00
         END-J  -28.85    23.25      .00
  30 CASE 3 END-I  120.68   30.75    .00    .00    .00    .01
         END-J  120.68               .00
  30 CASE 4 END-I  397.62  102.49    .00    .00    .00    .04
         END-J  397.62               .00

  31 CASE 1 END-I -114.78 -118.97    .00    .00    .00   1.02
        1/4-PT     .12   -96.04     .00
        1/2-PT   88.76    66.12     .00
        3/4-PT    5.84    89.05     .00
         END-J -101.59   111.99      .00
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```
      1/4-PT    .71   -5.31     .00
      1/2-PT   3.53     .03     .00
      3/4-PT    .64    5.38     .00
      END-J   -7.96   10.72     .00
31 CASE 3 END-I  162.18   76.88    .00    .00    .00   6.46
      END-J   166.49            .00
31 CASE 4 END-I  429.55  204.69    .00    .00    .00   1.95
      END-J   445.52            .00

32 CASE 1 END-I -106.41 -113.55    .00    .00    .00   2.84
      1/4-PT    .99  -91.02     .00
      1/2-PT  84.73  -68.48     .00
      3/4-PT   5.59   93.27     .00
      END-J -104.17  115.80     .00
32 CASE 2 END-I   -7.80  -10.70    .00    .00    .00    .29
      1/4-PT    .69   -5.45     .00
      1/2-PT   3.66    -.20     .00
      3/4-PT   1.12    5.05     .00
      END-J   -6.94   10.30     .00
32 CASE 3 END-I  144.13   67.73    .00    .00    .00    .78
      END-J   140.35            .00
32 CASE 4 END-I  453.28  212.76    .00    .00    .00    .24
      END-J   440.32            .00

33 CASE 1 END-I -402.69 -272.33    .00    .00    .00    .00
      1/4-PT  67.31 -222.40     .00
      1/2-PT 223.69    2.53     .00
      3/4-PT  63.11  219.13     .00
      END-J -400.68  269.06     .00
33 CASE 2 END-I  -27.85  -22.80    .00    .00    .00    .00
      1/4-PT   4.64  -11.40     .00
      1/2-PT  15.47     .00     .00
      3/4-PT   4.64   11.40     .00
      END-J  -27.85   22.80     .00
33 CASE 3 END-I  178.52   46.89    .00    .00    .00    .01
      END-J   178.52            .00
33 CASE 4 END-I  594.06  156.31    .00    .00    .00    .04
      END-J   594.06            .00

34 CASE 1 END-I -103.11 -115.32    .00    .00    .00  -2.84
      1/4-PT   6.15  -92.79     .00
      1/2-PT  84.79   68.96     .00
      3/4-PT    .56   91.49     .00
      END-J -107.34  114.02     .00
34 CASE 2 END-I   -6.94  -10.30    .00    .00    .00   -.29
      1/4-PT   1.12   -5.05     .00
      1/2-PT   3.66     .20     .00
```

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BAY OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID  ID POINT  MOMENT   SHEAR  MOMENT   SHEAR   FORCE  MOMENT
34 CASE 3 END-I  140.35   67.73    .00    .00    .00    .78
      END-J   144.13            .00
34 CASE 4 END-I  440.32  212.76    .00    .00    .00    .24
      END-J   453.29            .00

35 CASE 1 END-I -106.41 -113.55    .00    .00    .00  -2.84
      1/4-PT    .99  -91.02     .00
      1/2-PT  84.73  -68.48     .00
      3/4-PT   5.59   93.27     .00
      END-J -104.17  115.80     .00
35 CASE 2 END-I   -7.80  -10.70    .00    .00    .00   -.29
      1/4-PT    .69   -5.45     .00
      1/2-PT   3.66    -.20     .00
      3/4-PT   1.12    5.05     .00
      END-J   -6.94   10.30     .00
35 CASE 3 END-I  144.13   67.73    .00    .00    .00    .78
      END-J   140.35            .00
35 CASE 4 END-I  453.28  212.76    .00    .00    .00    .24
      END-J   440.32            .00

36 CASE 1 END-I -402.69 -272.33    .00    .00    .00    .00
      1/4-PT  67.31 -222.40     .00
      1/2-PT 223.69    2.53     .00
      3/4-PT  63.11  219.13     .00
      END-J -400.68  269.06     .00
36 CASE 2 END-I  -27.85  -22.80    .00    .00    .00    .00
      1/4-PT   4.64  -11.40     .00
      1/2-PT  15.47     .00     .00
      3/4-PT   4.64   11.40     .00
      END-J  -27.85   22.80     .00
36 CASE 3 END-I  178.51   46.89    .00    .00    .00    .01
      END-J   178.52            .00
36 CASE 4 END-I  594.05  156.30    .00    .00    .00    .04
      END-J   594.06            .00

37 CASE 1 END-I -103.11 -115.32    .00    .00    .00   2.84
      1/4-PT   6.15  -92.79     .00
      1/2-PT  84.79   68.96     .00
      3/4-PT    .56   91.49     .00
      END-J -107.34  114.02     .00
37 CASE 2 END-I   -6.94  -10.30    .00    .00    .00    .29
      1/4-PT   1.12   -5.05     .00
      1/2-PT   3.66     .20     .00
      3/4-PT    .69    5.45     .00
      END-J   -7.80   10.70     .00
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     END-J  144.12          .00
37 CASE 4 END-I  440.31  212.76    .00    .00    .00    .24
     END-J  453.28          .00

BAY OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID   ID POINT  MOMENT   SHEAR  MOMENT   SHEAR   FORCE  MOMENT
38 CASE 1 END-I  -100.68  -111.51    .00    .00    .00   1.02
     1/4-PT    6.24   -88.57    .00
     1/2-PT   88.65   -65.64    .00
     3/4-PT    -.50    96.51    .00
     END-J  -115.91   119.45    .00
38 CASE 2 END-I    -7.96   -10.72    .00    .00    .00    .16
     1/4-PT     .64    -5.38    .00
     1/2-PT    3.53     -.03    .00
     3/4-PT     .71     5.31    .00
     END-J    -7.82    10.65    .00
38 CASE 3 END-I   166.48    76.88    .00    .00    .00   6.46
     END-J   162.18             .00
38 CASE 4 END-I   445.51   204.69    .00    .00    .00   1.95
     END-J   429.54             .00

39 CASE 1 END-I  -313.08  -212.60    .00    .00    .00    .00
     1/4-PT   51.16  -163.39    .00
     1/2-PT  174.21     2.49    .00
     3/4-PT   47.23   160.04    .00
     END-J  -310.52   209.25    .00
39 CASE 2 END-I   -28.85   -23.25    .00    .00    .00    .00
     1/4-PT    4.93   -11.63    .00
     1/2-PT   16.19      .00    .00
     3/4-PT    4.93    11.63    .00
     END-J   -28.85    23.25    .00
39 CASE 3 END-I   120.68    30.75    .00    .00    .00    .01
     END-J   120.68             .00
39 CASE 4 END-I   397.61   102.49    .00    .00    .00    .04
     END-J   397.61             .00

40 CASE 1 END-I  -114.78  -118.97    .00    .00    .00  -1.02
     1/4-PT     .12   -96.04    .00
     1/2-PT   88.76    66.12    .00
     3/4-PT    5.84    89.05    .00
     END-J  -101.59   111.99    .00
40 CASE 2 END-I    -7.82   -10.65    .00    .00    .00   -.16
     1/4-PT     .71    -5.31    .00
     1/2-PT    3.53      .03    .00
     3/4-PT     .64     5.38    .00
     END-J    -7.96    10.72    .00
40 CASE 3 END-I   162.18    76.88    .00    .00    .00   6.46
     END-J   166.49             .00
40 CASE 4 END-I   429.55   204.69    .00    .00    .00   1.95

41 CASE 1 END-I  -100.69  -111.51    .00    .00    .00  -1.01
     1/4-PT    6.23   -88.58    .00
     1/2-PT   88.65   -65.64    .00
     3/4-PT    -.50    96.51    .00
     END-J  -115.90   119.44    .00

BAY OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID   ID POINT  MOMENT   SHEAR  MOMENT   SHEAR   FORCE  MOMENT
41 CASE 2 END-I    -7.98   -10.73    .00    .00    .00   -.15
     1/4-PT     .63    -5.38    .00
     1/2-PT    3.53     -.04    .00
     3/4-PT     .71     5.30    .00
     END-J    -7.81    10.65    .00
41 CASE 3 END-I   166.71    76.98    .00    .00    .00   6.49
     END-J   162.38             .00
41 CASE 4 END-I   445.56   204.70    .00    .00    .00   1.95
     END-J   429.52             .00

42 CASE 1 END-I  -313.07  -212.60    .00    .00    .00    .00
     1/4-PT   51.16  -163.39    .00
     1/2-PT  174.22     2.49    .00
     3/4-PT   47.23   160.04    .00
     END-J  -310.52   209.25    .00
42 CASE 2 END-I   -28.85   -23.25    .00    .00    .00    .00
     1/4-PT    4.94   -11.63    .00
     1/2-PT   16.20      .00    .00
     3/4-PT    4.94    11.63    .00
     END-J   -28.85    23.25    .00
42 CASE 3 END-I   120.70    30.75    .00    .00    .00    .00
     END-J   120.71             .00
42 CASE 4 END-I   397.66   102.50    .00    .00    .00    .01
     END-J   397.66             .00

43 CASE 1 END-I  -114.77  -118.97    .00    .00    .00   1.01
     1/4-PT     .12   -96.03    .00
     1/2-PT   88.76    66.12    .00
     3/4-PT    5.83    89.06    .00
     END-J  -101.60   111.99    .00
43 CASE 2 END-I    -7.81   -10.65    .00    .00    .00    .15
     1/4-PT     .71    -5.30    .00
     1/2-PT    3.53      .04    .00
     3/4-PT     .63     5.38    .00
     END-J    -7.98    10.73    .00
43 CASE 3 END-I   162.37    76.97    .00    .00    .00   6.49
     END-J   166.70             .00
43 CASE 4 END-I   429.52   204.70    .00    .00    .00   1.95
     END-J   445.56             .00
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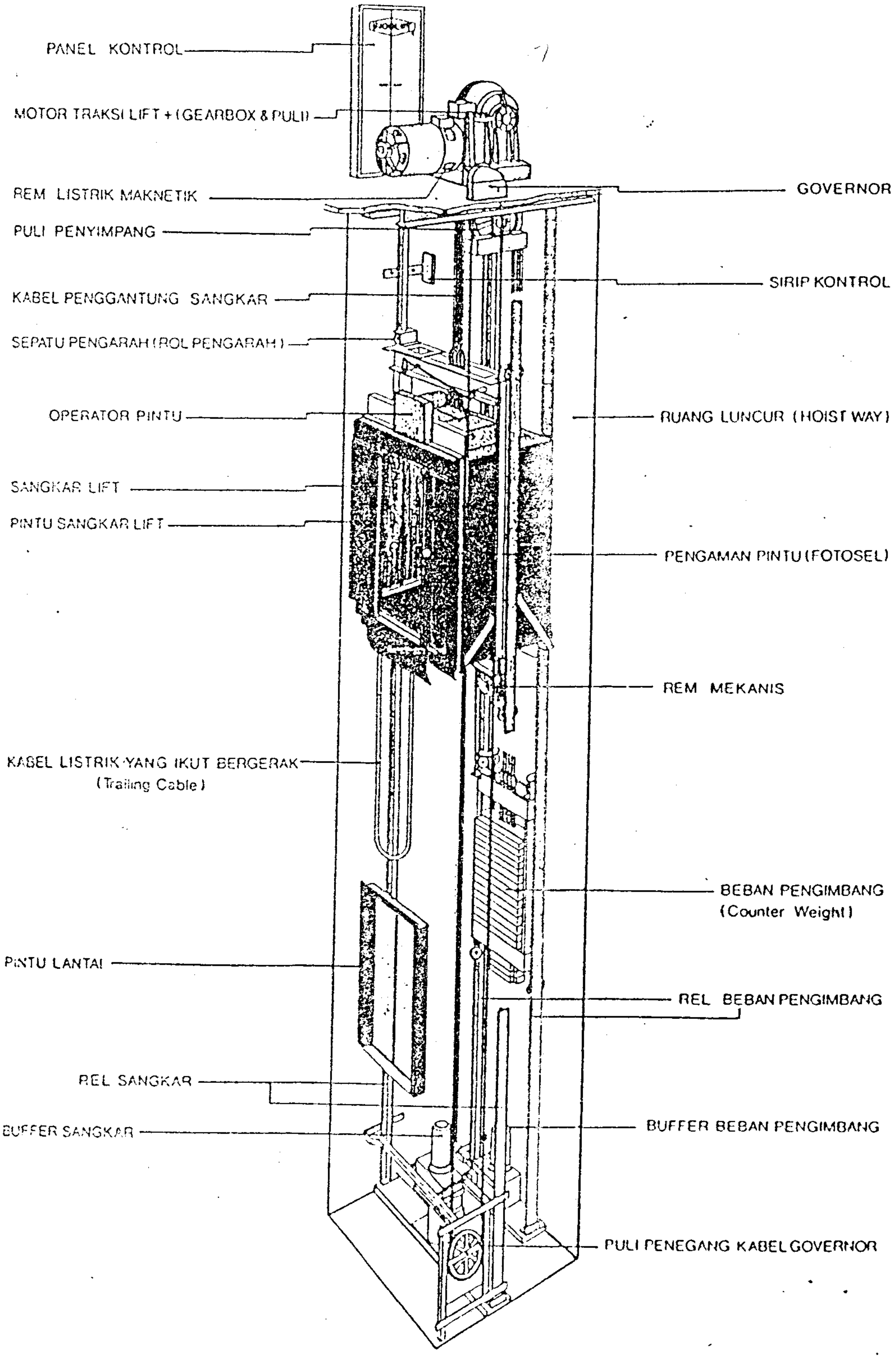
     1/4-PT   7.75  -87.14    .00
     1/2-PT  88.63  -64.21    .00
     3/4-PT  -2.06   97.95    .00
     END-J -118.99  120.88    .00
44 CASE 2 END-I   -7.27  -10.39    .00    .00    .00    .07
     1/4-PT    .98   -5.05    .00
     1/2-PT   3.52     .29    .00
     3/4-PT    .35    5.64    .00
     END-J  -8.53   10.98    .00

BAY OUTPUT OUTPUT   MAJOR   MAJOR   MINOR   MINOR   AXIAL TORSIONAL
ID  ID POINT  MOMENT   SHEAR  MOMENT   SHEAR   FORCE  MOMENT
44 CASE 3 END-I  130.66   59.99    .00    .00    .00   1.09
     END-J  125.80            .00
44 CASE 4 END-I  434.69  199.57    .00    .00    .00    .33
     END-J  418.48            .00

45 CASE 1 END-I -313.20 -212.60    .00    .00    .00    .00
     1/4-PT  51.03 -163.39    .00
     1/2-PT 174.08    2.49    .00
     3/4-PT  47.10  160.04    .00
     END-J -310.65  209.25    .00
45 CASE 2 END-I  -28.88  -23.25    .00    .00    .00    .00
```

```
     1/4-PT   4.91  -11.63    .00
     1/2-PT  16.17     .00    .00
     3/4-PT   4.91   11.63    .00
     END-J -28.88   23.25    .00
45 CASE 3 END-I  119.20   30.76    .00    .00    .00    .00
     END-J  119.20            .00
45 CASE 4 END-I  397.28  102.52    .00    .00    .00    .00
     END-J  397.28            .00

46 CASE 1 END-I -117.86 -120.40    .00    .00    .00   -.53
     1/4-PT  -1.44  -97.47    .00
     1/2-PT  88.74   64.68    .00
     3/4-PT   7.35   87.62    .00
     END-J  -98.55  110.55    .00
46 CASE 2 END-I   -8.53  -10.98    .00    .00    .00   -.07
     1/4-PT    .35   -5.64    .00
     1/2-PT   3.52    -.29    .00
     3/4-PT    .98    5.05    .00
     END-J   -7.27   10.39    .00
46 CASE 3 END-I  125.81   60.00    .00    .00    .00   1.09
     END-J  130.67            .00
46 CASE 4 END-I  418.49  199.57    .00    .00    .00    .33
     END-J  434.69            .00
```



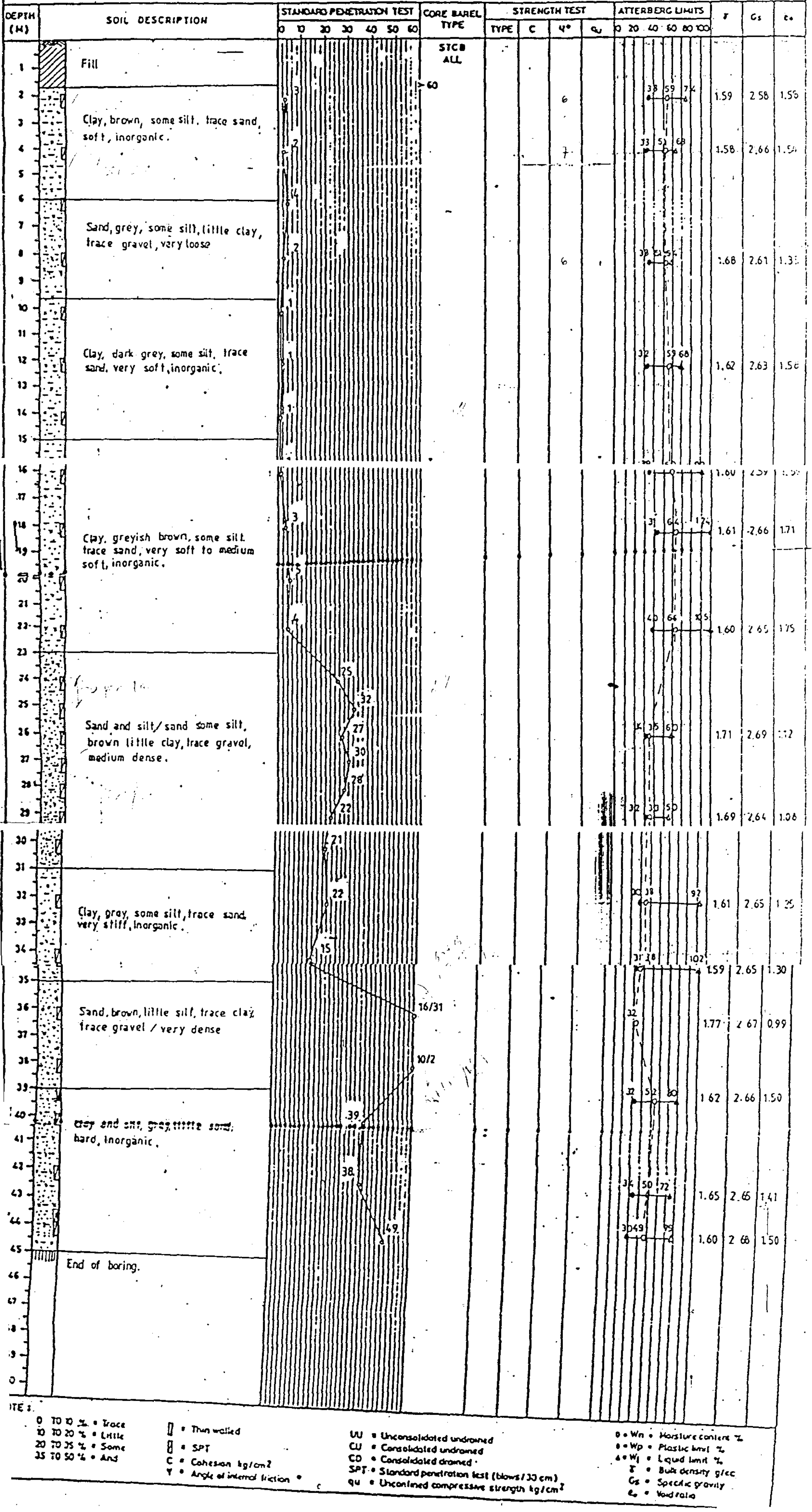
BAGIAN - BAGIAN POKOK LIFT - TRAKSI

Testana Engineering, Inc

BORING LOG

BOREHOLE NO : B - 5

PROJECT : METRO SEJAHTERA RESORT APARTMENTS.
LOCATION : Kebonsari - Surabaya.
COORDINATE :
BORING DEPTH : -45.00 m
GROUND WATER LEVEL : - 1.20 m
GROUND SURFACE LEVEL : ± 0.00 m



DEPTH (M)	SOIL DESCRIPTION	STANDARD PENETRATION TEST	CORE BAREL TYPE	STRENGTH TEST				ATTERBERG LIMITS	γ	Gs	e₀
				TYPE	C	φ°	qu				
1	Fill	> 60	STCB ALL								
2	Clay, brown, some silt, trace sand, soft, inorganic.	3				6		38 59 74	1.59	2.58	1.55
4		2				~~7~~		33 51 68	1.58	2.66	1.54
6	Sand, grey, some silt, little clay, trace gravel, very loose	4									
8		2				6		38 52 54	1.68	2.61	1.33
10	Clay, dark grey, some silt, trace sand, very soft, inorganic.	1									
12		1						32 59 68	1.62	2.63	1.56
14		1									
16	Clay, greyish brown, some silt, trace sand, very soft to medium soft, inorganic.								1.60	2.59	[illegible]
18		3						31 64 174	1.61	-2.66	1.71
20		5									
22		4						40 64 105	1.60	2.65	1.75
24	Sand and silt / sand some silt, brown little clay, trace gravel, medium dense.	25									
25		32									
26		27						25 35 60	1.71	2.69	1.12
27		30									
28		28									
29		22						32 30 50	1.69	2.64	1.06
30		21									
32	Clay, grey, some silt, trace sand very stiff, inorganic.	22						30 38 97	1.61	2.65	1.25
34		15						31 38 102	1.59	2.65	1.30
36	Sand, brown, little silt, trace clay trace gravel / very dense	16/31						32	1.77	2.67	0.99
38		10/2									
39	clay and silt, grey, little sand, hard, inorganic.							32 52 60	1.62	2.66	1.50
40		39									
42		38									
43								34 50 72	1.65	2.65	1.41
44		49						30 49 99	1.60	2.68	1.50
45	End of boring.										

NOTE :

0 TO 10 % = Trace
10 TO 20 % = Little
20 TO 35 % = Some
35 TO 50 % = And

▯ = Thin walled
▯ = SPT
C = Cohesion kg/cm²
φ = Angle of internal friction °

UU = Unconsolidated undrained
CU = Consolidated undrained
CD = Consolidated drained
SPT = Standard penetration test (blows / 30 cm)
qu = Unconfined compressive strength kg/cm²

○ = Wn = Moisture content %
● = Wp = Plastic limit %
▲ = Wl = Liquid limit %
γ = Bulk density g/cc
Gs = Specific gravity
e₀ = Void ratio