SKRIPSI

EVALUASI STRUKTUR GEDUNG MESJID AT-THOHAROH KECAMATAN MEDAN MARELAN TERHADAP KETAHANAN GEMPA BERDASARKAN SNI 1726 : 2019 DAN 2847 : 2019

Diajukan Untuk Memenuhi Persyaratan Dalam Menyelesaikan
Pendidikan Program Sarjana Strata Satu (SI)
Program Studi Teknik Sipil Fakultas Teknik
Universitas Islam Sumatera Utara

Disusun Oleh :

SATIO BINTANG RAMADHAN
71180913051

PROGRAM STUDI TEKNIK SIPIL
FAKULTAS TEKNIK
UNIVERSITAS ISLAM SUMATERA UTARA
MEDAN
2025

LEMBAR PENGESAHAN

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Disetujui Oleh :

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(Ronal H.T. Simbolon, ST.,MT.)	(Ir. M. Husni Malik Hasibuan, ST.MT.)

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Ketua Program Studi Teknik Sipil

(Ir. Jupriah Sarifah, MT.)

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KATA PENGATAR

Bismillahirrahamnnirrahim

Assalamu'alaikum Wr.Wb

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Skripsi ini merupakan salah satu syarat untuk menyelesaikan Program Sarjana (S1) Program Studi Teknik Sipil Universitas Islam Sumatera Utara. Tugas akhir skripsi ini tidak terlepas dari bantuan orang lain sehingga penulis ingin menyampaikan ucapan terimakasih saya kepada:

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Penulis

Medan, Juni 2025

Satio Bintang Ramadhan

71180913051

DAFTAR ISI

DAFTAR TABEL

DAFTAR GAMBAR

DAFTAR NOTASI DAN ISTILAH

T = Periode getar fundamental struktur

T_a = Periode fundamental pendekatan

S_s = Parameter percepatan tanah periode pendek

S_1 = Parameter percepatan tanah periode 1 detik

F_a = Faktor amplifikasi getaran terkait percepatan pada periode pendek

F_v = Faktor amplifikasi getaran terkait percepatan pada periode 1 detik

S_{MS} = Parameter respon spektral percepatan gempa untuk periode pendek

S_{M1} = Parameter respon spektral percepatan gempa untuk periode 1 detik

S_{DS} = Parameter percepatan spektral desain untuk periode pendek

S_{D1} = Percepatan spektral desain untuk periode 1 detik

R = Koefisien modifikasi respons

C_d = Faktor kuat lebih sistem

Ω_0 = Faktor pembesaran defleksi

V = Gaya geser dasar

δ_x = Simpangan pusat massa di tingkat-x

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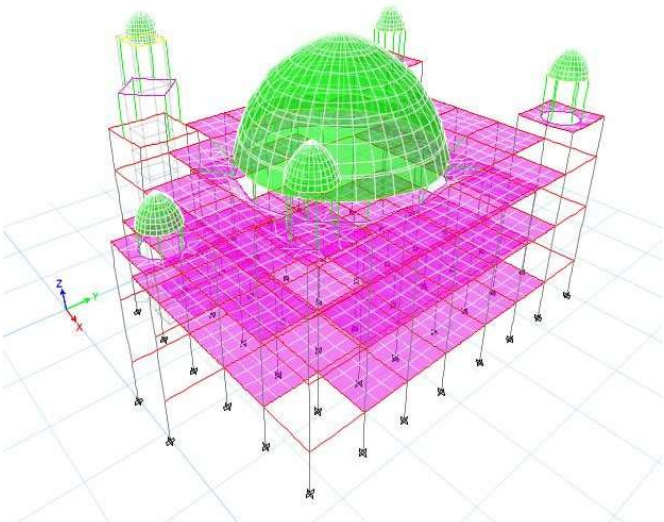
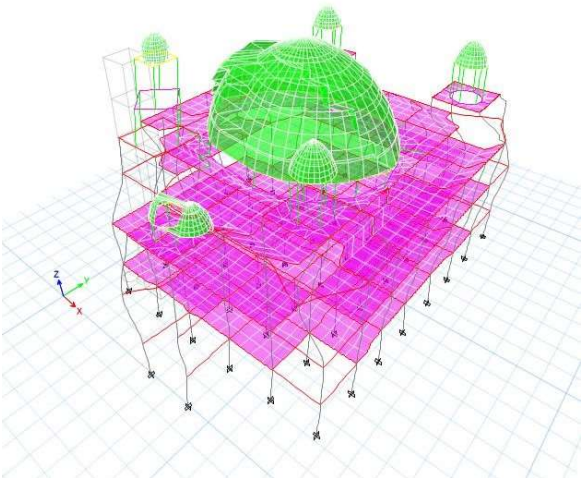
LAMPIRAN A
PERENCANAAN 3D & HASIL ANALISIS SOFTWARE ETABS MODEL 3D

Lampiran A.1 Perspektif 3D Model (1)

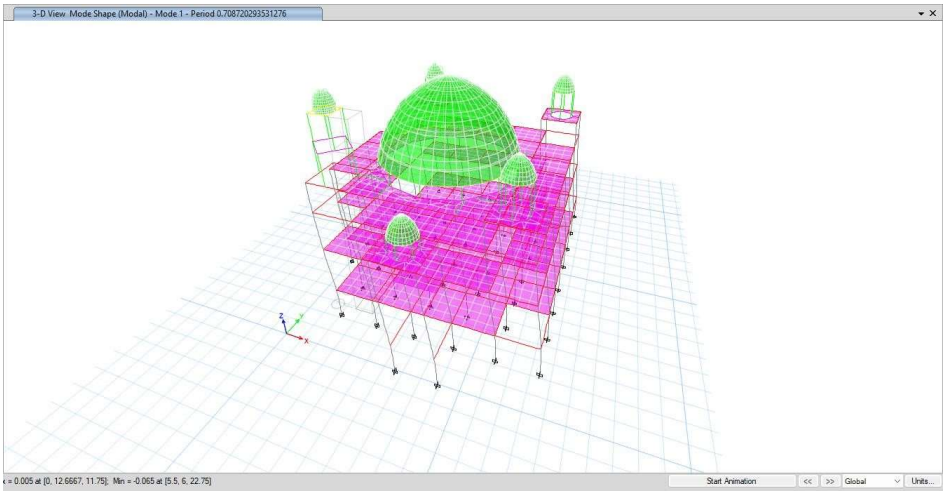
Lampiran A.2 Perspektif 3D Model (2)



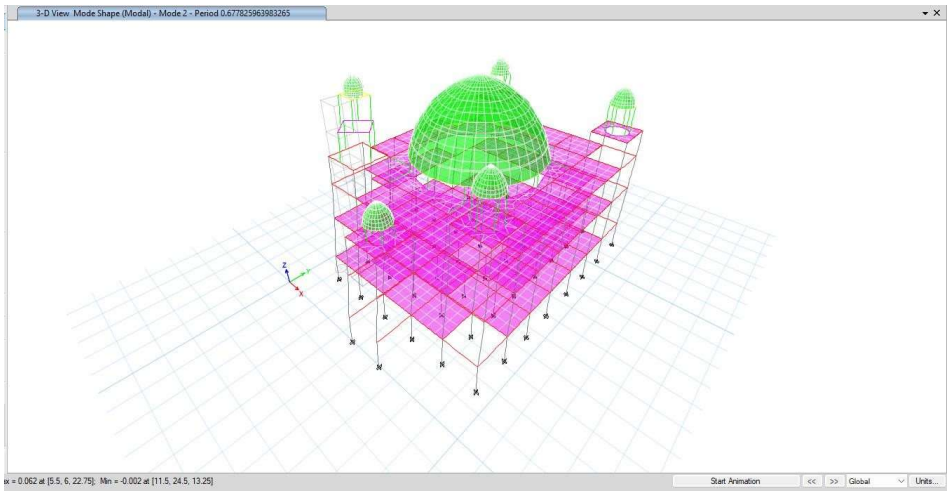
Lampiran A.3 Bentuk deformasi bangunan akibat beban mati



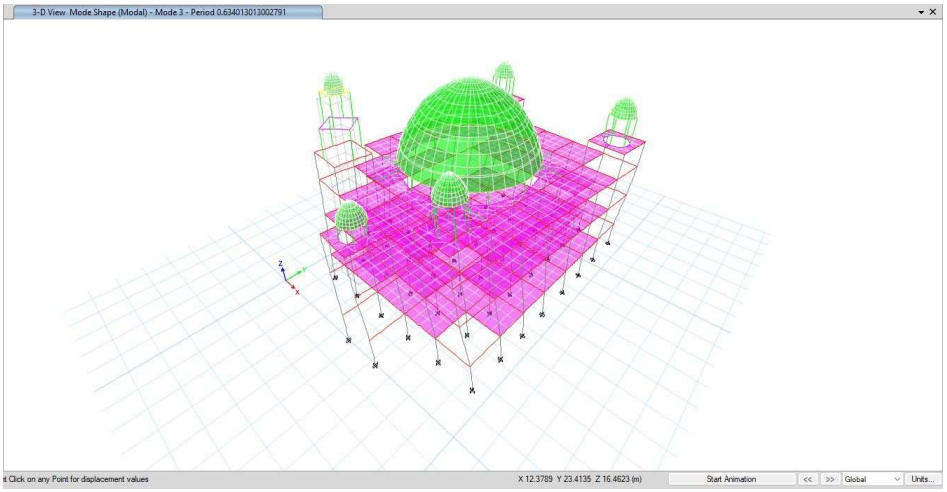
Lampiran A.4 Bentuk deformasi akiban beban *envelope*



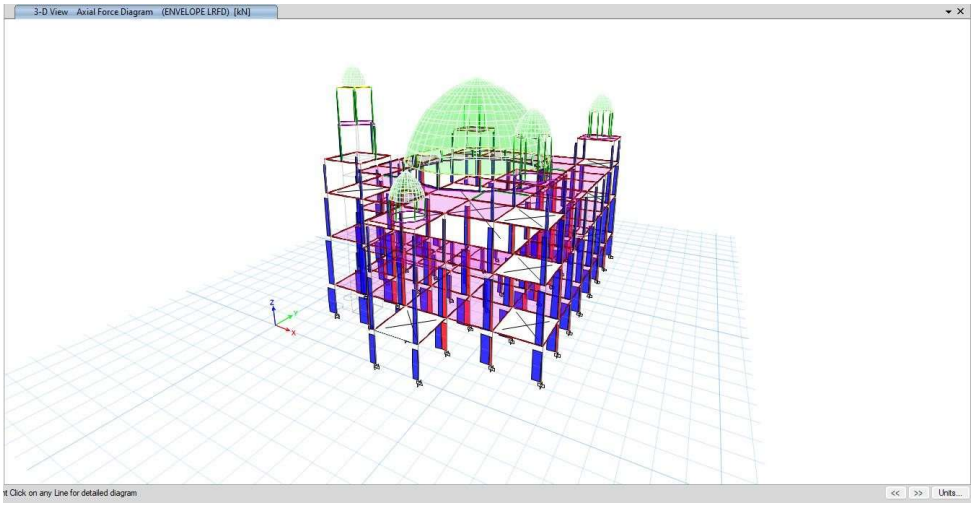
Lampiran A.5 Perilaku struktur mode 1 (translasi X)



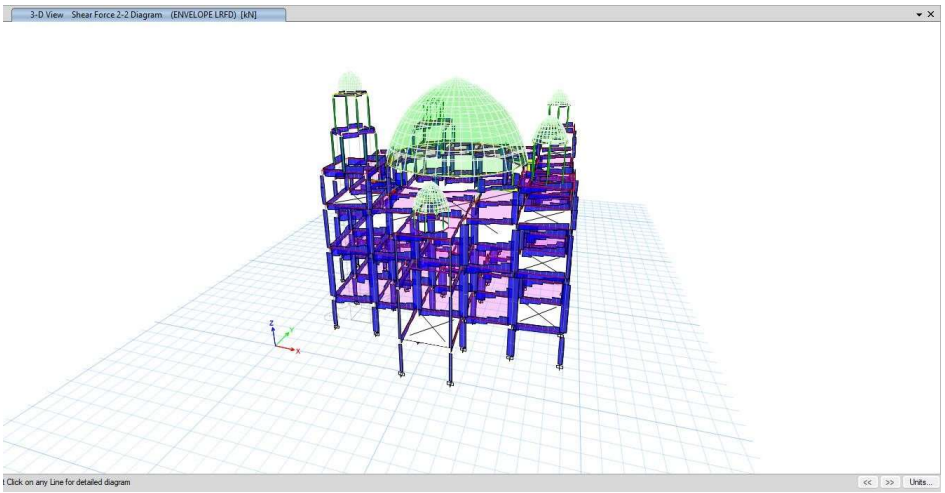
Lampiran A.6 Perilaku struktur mode 2 (tranlasi arah Y)



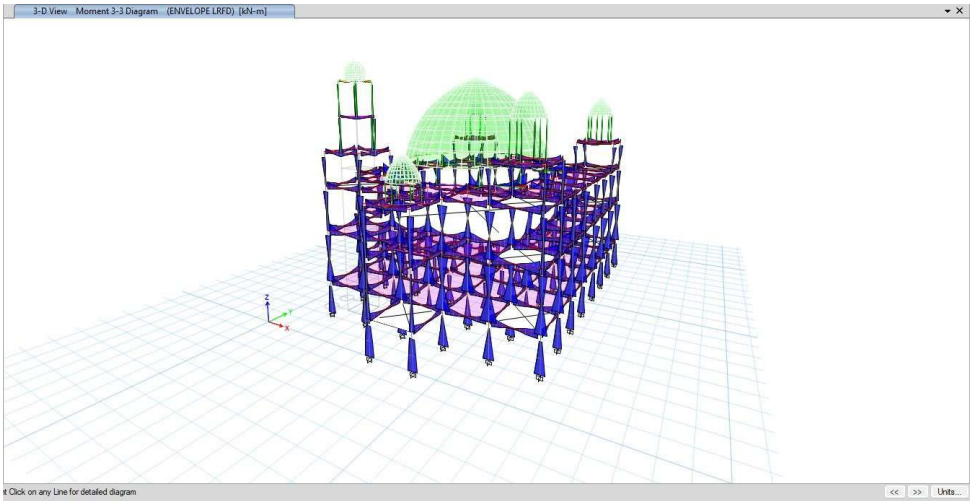
Lampiran A.7 Perilaku struktur mode 3 (rotasi arah Z)



Lampiran A.8 Diagram axial global struktur



Lampiran A.9 Diagram geser global struktur



Lampiran A.10 Diagram momen global struktur

LAMPIRAN B

PERHITUNGAN KAPASITAS ELEMEN STRUKTUR KOLOM DAN BALOK

Desain MAIN BEAM 300x500	Date	: 15/May/2024
STRUKTUR MASJID AT-THOHAROH MEDAN	Prepared by	: SATIO BINTANG
	Company	: -
	Revision	: -

1 Input Data

1.1 Geometri Balok

Lebar Balok	b	=		mm
Tinggi Balok	h	=		mm
Panjang Balok	L	=		mm
Selimut Bersih	c_c	=		mm
Panjang Kolom	c_1	=		mm
Lebar Kolom	c_2	=		mm

1.3 Material

Kuat Tekan Beton	f_c'	=		MPa
Kuat Leleh Baja Tulangan Longitudinal	f_y	=		MPa
Kuat Leleh Baja Tulangan Transversal	f_{yv}	=		MPa
Diameter Agregat	d_{ag}	=		mm

1.3 Diameter Tulangan

Diameter Tulangan Longitudinal	d_b	=		mm
Diameter Tulangan Pinggang	d_{bt}	=		mm
Diameter Tulangan Sengkang	d_s	=		mm

1.4 Jumlah Tulangan Longitudinal

		Tumpuan			Lapangan
Jumlah Tulangan Atas Baris 1	n_{ts1}	=		n_{tm1}	=
Jumlah Tulangan Atas Baris 2	n_{ts2}	=		n_{tm2}	=
Jumlah Tulangan Bawah Baris 1	n_{bs1}	=		n_{bm1}	=
Jumlah Tulangan Bawah Baris 2	n_{bs2}	=		n_{bm2}	=

Spasi Tulangan Lapis 1 ke Lapis 2	s_{12}	=		mm
Jumlah Pasang Tulangan Pinggang/Tengah	n_t	=		

1.5 Tulangan Transversal/Sengkang

Jumlah Kaki Tulangan Sengkang Tumpuan	n_{vs}	=		
Jumlah Kaki Tulangan Sengkang Lapangan	n_{vm}	=		
Spasi Sengkang Tumpuan	s_s	=		mm
Spasi Sengkang Lapangan	s_m	=		mm

1.6 Gaya Dalam

Momen Negatif Tumpuan	$M_{u,tum}$ (-)	=	-24.776	kNm
Momen Positif Tumpuan	$M_{u,tum}$ (+)	=	76.8638	kNm
Momen Negatif Lapangan	$M_{u,lap}$ (-)	=	-7.1998	kNm
Momen Positif Lapangan	$M_{u,lap}$ (+)	=	53.0555	kNm
Gaya Geser Tumpuan	$V_{u,tumpuan}$	=	138.0929	kN
Gaya Geser Lapangan	$V_{u,lapangan}$	=	92.1717	kN
Gaya Geser Gravitasi Tumpuan	$V_{g,tumpuan}$	=	45.1265	kN
Torsi	T_u	=	1.156	kNm
Gaya Aksial	P_u	=	-7.3513	kN

Desain MAIN BEAM 300x500	Date	: 15/May/2024
	Prepared by	: SATIO BINTANG
STRUKTUR MASJID AT-THOHAROH MEDAN	Company	: -
	Revision	: -

2 Parameter Material dan Geometri

Faktor Material Beton β_1

(SNI 2847:2019 tabel 22.2.2.4.3)

$$= 0.65 \le 0.85 - 0.05 \frac{f_c' - 28}{7} \le 0.85$$

$$= 0.65 \le 0.85 - 0.05 \frac{25.0 - 28}{7} \le 0.85$$

$$= 0.850$$

Regangan Leleh Baja Tulangan ε_{sy}

$$= \frac{f_y}{E_s} = \frac{420}{2000(0} = 0.0021$$

Tinggi Efektif Balok d

$$= h - c_c - d_s - \frac{d_b}{2}$$

$$= 500 - 4 - 1 - \frac{1(}{2}$$

$$= 442 \text{ mm}$$

Lokasi Tulangan Lapis 2 d_2

$$= d - s_{12}$$

$$= 442 - 5$$

$$= 392 \text{ mm}$$

Panjang Bersih Balok L_n

$$= L - c_1$$

$$= 4000 - 4(0$$

$$= 3550 \text{ mm}$$

Desain MAIN BEAM 300x500	Date	: 15/May/2024
STRUKTUR MASJID AT-THOHAROH MEDAN	Prepared by	: SATIO BINTANG
	Company	: -
	Revision	: -

3 Pengecekan Syarat Geometri

Bentang Bersih Minimum
(SNI 2847:2019 pasal 18.6.2)

$L_{n,min} = 4 \times d$
$= 4 \times 442$
$= 1768$ mm < 3550 mm OK

Syarat Lebar Minimum
(SNI 2847:2019 pasal 18.6.2)

$b_{min,1} = 0.3 \times h$
$= 0.3 \times 500$
$= 150$ mm

$b_{min,2} = 250$ mm

$b_{min} = \min(b_{min,1}; b_{min,2})$
$= \min(150; 250)$
$= 150$ mm < 300 mm OK

Syarat Lebar Maksimum
(SNI 2847:2019 pasal 18.6.2)

$b_{max,1} = c_2 + 2 \times c_1$
$= 450 + 2 \times 450$
$= 1350$ mm

$b_{max,2} = c_2 + 2 \times 0.75 \times c_1$
$= 450 + 2 \times 0.75 \times 450$
$= 1125$ mm

$b_{max} = \min(b_{max,1}; b_{max,2})$
$= \min(1350; 1125)$
$= 1125$ mm > 300 mm OK

STRUKTUR MASJID AT-THOHAROH MEDAN

4 Desain Lentur

4.1 Momen Negatif Tumpuan (Tulangan Tumpuan Atas)

Jumlah Tulangan Lapis 1 n_{ts1} = 5 --> $A_{s,1}$ = 1005.31 mm²

Jumlah Tulangan Lapis 2 n_{ts2} = 0 --> $A_{s,2}$ = 0 mm²

Jarak Bersih Tulangan Lapis 1 $s_{l,1}$ = 30 mm > 25 mm OK

Jarak Bersih Tulangan Lapis 2 $s_{l,2}$ = - mm > 25 mm OK

Luas Tulangan Total $A_s = A_{s,1} + A_{s,2} = 1005.31 + 0$

$= 1005.3$ mm²

Rasio Luas Tulangan $\rho = \frac{A_s}{b \times d} = \frac{1005.3}{300 \times 442} = 0.76\%$

Luas Tulangan Minimum $A_{s,min}$ = max $\sqrt{f_c'} \times b \times d$, $\frac{4}{f_y} \times b \times d$, $\frac{1.4}{f_y} \times b \times d$

(SNI 2847:2019 pasal 9.6.1.2)

= max $\frac{\sqrt{25}}{4 \times 420} \times 300 \times 442$, $\frac{1.4}{420} \times 300 \times 442$

= max 394.6 mm², 442.0 mm²

= 442.0 mm² < 1005.3 mm² OK

Rasio Luas Tulangan Maksimum ρ_{max} = 2.50% > 0.76% OK

(SNI 2847:2019 pasal 18.6.3.1)

Tinggi Blok Beton $a = \frac{A_s \times f_y}{0.85 \times f_c' \times b} = \frac{1005.3 \times 420}{0.85 \times 25 \times 300}$

(SNI 2847:2019 pasal 22.2.2.4.1)

$= 66.23$ mm

Tinggi Daerah Tekan Beton $c = \frac{a}{\beta_1} = \frac{66.23}{0.85} = 77.92$ mm

(SNI 2847:2019 pasal 22.2.2.4.1)

Regangan Tulangan Terluar $\varepsilon_{st} = \frac{d - c}{c} \times 0.003 = \frac{442 - 77.92}{77.92} \times 0.003$

$= 0.0140$

Faktor Reduksi $\Phi = 0.65 \le 0.65 + \frac{\varepsilon_{st} - \varepsilon_{sy}}{0.003} \times 0.25 \le 0.9$

(SNI 2847:2019 tabel 21.2.2)

$= 0.65 \le 0.65 + \frac{0.014 - 0.0021}{} \times 0.25$

= 0.90 0.003

Kapasitas Lentur Terfaktor $\Phi M_n = \Phi \times A_{s,1} \times f_y \times (d - a / 2)$

$+ A_{s,2} \times f_y \times (d_2 - a / 2)$

= 0.90 × 1005.3 × 420 × 442 - 66.232 / 2

+ 0.0 × 420 × 392 - 66.232 / 2

= 0.90 × 172.643 + 0.000

= 155.379 kNm > 124.776 kNm OK

Momen Nominal Tumpuan Negatif M_n = 172.6431 kNm

STRUKTUR MASJID AT-THOHAROH MEDAN

4.2 Momen Positif Tumpuan (Tulangan Tumpuan Bawah)

Jumlah Tulangan Lapis 1 n_{bs1} = 3 --> $A_{s,1}$ = 603.1858 mm²

Jumlah Tulangan Lapis 2 n_{bs2} = 0 --> $A_{s,2}$ = 0 mm²

Jarak Bersih Tulangan Lapis 1 $s_{l,1}$ = 76 mm > 25 mm OK

Jarak Bersih Tulangan Lapis 2 $s_{l,2}$ = - mm > 25 mm OK

Luas Tulangan Total $A_s = A_{s,1} + A_{s,2} = 603.1858 + 0$

$= 603.2$ mm²

Rasio Luas Tulangan $\rho = \frac{A_s}{b \times d} = \frac{603.2}{300 \times 442} = 0.45\%$

Luas Tulangan Minimum $A_{s,min} = \max \left(\frac{\sqrt{f_c'}}{4 \times f_y} \times b \times d ; \frac{1.4}{f_y} \times b \times d \right)$

(SNI 2847:2019 pasal 9.6.1.2)

$= \max \left(\frac{\sqrt{25}}{4 \times 420} \times 300 \times 442 ; \frac{1.4}{420} \times 300 \times 442 \right)$

$= \max$ (394.6 mm², 442.0 mm²)

$= 442.0$ mm² < 603.2 mm² OK

Rasio Luas Tulangan Maksimum $\rho_{max} = 2.50\% > 0.45\%$ OK

Tinggi Blok Beton $a = \frac{A_s \times f_y}{0.85 \times f_c' \times b} = \frac{603.2 \times 420}{0.85 \times 25 \times 300}$

(SNI 2847:2019 pasal 22.2.2.4.1)

$= 39.74$ mm

Tinggi Daerah Tekan Beton $c = \frac{a}{\beta_1} = \frac{39.74}{0.85} = 46.75$ mm

(SNI 2847:2019 pasal 22.2.2.4.1)

Regangan Tulangan Terluar $\varepsilon_{st} = \frac{d - c}{c} \times 0.003 = \frac{442 - 46.75}{46.75} \times 0.003$

$= 0.0254$

Faktor Reduksi $\Phi = 0.65 \le 0.65 + \frac{\varepsilon_{st} - \varepsilon_{sy}}{0.003} \times 0.25 \le 0.9$

(SNI 2847:2019 tabel 21.2.2)

$= 0.65 \le 0.65 + \frac{0.025 - 0.0021}{0.003} \times 0.25$

$= 0.90$

Kapasitas Lentur Terfaktor $\Phi M_n = \Phi \times A_{s,1} \times f_y \times (d - a / 2)$

$$+ A_{s,2} \times f_y \times \left(d_2 - a / 2 \right)$$

$$= 0.90 \times 603.2 \times 420 \times \left(442 - \frac{39.739}{2} \right) + 0.0 \times 420 \times \left(392 - \frac{39.739}{2} \right)$$

$$= 0.90 \times \{ 106.942 + 0.000 \}$$

$$= 96.248 \text{ kNm} > 76.864 \text{ kNm} \quad \text{OK}$$

Momen Nominal Tumpuan Positif Minimum
(SNI 2847:2019 pasal 18.6.3.2)

$$M_{n,min} = 50\% \times M_{n,tum} \text{ (-)}$$

$$= 50\% \times 172.6431$$

$$= 86.32154 \text{ kNm} < 106.9417 \text{ kNm} \quad \text{OK}$$

4.3 Momen Negatif Lapangan (Tulangan Lapangan Atas)

Jumlah Tulangan Lapis 1 n_{tm1} = 3 --> $A_{s,1}$ = 603.1858 mm²

Jumlah Tulangan Lapis 2 n_{tm2} = 0 --> $A_{s,2}$ = 0 mm²

Jarak Bersih Tulangan Lapis 1 $s_{l,1}$ = 76 mm > 25 mm OK

Jarak Bersih Tulangan Lapis 2 $s_{l,2}$ = - mm > 25 mm OK

Luas Tulangan Total $A_s = A_{s,1} + A_{s,2} = 603.1858 + 0$

$= 603.2$ mm²

Rasio Luas Tulangan $\rho = \frac{A_s}{b \times d} = \frac{603.2}{300 \times 442} = 0.45\%$

Luas Tulangan Minimum $A_{s,min} = \max \left(\frac{\sqrt{f_c'}}{4 \times f_y} \times b \times d ; \frac{1.4}{f_y} \times b \times d \right)$

(SNI 2847:2019 pasal 9.6.1.2)

$= \max \left(\frac{\sqrt{25}}{4 \times 420} \times 300 \times 442 ; \frac{1.4}{420} \times 300 \times 442 \right)$

$= \max$ (394.6 mm², 442.0 mm²)

$= 442.0$ mm² < 603.2 mm² OK

Rasio Luas Tulangan Maksimum $\rho_{max} = 2.50\% > 0.45\%$ OK

Tinggi Blok Beton $a = \frac{A_s \times f_y}{0.85 \times f_c' \times b} = \frac{603.2 \times 420}{0.85 \times 25 \times 300}$

(SNI 2847:2019 pasal 22.2.2.4.1)

$= 39.74$ mm

Tinggi Daerah Tekan Beton $c = \frac{a}{\beta_1} = \frac{39.74}{0.85} = 46.75$ mm

(SNI 2847:2019 pasal 22.2.2.4.1)

Regangan Tulangan Terluar $\varepsilon_{st} = \frac{d - c}{c} \times 0.003 = \frac{442 - 46.75}{46.75} \times 0.003$

$= 0.0254$

Faktor Reduksi $\Phi = 0.65 \le 0.65 + \frac{\varepsilon_{st} - \varepsilon_{sy}}{0.003} \times 0.25 \le 0.9$

(SNI 2847:2019 tabel 21.2.2)

$= 0.65 \le 0.65 + \frac{0.025 - 0.0021}{0.003} \times 0.25$

$= 0.90$

Kapasitas Lentur Terfaktor $\Phi M_n = \Phi \times A_{s,1} \times f_y \times (d - a/2)$

$$+ A_{s,2} \times f_y \times \left(d_2 - \frac{a}{2} \right)$$

$$= 0.90 \times 603.2 \times 420 \times \left(442 - \frac{39.739}{2} \right) + 0.0 \times 420 \times \left(392 - \frac{39.739}{2} \right)$$

$$= 0.90 \times 106.942 + 0.000$$

$$= 96.248 \text{ kNm} > 27.200 \text{ kNm} \quad \text{OK}$$

Momen Nominal Lapangan Minimum *(SNI 2847:2019 pasal 18.6.3.2)*

$$M_{n,min} = 25\% \times M_{n,tum} \text{ (-)}$$

$$= 25\% \times 172.6431$$

$$= 43.16077 \text{ kNm} < 106.9417 \text{ kNm} \quad \text{OK}$$

4.4 Momen Positif Lapangan (Tulangan Lapangan Bawah)

Jumlah Tulangan Lapis 1 n_{tm1} = 5 --> $A_{s,1}$ = 1005.31 mm²

Jumlah Tulangan Lapis 2 n_{tm2} = 0 --> $A_{s,2}$ = 0 mm²

Jarak Bersih Tulangan Lapis 1 $s_{l,1}$ = 30 mm > 25 mm OK

Jarak Bersih Tulangan Lapis 2 $s_{l,2}$ = - mm > 25 mm OK

Luas Tulangan Total $A_s = A_{s,1} + A_{s,2} = 1005.31 + 0$

$= 1005.3$ mm²

Rasio Luas Tulangan $\rho = \frac{A_s}{b \times d} = \frac{1005.3}{300 \times 442} = 0.76\%$

Luas Tulangan Minimum $A_{s,min} = \max \left(\frac{\sqrt{f_c'}}{4 \times f_y} \times b \times d ; \frac{1.4}{f_y} \times b \times d \right)$

(SNI 2847:2019 pasal 9.6.1.2)

$= \max \left(\frac{\sqrt{25}}{4 \times 420} \times 300 \times 442 ; \frac{1.4}{420} \times 300 \times 442 \right)$

$= \max (394.6 \text{ mm}^2 ; 442.0 \text{ mm}^2)$

$= 442.0$ mm² < 1005.3 mm² OK

Rasio Luas Tulangan Maksimum ρ_{max} = 2.50% > 0.76% OK

Tinggi Blok Beton $a = \frac{A_s \times f_y}{0.85 \times f_c' \times b} = \frac{1005.3 \times 420}{0.85 \times 25 \times 300}$

(SNI 2847:2019 pasal 22.2.2.4.1)

$= 66.23$ mm

Tinggi Daerah Tekan Beton $c = \frac{a}{\beta_1} = \frac{66.23}{0.85} = 77.92$ mm

(SNI 2847:2019 pasal 22.2.2.4.1)

Regangan Tulangan Terluar $\varepsilon_{st} = \frac{d - c}{c} \times 0.003 = \frac{442 - 77.92}{77.92} \times 0.003$

$= 0.0140$

Faktor Reduksi $\Phi = 0.65 \le 0.65 + \frac{\varepsilon_{st} - \varepsilon_{sy}}{0.003} \times 0.25 \le 0.9$

(SNI 2847:2019 tabel 21.2.2)

$= 0.65 \le 0.65 + \frac{0.014 - 0.0021}{0.003} \times 0.25$

$= 0.90$

Kapasitas Lentur Terfaktor $\Phi M_n = \Phi \times A_{s,1} \times f_y \times (d - a / 2)$

$$+ A_{s,2} \times f_y \times \left(d_2 - \frac{a}{2} \right)$$

$$= 0.90 \times 1005.3 \times 420 \times \left(442 - \frac{66.232}{2} \right) + 0.0 \times 420 \times \left(392 - \frac{66.232}{2} \right)$$

$$= 0.90 \times 172.643 + 0.000$$

$$= 155.379 \text{ kNm} > 153.056 \text{ kNm} \quad \text{OK}$$

Momen Nominal Lapangan Minimum *(SNI 2847:2019 pasal 18.6.3.2)*

$$M_{n,min} = 25\% \times M_{n,tum} \text{ (-)}$$

$$= 25\% \times 172.6431$$

$$= 43.16077 \text{ kNm} < 172.6431 \text{ kNm} \quad \text{OK}$$

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5 Desain Geser

5.1 Geser Tumpuan

Tinggi Blok Beton Probable Negatif

$a_{pr}^{-} = 1.25 \times a_{tumpuan\ negatif} = 1.25 \times 66.23$

$= 82.79$ mm

Tinggi Blok Beton Probable Positif

$a_{pr}^{+} = 1.25 \times a_{tumpuan\ positif} = 1.25 \times 39.74$

$= 49.67$ mm

Tegangan Baja Probable

$f_{pr} = 1.25 \times f_y = 1.25 \times 420$

$= 525$ MPa

Momen Negatif Tumpuan Probable

$M_{pr}^{-} = A_{s,1} \times f_{pr} \times (d - a_{pr} / 2) + A_{s,2} \times f_{pr} \times (d_2 - a_{pr} / 2)$

$= \left\{ 1005.3 \times 525 \times \left(442 - \frac{82.79}{2} \right) + 0.0 \times 525 \times \left(392 - \frac{82.79}{2} \right) \right\}$

$= 211.43 + 0.00$

$= 211.43$ kNm

Momen Positif Tumpuan Probable

$M_{pr}^{+} = A_{s,1} \times f_{pr} \times (d - a_{pr} / 2) + A_{s,2} \times f_{pr} \times (d_2 - a_{pr} / 2)$

$= \left\{ 603.2 \times 525 \times \left(442 - \frac{49.7}{2} \right) + 0.0 \times 525 \times \left(392 - \frac{49.7}{2} \right) \right\}$

$= 132.10 + 0.00$

$= 132.10$ kNm

Gaya Geser Probable

$V_{pr} = \frac{M_{pr}^{+} + M_{pr}^{-}}{L_n} = \frac{132.10 + 211.43}{3.55}$

$= 96.77136$ kN

Gaya Geser Desain

$V_e = V_g + V_{pr} = 145.1265 + 96.77136$

(SNI 2847:2019 pasal 18.6.5.1)

$= 241.8979$ kN

Gaya Geser Pakai

$V_u = \max(V_{u,tumpuan} ; V_e)$

$= \max(238.0929 ; 241.8979)$

$= 241.8979$ kN

Vc = 0 jika...

$\rightarrow V_{pr} \geq \frac{V_e}{2}$ dan $P_u < \frac{A_g \times f_c'}{20}$

(SNI 2847:2019 pasal 18.6.5.2)

1 --> 96.77136 < 120.9489

2 --> -87.3513 < 187.5 **Vc diperhitungkan**

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Jumlah Kaki $n_{vs} = 2$

Luas Tulangan Sengkang $A_v = n \times \pi/4 \times d_s^2 = 2 \times \pi/4 \times 10 \text{ ^2}$

$= 157.0796 \text{ mm}^2$

Spasi Sengkang $s_s = 95 \text{ mm}$

Spasi Maksimum $s_{max} = \min \begin{Bmatrix} d / 4 \\ 6 \times d_b \\ 150 \end{Bmatrix}$

(SNI 2847:2019 pasal 18.6.4.4)

$= \min \begin{Bmatrix} 442 / 4 \\ 6 \times 16 \\ 150 \end{Bmatrix}$

$= \min \begin{Bmatrix} 110.5 \\ 96 \\ 150 \end{Bmatrix}$

$= 96 \text{ mm} > 95 \text{ mm}$ OK

Jarak Antar Kaki Sengkang $h_x = 210 \text{ mm} < 350 \text{ mm}$ OK

(SNI 2847:2019 gambar 18.6.4)

Tahanan Geser Beton $V_c = 0.17 \times \sqrt{f_c'} \times b \times d$ atau 0

(SNI 2847:2019 pasal 18.6.5.2)

$= 0.17 \times \sqrt{25} \times 300 \times 442$ atau 0

$= 112710 \text{ N}$

Tahanan Geser Baja $V_s = \min \begin{Bmatrix} \dfrac{A_v \times f_{yv} \times d}{s} \\ 1 \times \sqrt{f_c'} \times b \times d \end{Bmatrix}$

(SNI 2847:2019 pasal 22.5.10.5.3)

$= \min \begin{Bmatrix} \dfrac{157.1 \times 420 \times 442}{95} \\ 1 \times \sqrt{25} \times 300 \times 442 \end{Bmatrix}$

$= \min \begin{Bmatrix} 306950 \\ 437580 \end{Bmatrix}$

$= 306950 \text{ N}$

Faktor Reduksi $\Phi = 0.75$

(SNI 2847:2019 pasal 12.5.3.2)

Kapasitas Geser $\Phi V_n = \Phi \times (V_c + V_s)$

(SNI 2847:2019 pasal 22.5.10.1)

$= 0.75 \times (112.71 + 306.9501)$

$= 314.7451 \text{ kN} > 241.8979 \text{ kN}$ OK

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5.2 Geser Lapangan

Jumlah Kaki n_{vm} = 2

Luas Tulangan Sengkang A_v = $n \times \pi/4 \times d_s^2$ = 2 × π/4 × 10 ^2

= 157.0796 mm^2

Spasi Sengkang s_m = 150 mm

Spasi Maksimum s_{max} = $\frac{d}{2}$

(SNI 2847:2019 pasal 18.6.4.6)

= $\frac{442}{2}$

= 221 mm > 150 mm OK

Tahanan Geser Beton V_c = $0.17 \times \sqrt{f_c'} \times b \times d$

(SNI 2847:2019 pasal 22.5.5.1)

= $0.17 \times \sqrt{25} \times 300 \times 442$

= 112710 N

Tahanan Geser Baja V_s = $\min \left\{ \frac{A_v \times f_{yv} \times d}{s} ; 0.66 \times \sqrt{f_c'} \times b \times d \right\}$

(SNI 2847:2019 pasal 22.5.10.1)

= $\min \left\{ \frac{157 \times 420 \times 442}{150} ; 0.66 \times \sqrt{25} \times 300 \times 442 \right\}$

= $\min \left\{ 194402 ; 437580 \right\}$

= 194402 N

Faktor Reduksi Φ = 0.75

(SNI 2847:2019 pasal 12.5.3.2)

Kapasitas Geser ΦV_n = $\Phi \times \left(V_c + V_s \right)$

(SNI 2847:2019 pasal 22.5.10.1)

= $0.75 \times \left(112.71 + 194.4018 \right)$

= 230.3338 kN > 192.1717 kN OK

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6 Desain Torsi

6.1 Parameter Penampang untuk Perhitungan Torsi

Luas Penampang Penuh $A_{cp} = b \times h = 300 \times 500$

$= 150000 \text{ mm}^2$

Keliling Penampang Penuh $P_{cp} = 2 \times (b + h) = 2 \times (300 + 500$

$= 1600 \text{ mm}$

Lebar Penampang Inti $x_o = b - 2 \times c_c - d_s$

(SNI 2847:2019 pasal 22.7.6.1.1) $= 300 - 2 \times 40 - 10$

$= 210 \text{ mm}$

Tinggi Penampang Inti $y_o = h - 2 \times c_c - d_s$

(SNI 2847:2019 pasal 22.7.6.1.1) $= 500 - 2 \times 40 - 10$

$= 410 \text{ mm}$

Luas Penampang Inti $A_{oh} = x_o \times y_o = 210 \times 410$

(SNI 2847:2019 pasal 22.7.6.1.1) $= 86100 \text{ mm}^2$

Luas Efektif Penampang Inti $A_o = 0.85 \times A_{oh} = 0.85 \times 86100$

(SNI 2847:2019 pasal 22.7.6.1.1) $= 73185 \text{ mm}^2$

Keliling Penampang Inti $P_h = 2 \times x_o + y_o = 2 \times 210 + 410$

(SNI 2847:2019 pasal 22.7.6.1.1) $= 1240 \text{ mm}$

6.2 Pengecekan Kebutuhan Tulangan Torsi

Tahanan Retak Torsi $T_{cr} = 0.33 \times \sqrt{f_c'} \times \frac{A_{cp}^2}{P_{cp}}$

(SNI 2847:2019 pasal 22.7.5.1)

$= 0.33 \times \sqrt{25} \times \frac{150000 \text{ ^2}}{1600}$

$= 23.203 \text{ kNm}$

Faktor Reduksi $\Phi = 0.75$

(SNI 2847:2019 tabel 21.2.1)

Ambang Batas Kebutuhan Tulangan Torsi

(SNI 2847:2019 tabel 22.7.4.1)

$= \frac{\Phi \times T_{cr}}{4}$

$= \frac{0.75 \times 23.203}{4}$

$= 4.351 \text{ kNm} > 1.156 \text{ kNm}$

--> **Tidak Perlu Tulangan Torsi**

Perhitungan di bawah ini dapat diabaikan

6.3 Pengecekan Kecukupan Dimensi

Momen Torsi Pakai — T_u
(SNI 2847:2019 pasal 22.7.3.2)

$$T_u = \min \begin{cases} \Phi \times T_{cr} \\ T_u \end{cases}$$

$$= \min \begin{matrix} 0.75 \times 23.203 \\ 1.156 \end{matrix}$$

$$= \min \begin{matrix} 17.402 \\ 1.156 \end{matrix}$$

$$= 1.156 \text{ kNm}$$

Tegangan Akibat Geser + Torsi — σ_u

(SNI 2847:2019 pasal 22.7.7.1)

$$\sigma_u = \sqrt{\left(\frac{V_u}{b \times d}\right)^2 + \left(\frac{T_u \times P_h}{1.7 \times A_{oh}^2}\right)^2}$$

$$= \sqrt{\left(\frac{241.898}{300 \times 442}\right)^2 + \left(\frac{1.156 \times 1240}{1.7 \times 86100}\right)^2}$$

$$= \sqrt{1.824^2 + 0.114^2}$$

$$= 1.828 \text{ MPa}$$

Tahanan Tegangan Geser+Torsi Beton — σ_n

(SNI 2847:2019 pasal 22.7.7.1)

$$= \Phi \left(\frac{V_c}{b \times d} + 0.66 \times \sqrt{f_c'}\right)$$

$$= 0.75 \left(\frac{112710}{300 \times 442} + 0.66 \times \sqrt{25}\right)$$

$$= 3.113 \text{ MPa} > 1.828 \text{ MPa} \quad -$$

6.4 Tulangan Transversal Torsi

Spasi Maksimum — s_{max}
(SNI 2847:2019 pasal 9.7.6.3.3)

$$= \min \begin{matrix} \frac{P_h}{8} \\ \frac{d_b}{0.042} \\ 300 \end{matrix}$$

$$= \min \begin{matrix} 1240 \\ 8 \\ 16 \\ 0.042 \\ 300 \end{matrix}$$

$$= \min \begin{matrix} 155 \\ 380.9524 \\ 300 \end{matrix}$$

$$= 155 \text{ mm} > 95 \text{ mm} \quad - \quad \text{(tumpuan)}$$

$$> 150 \text{ mm} \quad - \quad \text{(lapangan)}$$

Kebutuhan Tulangan Transversal Torsi — A_t/s
(SNI 2847:2019 pasal 22.7.6.1)

$$= \frac{T_u}{2 \times \Phi \times A_o \times f_{yv}}$$

$$= \frac{1.156 \times 10^6}{}$$

$$2 \times 0.75 \times \frac{73185}{} \times 420$$

$$= 0.025 \ \text{mm}^2/\text{mm}$$

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Kebutuhan Tulangan Geser Tumpuan

$$A_v/s = \frac{\left(\frac{V_u}{\Phi} - V_c\right)}{f_{yv} \times d}$$

$$= \frac{\left(\frac{241.8979}{0.75} - 113\right)}{420 \times 442}$$

$$= 1.130 \text{ mm}^2/\text{mm}$$

Kebutuhan Tulangan Geser Lapangan

$$A_v/s = \frac{\left(\frac{V_u}{\Phi} - V_c\right)}{f_{yv} \times d}$$

$$= \frac{\left(\frac{192.1717}{0.75} - 113\right)}{420 \times 442}$$

$$= 0.773 \text{ mm}^2/\text{mm}$$

Kebutuhan Tulangan Geser+Torsi Tumpuan

(SNI 2847:2019 pasal 9.5.4.3)

$$A_{v+t}/s = 2 \times A_t/s + A_v/s$$

$$= 2 \times 0.025 + 1.130$$

$$= 1.180 \text{ mm}^2/\text{mm} < 1.653 \text{ mm}^2/\text{mm} \text{ -}$$

Kebutuhan Tulangan Geser+Torsi Lapangan

(SNI 2847:2019 pasal 9.5.4.3)

$$A_{v+t}/s = 2 \times A_t/s + A_v/s$$

$$= 2 \times 0.025 + 0.773$$

$$= 0.823 \text{ mm}^2/\text{mm} < 1.047 \text{ mm}^2/\text{mm} \text{ -}$$

Tulangan Transversal Minimum

(SNI 2847:2019 pasal 9.6.4.2)

$$A/s_{min} = \max\left\{\begin{array}{l} 0.062 \times \sqrt{f_c'} \times \frac{b}{f_{yv}} \\ 0.350 \times \frac{b}{f_{yv}} \end{array}\right.$$

$$A/s_{min} = \max\left\{\begin{array}{l} 0.062 \times \sqrt{25} \times \frac{300}{420} \\ 0.350 \times \frac{300}{420} \end{array}\right.$$

$$= \max\left\{\begin{array}{l} 0.221 \\ 0.250 \end{array}\right.$$

$$= 0.250 \text{ mm}^2/\text{mm} < 1.653 \text{ mm}^2/\text{mm} \text{ -}$$

$$< 1.047 \text{ mm}^2/\text{mm} \text{ -}$$

6.5 Tulangan Longitudinal Torsi

Kebutuhan Tulangan Longitudinal Torsi

(SNI 2847:2019 pasal 22.7.6.1)

$$A_l = A_t/s \times P_h \times \frac{f_{yv}}{f_y}$$

$$= 0.025 \times 1240 \times \frac{420}{420}$$

$$= 31.090 \text{ mm}^2$$

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Tulangan Longitudinal Torsi Minimum A_l

(SNI 2847:2019 pasal 9.6.4.3)

$$A_l = \min \begin{cases} 0.42 \times \sqrt{f_c'} \times \frac{A_{cp}}{f_{yv}} - A_t/s \times P_h \times \frac{f_{yv}}{f_y} \\ 0.42 \times \sqrt{f_c'} \times \frac{A_{cp}}{f_{yv}} - \frac{0.175\ b\ P_h}{f_{yv}} \times \frac{f_{yv}}{f_y} \end{cases}$$

$$= \min \begin{cases} 0.42 \times \sqrt{25} \times \frac{150000}{420} - 0.025 \times 1240 \times 1 \\ 0.42 \times \sqrt{25} \times \frac{150000}{420} - \frac{0.175 \times 300}{420} \times 1240 \times 1 \end{cases}$$

$$= \min \begin{cases} 718.91 \\ 595.00 \end{cases}$$

$$= 595.00 \text{ mm}^2$$

Ketersediaan Tulangan Longitudinal untuk Torsi $A_{s,tor} = \frac{\Phi M_n - M_u}{\Phi M_n} \times A_s$

Tumpuan Negatif	-->	$\frac{155.379 - 124.776}{155.379}$	×	1005.3	=	198.002		
Tumpuan Positif	-->	$\frac{96.248 - 76.8638}{96.248}$	×	603.2	=	121.478		
Lapangan Negatif	-->	$\frac{96.248 - 27.1998}{96.248}$	×	603.2	=	432.724		
Lapangan Positif	-->	$\frac{155.379 - 153.0555}{155.379}$	×	1005.3	=	15.032		
Tulangan Tengah	=	402.1239 mm²						

Longitudinal Torsi Tumpuan	=	721.60 mm²	>	595.00 mm²	-	
Longitudinal Torsi Lapangan	=	849.88 mm²	>	595.00 mm²	-	

Spasi Vertikal Tulangan Longitudinal s_{vl}

(SNI 2847:2019 pasal 9.7.5.1)

$$= \frac{h - 2 \times c_c - 2 \times d_s - d_b}{2 + n_t - 1} \quad \text{(1 lapis)}$$

$$\frac{h - 2 \times c_c - 2 \times d_s - d_b - s_{12}}{2 + n_t - 1} \quad \text{(2 lapis atas/bawah)}$$

$$\frac{h - 2 \times c_c - 2 \times d_s - d_b - 2\,s_{12}}{2 + n_t - 1} \quad \text{(2 lapis atas dan bawah)}$$

Tumpuan	-->	192 mm	<	300 mm	-	
Lapangan	-->	192 mm	<	300 mm	-	

Spasi Horizontal Tulangan Longitudinal $s_{hl} = \frac{b - 2 \times c_c - 2 \times d_s - d_b}{n - 1}$

(SNI 2847:2019 pasal 9.7.5.1)

Tumpuan Atas	-->	46.000 mm	<	300 mm	-
Tumpuan Bawah	-->	92.000 mm	<	300 mm	-
Lapangan Atas	-->	92.000 mm	<	300 mm	-
Lapangan Bawah	-->	46.000 mm	<	300 mm	-

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7 Kesimpulan

7.1 Sketsa Balok

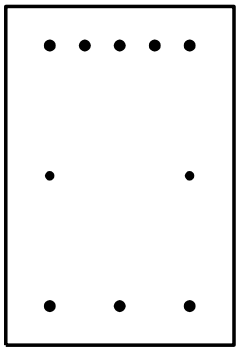
Tumpuan

300 × 500

5 D 16

2 D 16

3 D 16



Sengkang: 2 D 10 - 95

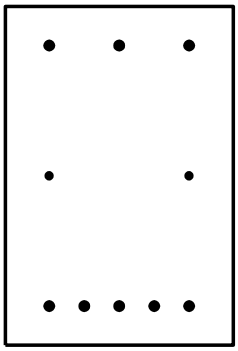
Lapangan

300 × 500

3 D 16

2 D 16

5 D 16



Sengkang: 2 D 10 - 150

7.2 Rekapitulasi Hasil Desain

No	Parameter	Cek
1	Syarat Gaya dan Geometri	OK
2	Tulangan Longitudinal Tumpuan Atas	OK
3	Tulangan Longitudinal Tumpuan Bawah	OK
4	Tulangan Longitudinal Lapangan Atas	OK
5	Tulangan Longitudinal Lapangan Bawah	OK
6	Tulangan Sengkang Tumpuan	OK
7	Tulangan Sengkang Lapangan	OK
8	Perlu Tulangan Torsi?	Tidak Perlu Tulangan Torsi
9	Kecukupan Dimensi	-
10	Tulangan Sengkang Torsi Tumpuan	-
11	Tulangan Sengkang Torsi Lapangan	-
12	Tulangan Longitudinal Torsi Tumpuan	-
13	Tulangan Longitudinal Torsi Lapangan	-

DESAIN BALOK 40x60	Date	: 15/May/2024
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1 Input Data

1.1 Geometri Balok

Lebar Balok	b	=	400	mm
Tinggi Balok	h	=	600	mm
Panjang Balok	L	=	3254.8	mm
Selimut Bersih	c_c	=	40	mm

1.3 Material

Kuat Tekan Beton	f_c'	=		MPa
Kuat Leleh Baja Tulangan Longitudinal	f_y	=		MPa
Kuat Leleh Baja Tulangan Transversal	f_{yv}	=		MPa

1.3 Diameter Tulangan

Diameter Tulangan Longitudinal	d_b	=		mm
Diameter Tulangan Pinggang	d_{bt}	=		mm
Diameter Tulangan Sengkang	d_s	=		mm

1.4 Jumlah Tulangan Longitudinal

Jumlah Tulangan Atas Baris 1	n_{ts1}	=	
Jumlah Tulangan Atas Baris 2	n_{ts2}	=	
Jumlah Tulangan Bawah Baris 1	n_{bs1}	=	
Jumlah Tulangan Bawah Baris 2	n_{bs2}	=	
Jumlah Tulangan Ujung Baris 1	n_{m1}	=	
Jumlah Tulangan Ujung Baris 2	n_{m2}	=	

Spasi Tulangan Lapis 1 ke Lapis 2	s_{12}	=		mm
Jumlah Pasang Tulangan Pinggang/Tengah	n_t	=		

1.5 Tulangan Transversal/Sengkang

Jumlah Kaki Tulangan Sengkang Tumpuan	n_{vs}	=		
Jumlah Kaki Tulangan Sengkang Ujung	n_{vm}	=		
Spasi Sengkang Tumpuan	s_s	=		mm
Spasi Sengkang Ujung	s_m	=		mm

1.6 Gaya Dalam

Momen Negatif	M_u (-)	=		kNm
Momen Positif	M_u (+)	=		kNm
Gaya Geser	V_u	=		kN
Torsi	T_u	=		kNm

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2 Parameter Material dan Geometri

Faktor Material Beton β_1

(SNI 2847:2019 tabel 22.2.2.4.3)

$$= 0.65 \le 0.85 - 0.05\,\frac{f_c' - 28}{7} \le 0.85$$

$$= 0.65 \le 0.85 - 0.05\,\frac{25.0 - 28}{7} \le 0.85$$

$$= 0.850$$

Regangan Leleh Baja Tulangan ε_{sy}

$$= \frac{f_y}{E_s} = \frac{420}{2000(0} = 0.0021$$

Tinggi Efektif Balok d

$$= h - c_c - d_s - \frac{d_b}{2}$$

$$= 600 - 4 - 1 - \frac{16}{2}$$

$$= 542 \text{ mm}$$

Lokasi Tulangan Lapis 2 d_2

$$= d - s_{12}$$

$$= 542 - 5$$

$$= 492 \text{ mm}$$

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3 Desain Lentur

3.1 Momen Negatif (Tulangan Tumpuan Atas)

Jumlah Tulangan Lapis 1 n_{ts1} = 7 --> $A_{s,1}$ = 1407.434 mm^2

Jumlah Tulangan Lapis 2 n_{ts2} = 0 --> $A_{s,2}$ = 0 mm^2

Jarak Bersih Tulangan Lapis 1 $s_{l,1}$ = 31.33 mm > 25 mm OK

Jarak Bersih Tulangan Lapis 2 $s_{l,2}$ = - mm > 25 mm OK

Luas Tulangan Total $A_s = A_{s,1} + A_{s,2} = 1407.434 + 0$

$= 1407.4 \ mm^2$

Rasio Luas Tulangan $\rho = \frac{A_s}{b \times d} = \frac{1407.4}{400 \times 542} = 0.65\%$

Luas Tulangan Minimum $A_{s,min}$

(SNI 2847:2019 pasal 9.6.1.2)

$$= \max \left\{ \begin{array}{l} \frac{\sqrt{f_c'}}{4 \times f_y} \times b \times d \\ \frac{1.4}{f_y} \times b \times d \end{array} \right.$$

$$= \max \left\{ \begin{array}{l} \frac{\sqrt{25}}{4 \times 420} \times 400 \times 542 \\ \frac{1.4}{420} \times 400 \times 542 \end{array} \right.$$

$$= \max \left\{ \begin{array}{l} 645.2 \ mm^2 \\ 722.7 \ mm^2 \end{array} \right.$$

$= 722.7 \ mm^2 < 1407.4 \ mm^2$ OK

Tinggi Blok Beton $a = \frac{A_s \times f_y}{0.85 \times f_c' \times b} = \frac{1407.4 \times 420}{0.85 \times 25 \times 400}$

(SNI 2847:2019 pasal 22.2.2.4.1)

$= 69.54 \ mm$

Tinggi Daerah Tekan Beton $c = \frac{a}{\beta_1} = \frac{69.54}{0.85} = 81.82 \ mm$

(SNI 2847:2019 pasal 22.2.2.4.1)

Regangan Tulangan Terluar $\varepsilon_{st} = \frac{d - c}{c} \times 0.003 = \frac{542 - 81.82}{81.82} \times 0.003$

$= 0.0169$

Faktor Reduksi $\Phi = 0.65 \le 0.65 + \frac{\varepsilon_{st} - \varepsilon_{sy}}{0.003} \times 0.25 \le 0.9$

(SNI 2847:2019 tabel 21.2.2)

$= 0.65 \le 0.65 + \frac{0.017 - 0.0021}{0.003} \times 0.25$

$= 0.90$

Kapasitas Momen $\Phi M_n = \Phi \times \left\{ \begin{array}{l} A_{s,1} \times f_y \times (d - a / 2) \\ + A_{s,2} \times f_y \times (d_2 - a / 2) \end{array} \right.$

$$= 0.90 \times \left\{ \begin{array}{l} 1407.4 \times 420 \times \left(542 - \frac{69.544}{2} \right) \\ + 0.0 \times 420 \times \left(492 - \frac{69.544}{2} \right) \end{array} \right.$$

$= 0.90 \times \{ 299.834 + 0.000 \}$

$= 269.850$ kNm > 266.424 kNm OK

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3.2 Momen Positif (Tulangan Tumpuan Bawah)

Jumlah Tulangan Lapis 1 $n_{bs1} = 4$ --> $A_{s,1} = 804.2477$ mm²

Jumlah Tulangan Lapis 2 $n_{bs2} = 0$ --> $A_{s,2} = 0$ mm²

Jarak Bersih Tulangan Lapis 1 $s_{l,1} = 78.67$ mm > 25 mm OK

Jarak Bersih Tulangan Lapis 2 $s_{l,2} = -$ mm > 25 mm OK

Luas Tulangan Total $A_s = A_{s,1} + A_{s,2} = 804.2477 + 0$

$= 804.2$ mm²

Rasio Luas Tulangan $\rho = \dfrac{A_s}{b \times d} = \dfrac{804.2}{400 \times 542} = 0.37\%$

Luas Tulangan Minimum *(SNI 2847:2019 pasal 9.6.1.2)*

$$A_{s,min} = \max\left\{\begin{array}{l}\dfrac{\sqrt{f_c'}}{4 \text{ x } f_y} \times b \times d \\ \dfrac{1.4}{f_y} \times b \times d\end{array}\right.$$

$$= \max\left\{\begin{array}{l}\dfrac{\sqrt{25}}{4 \text{ x } 420} \times 400 \times 542 \\ \dfrac{1.4}{420} \times 400 \times 542\end{array}\right.$$

$$= \max\left\{\begin{array}{l}645.2 \text{ mm}^2 \\ 722.7 \text{ mm}^2\end{array}\right.$$

$= 722.7$ mm² < 804.2 mm² OK

Tinggi Blok Beton *(SNI 2847:2019 pasal 22.2.2.4.1)*

$$a = \frac{A_s \times f_y}{0.85 \times f_c' \times b} = \frac{804.2 \times 420}{0.85 \times 25 \times 400}$$

$= 39.74$ mm

Tinggi Daerah Tekan Beton *(SNI 2847:2019 pasal 22.2.2.4.1)*

$$c = \frac{a}{\beta_1} = \frac{39.74}{0.85} = 46.75 \text{ mm}$$

Regangan Tulangan Terluar

$$\varepsilon_{st} = \frac{d - c}{c} \text{ x } 0.003 = \frac{542 - 46.75}{46.75} \times 0.003$$

$= 0.0318$

Faktor Reduksi *(SNI 2847:2019 tabel 21.2.2)*

$$\Phi = 0.65 \le 0.65 + \frac{\varepsilon_{st} - \varepsilon_{sy}}{0.003} \times 0.25 \le 0.9$$

$$= 0.65 \le 0.65 + \frac{0.032 - 0.0021}{0.003} \times 0.25$$

$= 0.90$

Kapasitas Momen

$$\Phi M_n = \Phi \times \left\{\begin{array}{l}A_{s,1} \times f_y \times (d - a/2) \\ + A_{s,2} \times f_y \times (d_2 - a/2)\end{array}\right.$$

$$= 0.90 \times \left\{\begin{array}{l}804.2 \times 420 \times \left(542 - \dfrac{39.739}{2}\right) \\ + 0.0 \times 420 \times \left(492 - \dfrac{39.739}{2}\right)\end{array}\right.$$

$$= 0.90 \times \{ 176.367 + 0.000 \}$$

$= 158.731$ kNm > 15.081 kNm OK

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3.3 Tulangan Ujung Atas dan Bawah

Jumlah Tulangan Lapis 1 n_{m1} = 4 --> $A_{s,1}$ = 804.2477 mm^2

Jumlah Tulangan Lapis 2 n_{m2} = 0 --> $A_{s,2}$ = 0 mm^2

Jarak Bersih Tulangan Lapis 1 $s_{l,1}$ = 78.67 mm > 25 mm OK

Jarak Bersih Tulangan Lapis 2 $s_{l,2}$ = - mm > 25 mm OK

Luas Tulangan Total $A_s = A_{s,1} + A_{s,2} = 804.2477 + 0$

$= 804.2 \ mm^2$

Rasio Luas Tulangan $\rho = \dfrac{A_s}{b \times d} = \dfrac{804.2}{400 \times 542} = 0.37\%$

Luas Tulangan Minimum $A_{s,min}$

(SNI 2847:2019 pasal 9.6.1.2)

$$= \max \left\{ \begin{array}{l} \dfrac{\sqrt{f_c'}}{4 \text{ x } f_y} \times b \times d \\ \dfrac{1.4}{f_y} \times b \times d \end{array} \right.$$

$$= \max \left\{ \begin{array}{l} \dfrac{\sqrt{25}}{4 \text{ x } 420} \times 400 \times 542 \\ \dfrac{1.4}{420} \times 400 \times 542 \end{array} \right.$$

$$= \max \left\{ \begin{array}{l} 645.2 \ mm^2 \\ 722.7 \ mm^2 \end{array} \right.$$

$= 722.7 \ mm^2 < 804.2 \ mm^2$ OK

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4 Desain Geser

4.1 Desain Geser Tumpuan

Jumlah Kaki $n_{vs} = 2$

Luas Tulangan Sengkang $A_v = n \times \pi/4 \times d_s^2 = 2 \times \pi/4 \times 10 \text{ ^2}$

$= 157.0796 \text{ mm}^2$

Spasi Sengkang $s_s = 100 \text{ mm}$

Tahanan Geser Beton $V_c = 0.17 \times \sqrt{f_c'} \times b \times d$

(SNI 2847:2019 pasal 22.5.5.1) $= 0.17 \times \sqrt{25} \times 400 \times 542$

$= 184280 \text{ N}$

Batas Penentu Spasi Maksimum $Batas = 0.33 \times \sqrt{f_c'} \times b \times d$

(SNI 2847:2019 tabel 9.7.6.2.2) $= 0.33 \times \sqrt{25} \times 400 \times 542$

$= 357720 \text{ N} < 475399.9 \text{ N}$

Spasi Maksimum $s_{max} = \min \begin{Bmatrix} d/4 \\ 300 \end{Bmatrix}$

(SNI 2847:2019 tabel 9.7.6.2.2)

$= \min \begin{Bmatrix} 542/4 \\ 300 \end{Bmatrix}$

$= \min \begin{Bmatrix} 135.5 \\ 300 \end{Bmatrix}$

$= 135.5 \text{ mm} > 100 \text{ mm}$ OK

Tahanan Geser Baja $V_s = \min \left\{ \begin{array}{l} \dfrac{A_v \times f_{yv} \times d}{s} \\ 0.66 \times \sqrt{f_c'} \times b \times d \end{array} \right.$

(SNI 2847:2019 pasal 22.10.5.3)

$= \min \left\{ \begin{array}{l} \dfrac{157 \times 420 \times 542}{100} \\ 0.66 \times \sqrt{25} \times 400 \times 542 \end{array} \right.$

$= \min \begin{Bmatrix} 357576 \\ 715440 \end{Bmatrix}$

$= 357576 \text{ N}$

Faktor Reduksi $\Phi = 0.75$

(SNI 2847:2019 pasal 12.5.3.2)

Kapasitas Geser $\Phi V_n = \Phi \times (V_c + V_s)$

$= 0.75 \times (184.28 + 357.5761)$

$= 406.3921 \text{ kN} > 356.5499 \text{ kN}$ OK

4.2 Tulangan Transversal Ujung

Spasi Sengkang $s_m = 150 \text{ mm}$

Spasi Maksimum $s_{max} = \min \begin{Bmatrix} d/2 \\ 600 \end{Bmatrix}$

(SNI 2847:2019 tabel 9.7.6.2.2)

$= \min \begin{Bmatrix} 542/2 \\ 600 \end{Bmatrix}$

$= \min \begin{Bmatrix} 271 \\ 600 \end{Bmatrix}$

$= 271 \text{ mm} > 150 \text{ mm}$ OK

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5 Desain Torsi

5.1 Parameter Penampang untuk Perhitungan Torsi

Luas Penampang Penuh $A_{cp} = b \times h = 400 \times 600$

$= 240000 \text{ mm}^2$

Keliling Penampang Penuh $P_{cp} = 2 \times (b + h) = 2 \times (400 + 600)$

$= 2000 \text{ mm}$

Lebar Penampang Inti $x_o = b - 2 \times c_c - d_s$

(SNI 2847:2019 pasal 22.7.6.1.1) $= 400 - 2 \times 40 - 10$

$= 310 \text{ mm}$

Tinggi Penampang Inti $y_o = h - 2 \times c_c - d_s$

(SNI 2847:2019 pasal 22.7.6.1.1) $= 600 - 2 \times 40 - 10$

$= 510 \text{ mm}$

Luas Penampang Inti $A_{oh} = x_o \times y_o = 310 \times 510$

(SNI 2847:2019 pasal 22.7.6.1.1) $= 158100 \text{ mm}^2$

Luas Efektif Penampang Inti $A_o = 0.85 \times A_{oh} = 0.85 \times 158100$

(SNI 2847:2019 pasal 22.7.6.1.1) $= 134385 \text{ mm}^2$

Keliling Penampang Inti $P_h = 2 \times x_o + y_o = 2 \times 310 + 510$

(SNI 2847:2019 pasal 22.7.6.1.1) $= 1640 \text{ mm}$

5.2 Pengecekan Kebutuhan Tulangan Torsi

Tahanan Retak Torsi $T_{cr} = 0.33 \times \sqrt{f_c'} \times \frac{A_{cp}^2}{P_{cp}}$

(SNI 2847:2019 pasal 22.7.5.1)

$= 0.33 \times \sqrt{25} \times \frac{240000 \text{ ^2}}{2000}$

$= 47.520 \text{ kNm}$

Faktor Reduksi $\Phi = 0.75$

(SNI 2847:2019 tabel 21.2.1)

Ambang Batas Kebutuhan Tulangan Torsi

(SNI 2847:2019 tabel 22.7.4.1)

$= \frac{\Phi \times T_{cr}}{4}$

$= \frac{0.75 \times 47.520}{4}$

$= 8.910 \text{ kNm} > 1.7068 \text{ kNm}$

--> **Tidak Perlu Tulangan Torsi**

Perhitungan di bawah ini dapat diabaikan

5.3 Pengecekan Kecukupan Dimensi

Momen Torsi Pakai T_u = min { $\Phi \times T_{cr}$; T_u }

(SNI 2847:2019 pasal 22.7.3.2)

= min { 0.75 × 47.520 ; 1.707 }

= min { 35.640 ; 1.707 }

= 1.707 kNm

Tegangan Akibat Geser + Torsi σ_u = $\sqrt{\left(\frac{V_u}{b \times d}\right)^2 + \left(\frac{T_u \times P_h}{1.7 \times A_{oh}^2}\right)^2}$

(SNI 2847:2019 pasal 22.7.7.1)

= $\sqrt{\left(\frac{356.550}{400 \times 542}\right)^2 + \left(\frac{1.707 \times 1640}{1.7 \times 158100}\right)^2}$

= √{ 1.645 ^2 + 0.066 ^2 }

= 1.646 MPa

Tahanan Tegangan Geser+Torsi Beton σ_n = $\Phi \left(\frac{V_c}{b \times d} + 0.66 \times \sqrt{f_c'}\right)$

(SNI 2847:2019 pasal 22.7.7.1)

= 0.75 (184280 / (400 × 542) + 0.66 × √ 25)

= 3.113 MPa > 1.646 MPa -

5.4 Tulangan Transversal Torsi

Spasi Maksimum s_{max} = min { $P_h / 8$; d_b ; 0.042 × 300 }

(SNI 2847:2019 pasal 9.7.6.3.3)

= min { 1640 / 8 ; 16 ; 0.042 × 300 }

= min { 205 ; 380.9524 ; 300 }

= 205 mm > 100 mm -

Kebutuhan Tulangan Transversal Torsi A_t/s = $\frac{T_u}{2 \times \Phi \times A_o \times f_{yv}}$

(SNI 2847:2019 pasal 22.7.6.1)

= 1.707 × 10^6

$$2 \times 0.75 \times 134385 \times 420$$

$$= 0.020 \text{ mm}^2/\text{mm}$$

Kebutuhan Tulangan Geser

$$A_v/s = \left(\frac{V_u - V_c}{\Phi}\right) \Big/ f_{yv} \times d$$

$$= \left(\frac{356.5499 - 184}{0.75}\right) \Big/ 420 \times 542$$

$$= 1.279 \text{ mm}^2/\text{mm}$$

Kebutuhan Tulangan Geser+Torsi *(SNI 2847:2019 pasal 9.5.4.3)*

$$A_{v+t}/s = 2 \times A_t/s + A_v/s$$

$$= 2 \times 0.020 + 1.279$$

$$= 1.319 \text{ mm}^2/\text{mm} < 1.571 \text{ mm}^2/\text{mm} \text{ -}$$

Tulangan Transversal Minimum *(SNI 2847:2019 pasal 9.6.4.2)*

$$A/s_{min} = \max \begin{cases} 0.062 \times \sqrt{f_c'} \times \dfrac{b}{f_{yv}} \\ 0.350 \times \dfrac{b}{f_{yv}} \end{cases}$$

$$A/s_{min} = \max \begin{cases} 0.062 \times \sqrt{25} \times \dfrac{400}{420} \\ 0.350 \times \dfrac{400}{420} \end{cases}$$

$$= \max \begin{cases} 0.295 \\ 0.333 \end{cases}$$

$$= 0.333 \text{ mm}^2/\text{mm} < 1.571 \text{ mm}^2/\text{mm} \text{ -}$$

5.5 Tulangan Longitudinal Torsi

Kebutuhan Tulangan Longitudinal Torsi *(SNI 2847:2019 pasal 22.7.6.1)*

$$A_l = A_t/s \times P_h \times \frac{f_{yv}}{f_y}$$

$$= 0.020 \times 1640 \times \frac{420}{420}$$

$$= 33.062 \text{ mm}^2$$

Tulangan Longitudinal Torsi Minimum *(SNI 2847:2019 pasal 9.6.4.3)*

$$A_l = \min \begin{cases} 0.42 \times \sqrt{f_c'} \times \dfrac{A_{cp}}{f_{yv}} - A_t/s \times P_h \times \dfrac{f_{yv}}{f_y} \\ 0.42 \times \sqrt{f_c'} \times \dfrac{A_{cp}}{f_{yv}} - \dfrac{0.175 \text{ b } P_h}{f_{yv}} \times \dfrac{f_{yv}}{f_y} \end{cases}$$

$$\min \begin{cases} 0.42 \times \sqrt{25} \times \dfrac{240000}{420} - 0.020 \times 1640 \times 1 \\ 0.42 \times \sqrt{25} \times \dfrac{240000}{420} - \dfrac{0.175 \times 400 \times 1640 \times 1}{420} \end{cases}$$

$$= \min \begin{cases} 1166.94 \\ 926.67 \end{cases}$$

$$= 926.67 \text{ mm}^2$$

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Ketersediaan Tulangan Longitudinal untuk Torsi $A_{s,tor} = \frac{\Phi M_n - M_u}{\Phi M_n} \times A_s$

Negatif --> $\frac{269.850 - 266.4239}{269.850} \times 1407.4 = 17.871$

Positif --> $\frac{158.731 - 15.0811}{158.731} \times 804.2 = 727.836$

Tulangan Tengah = 201.0619 mm^2

Longitudinal Torsi = 946.77 mm^2 > 926.67 mm^2 -

Spasi Vertikal Tulangan Longitudinal *(SNI 2847:2019 pasal 9.6.5.1)*

$s_{vl} = \frac{h - 2 \times c_c - 2 \times d_s - d_b}{2 + n_t - 1}$ (1 lapis)

$\frac{h - 2 \times c_c - 2 \times d_s - d_b - s_{12}}{2 + n_t - 1}$ (2 lapis atas/bawah)

$\frac{h - 2 \times c_c - 2 \times d_s - d_b - 2 s_{12}}{2 + n_t - 1}$ (2 lapis atas dan bawah)

--> 242 mm < 300 mm -

Spasi Horizontal Tulangan Longitudinal *(SNI 2847:2019 pasal 9.6.5.1)*

$s_{hl} = \frac{b - 2 \times c_c - 2 \times d_s - d_b}{n - 1}$

Atas --> 47.333 mm < 300 mm -

Bawah --> 94.667 mm < 300 mm -

Ujung --> 94.667 mm < 300 mm -

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6 Kesimpulan

6.1 Sketsa Balok

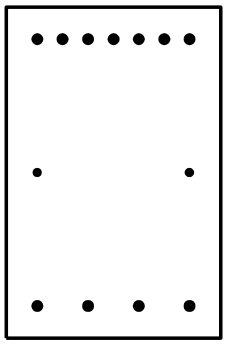
Tumpuan

400 × 600

7 D 16

2 D 16

4 D 16



Sengkang: 2 D 10 - 100

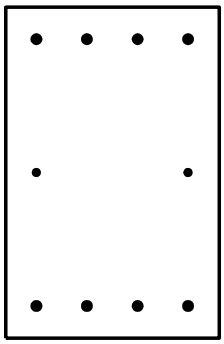
Ujung

400 × 600

4 D 16

2 D 16

4 D 16



Sengkang: 2 D 10 - 150

6.2 Rekapitulasi Hasil Desain

No	Parameter	Cek
1	Tulangan Longitudinal Tumpuan Atas	OK
2	Tulangan Longitudinal Tumpuan Bawah	OK
3	Tulangan Ujung Atas dan Bawah	OK
4	Tulangan Sengkang	OK
5	Perlu Tulangan Torsi?	Tidak Perlu Tulangan Torsi
6	Kecukupan Dimensi	-
7	Tulangan Sengkang Torsi	-
8	Tulangan Longitudinal Torsi	-

DESAIN BALOK 30x40	Date	: 15/May/2024
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1 Input Data

1.1 Geometri Balok

Lebar Balok	b	=	300	mm
Tinggi Balok	h	=	400	mm
Panjang Balok	L	=	3882.3	mm
Selimut Bersih	c_c	=	40	mm

1.3 Material

Kuat Tekan Beton	f_c'	=		Kuat
Leleh Baja Tulangan Longitudinal	f_y	=		Kuat
Leleh Baja Tulangan Transversal	f_{yv}	=		MPa

1.3 Diameter Tulangan

Diameter Tulangan Longitudinal	d_b	=		mm
Diameter Tulangan Pinggang	d_{bt}	=		mm
Diameter Tulangan Sengkang	d_s	=		mm

1.4 Jumlah Tulangan Longitudinal

	Tumpuan			Lapangan		
Jumlah Tulangan Atas Baris 1	n_{ts1}	=		n_{tm1}	=	
Jumlah Tulangan Atas Baris 2	n_{ts2}	=		n_{tm2}	=	
Jumlah Tulangan Bawah Baris 1	n_{bs1}	=		n_{bm1}	=	
Jumlah Tulangan Bawah Baris 2	n_{bs2}	=		n_{bm2}	=	

Spasi Tulangan Lapis 1 ke Lapis 2	s_{12}	=		mm
Jumlah Pasang Tulangan Pinggang/Tengah	n_t	=		

1.5 Tulangan Transversal/Sengkang

Jumlah Kaki Tulangan Sengkang Tumpuan	n_{vs}	=		
Jumlah Kaki Tulangan Sengkang Lapangan	n_{vm}	=		
Spasi Sengkang Tumpuan	s_s	=		mm
Spasi Sengkang Lapangan	s_m	=		mm

1.6 Gaya Dalam

Momen Negatif Tumpuan	$M_{u,tum}$ (-)	=		kNm
Momen Positif Tumpuan	$M_{u,tum}$ (+)	=		kNm
Momen Negatif Lapangan	$M_{u,lap}$ (-)	=		kNm
Momen Positif Lapangan	$M_{u,lap}$ (+)	=		kNm
Gaya Geser Tumpuan	$V_{u,tumpuan}$	=		kN
Gaya Geser Lapangan	$V_{u,lapangan}$	=		kN
Torsi	T_u	=		kNm

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2 Parameter Material dan Geometri

Faktor Material Beton β_1

(SNI 2847:2019 tabel 22.2.2.4.3)

$$= 0.65 \le 0.85 - 0.05 \frac{f_c' - 28}{7} \le 0.85$$

$$= 0.65 \le 0.85 - 0.05 \frac{25.0 - 28}{7} \le 0.85$$

$$= 0.850$$

Regangan Leleh Baja Tulangan ε_{sy}

$$= \frac{f_y}{E_s} = \frac{420}{2000(0} = 0.0021$$

Tinggi Efektif Balok d

$$= h - c_c - d_s - \frac{d_b}{2}$$

$$= 400 - 4 - 1 - \frac{16}{2}$$

$$= 342 \text{ mm}$$

Lokasi Tulangan Lapis 2 d_2

$$= d - s_{12}$$

$$= 342 - 5$$

$$= 292 \text{ mm}$$

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3 Desain Lentur

3.1 Momen Negatif Tumpuan (Tulangan Tumpuan Atas)

Jumlah Tulangan Lapis 1 n_{ts1} = 3 --> $A_{s,1}$ = 603.1858 mm²

Jumlah Tulangan Lapis 2 n_{ts2} = 0 --> $A_{s,2}$ = 0 mm²

Jarak Bersih Tulangan Lapis 1 $s_{l,1}$ = 76 mm > 25 mm OK

Jarak Bersih Tulangan Lapis 2 $s_{l,2}$ = - mm > 25 mm OK

Luas Tulangan Total $A_s = A_{s,1} + A_{s,2} = 603.1858 + 0$

$= 603.2$ mm²

Rasio Luas Tulangan $\rho = \frac{A_s}{b \times d} = \frac{603.2}{300 \times 342} = 0.59\%$

Luas Tulangan Minimum $A_{s,min}$

(SNI 2847:2019 pasal 9.6.1.2)

$$= \max\left\{\begin{array}{l} \frac{\sqrt{f_c'}}{4 \times f_y} \times b \times d \\ \frac{1.4}{f_y} \times b \times d \end{array}\right.$$

$$= \max\left\{\begin{array}{l} \frac{\sqrt{25}}{4 \times 420} \times 300 \times 342 \\ \frac{1.4}{420} \times 300 \times 342 \end{array}\right.$$

$$= \max\left\{\begin{array}{l} 305.4 \text{ mm}^2 \\ 342.0 \text{ mm}^2 \end{array}\right.$$

$= 342.0$ mm² < 603.2 mm² OK

Tinggi Blok Beton $a = \frac{A_s \times f_y}{0.85 \times f_c' \times b} = \frac{603.2 \times 420}{0.85 \times 25 \times 300}$

(SNI 2847:2019 pasal 22.2.2.4.1)

$= 39.74$ mm

Tinggi Daerah Tekan Beton $c = \frac{a}{\beta_1} = \frac{39.74}{0.85} = 46.75$ mm

(SNI 2847:2019 pasal 22.2.2.4.1)

Regangan Tulangan Terluar $\varepsilon_{st} = \frac{d - c}{c} \times 0.003 = \frac{342 - 46.75}{46.75} \times 0.003$

$= 0.0189$

Faktor Reduksi $\Phi = 0.65 \le 0.65 + \frac{\varepsilon_{st} - \varepsilon_{sy}}{0.003} \times 0.25 \le 0.9$

(SNI 2847:2019 tabel 21.2.2)

$= 0.65 \le 0.65 + \frac{0.019 - 0.0021}{0.003} \times 0.25$

$= 0.90$

Kapasitas Momen $\Phi M_n = \Phi \times \left\{\begin{array}{l} A_{s,1} \times f_y \times (d - a/2) \\ + A_{s,2} \times f_y \times (d_2 - a/2) \end{array}\right.$

$$= 0.90 \times \left\{\begin{array}{l} 603.2 \times 420 \times \left(342 - \frac{39.739}{2}\right) \\ + 0.0 \times 420 \times \left(292 - \frac{39.739}{2}\right) \end{array}\right.$$

$= 0.90 \times \{ 81.608 + 0.000 \}$

$= 73.447$ kNm > 13.789 kNm OK

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3.2 Momen Positif Tumpuan (Tulangan Tumpuan Bawah)

Jumlah Tulangan Lapis 1 $n_{bs1} = 3$ --> $A_{s,1} = 603.1858$ mm²

Jumlah Tulangan Lapis 2 $n_{bs2} = 0$ --> $A_{s,2} = 0$ mm²

Jarak Bersih Tulangan Lapis 1 $s_{l,1} = 76$ mm > 25 mm OK

Jarak Bersih Tulangan Lapis 2 $s_{l,2} = -$ mm > 25 mm OK

Luas Tulangan Total $A_s = A_{s,1} + A_{s,2} = 603.1858 + 0$

$= 603.2$ mm²

Rasio Luas Tulangan $\rho = \dfrac{A_s}{b \times d} = \dfrac{603.2}{300 \times 342} = 0.59\%$

Luas Tulangan Minimum $A_{s,min}$

(SNI 2847:2019 pasal 9.6.1.2)

$$= \max\left\{\begin{array}{l}\dfrac{\sqrt{f_c'}}{4 \text{ x } f_y} \times b \times d \\ \dfrac{1.4}{f_y} \times b \times d\end{array}\right.$$

$$= \max\left\{\begin{array}{l}\dfrac{\sqrt{25}}{4 \text{ x } 420} \times 300 \times 342 \\ \dfrac{1.4}{420} \times 300 \times 342\end{array}\right.$$

$$= \max\left\{\begin{array}{l}305.4 \text{ mm}^2 \\ 342.0 \text{ mm}^2\end{array}\right.$$

$= 342.0$ mm² < 603.2 mm² OK

Tinggi Blok Beton $a = \dfrac{A_s \times f_y}{0.85 \times f_c' \times b} = \dfrac{603.2 \times 420}{0.85 \times 25 \times 300}$

(SNI 2847:2019 pasal 22.2.2.4.1)

$= 39.74$ mm

Tinggi Daerah Tekan Beton $c = \dfrac{a}{\beta_1} = \dfrac{39.74}{0.85} = 46.75$ mm

(SNI 2847:2019 pasal 22.2.2.4.1)

Regangan Tulangan Terluar $\varepsilon_{st} = \dfrac{d - c}{c} \text{ x } 0.003 = \dfrac{342 - 46.75}{46.75} \times 0.003$

$= 0.0189$

Faktor Reduksi $\Phi = 0.65 \le 0.65 + \dfrac{\varepsilon_{st} - \varepsilon_{sy}}{0.003} \times 0.25 \le 0.9$

(SNI 2847:2019 tabel 21.2.2)

$= 0.65 \le 0.65 + \dfrac{0.019 - 0.0021}{0.003} \times 0.25$

$= 0.90$

Kapasitas Momen $\Phi M_n = \Phi \times \left\{\begin{array}{l}A_{s,1} \times f_y \times (d - a/2) \\ + A_{s,2} \times f_y \times (d_2 - a/2)\end{array}\right.$

$$= 0.90 \times \left\{\begin{array}{l}603.2 \times 420 \times \left(342 - \dfrac{39.739}{2}\right) \\ + 0.0 \times 420 \times \left(292 - \dfrac{39.739}{2}\right)\end{array}\right.$$

$= 0.90 \times \{ 81.608 + 0.000 \}$

$= 73.447$ kNm > 53.904 kNm OK

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3.3 Momen Negatif Lapangan (Tulangan Lapangan Atas)

Jumlah Tulangan Lapis 1 $n_{tm1} = 3$ --> $A_{s,1} = 603.1858$ mm²

Jumlah Tulangan Lapis 2 $n_{tm2} = 0$ --> $A_{s,2} = 0$ mm²

Jarak Bersih Tulangan Lapis 1 $s_{l,1} = 76$ mm > 25 mm OK

Jarak Bersih Tulangan Lapis 2 $s_{l,2} = -$ mm > 25 mm OK

Luas Tulangan Total $A_s = A_{s,1} + A_{s,2} = 603.1858 + 0$

$= 603.2$ mm²

Rasio Luas Tulangan $\rho = \dfrac{A_s}{b \times d} = \dfrac{603.2}{300 \times 342} = 0.59\%$

Luas Tulangan Minimum $A_{s,min}$

(SNI 2847:2019 pasal 9.6.1.2)

$$= \max\left\{ \frac{\sqrt{f_c'}}{4 \text{ x } f_y} \times b \times d \;;\; \frac{1.4}{f_y} \times b \times d \right\}$$

$$= \max\left\{ \frac{\sqrt{25}}{4 \text{ x } 420} \times 300 \times 342 \;;\; \frac{1.4}{420} \times 300 \times 342 \right\}$$

$$= \max\left\{ 305.4 \text{ mm}^2 \;;\; 342.0 \text{ mm}^2 \right\}$$

$= 342.0$ mm² < 603.2 mm² OK

Tinggi Blok Beton $a = \dfrac{A_s \times f_y}{0.85 \times f_c' \times b} = \dfrac{603.2 \times 420}{0.85 \times 25 \times 300}$

(SNI 2847:2019 pasal 22.2.2.4.1)

$= 39.74$ mm

Tinggi Daerah Tekan Beton $c = \dfrac{a}{\beta_1} = \dfrac{39.74}{0.85} = 46.75$ mm

(SNI 2847:2019 pasal 22.2.2.4.1)

Regangan Tulangan Terluar $\varepsilon_{st} = \dfrac{d - c}{c} \text{ x } 0.003 = \dfrac{342 - 46.75}{46.75} \times 0.003$

$= 0.0189$

Faktor Reduksi $\Phi = 0.65 \le 0.65 + \dfrac{\varepsilon_{st} - \varepsilon_{sy}}{0.003} \times 0.25 \le 0.9$

(SNI 2847:2019 tabel 21.2.2)

$= 0.65 \le 0.65 + \dfrac{0.019 - 0.0021}{0.003} \times 0.25$

$= 0.90$

Kapasitas Momen $\Phi M_n = \Phi \times \{ A_{s,1} \times f_y \times (d - a / 2) + A_{s,2} \times f_y \times (d_2 - a / 2) \}$

$$= 0.90 \times \left\{ 603.2 \times 420 \times \left(342 - \frac{39.739}{2} \right) + 0.0 \times 420 \times \left(292 - \frac{39.739}{2} \right) \right\}$$

$= 0.90 \times \{ 81.608 + 0.000 \}$

$= 73.447$ kNm > 10.999 kNm OK

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3.4 Momen Positif Lapangan (Tulangan Lapangan Bawah)

Jumlah Tulangan Lapis 1 $n_{tm1} = 3$ --> $A_{s,1} = 603.1858$ mm²

Jumlah Tulangan Lapis 2 $n_{tm2} = 0$ --> $A_{s,2} = 0$ mm²

Jarak Bersih Tulangan Lapis 1 $s_{l,1} = 76$ mm > 25 mm OK

Jarak Bersih Tulangan Lapis 2 $s_{l,2} = -$ mm > 25 mm OK

Luas Tulangan Total $A_s = A_{s,1} + A_{s,2} = 603.1858 + 0$

$= 603.2$ mm²

Rasio Luas Tulangan $\rho = \dfrac{A_s}{b \times d} = \dfrac{603.2}{300 \times 342} = 0.59\%$

Luas Tulangan Minimum $A_{s,min}$

(SNI 2847:2019 pasal 9.6.1.2)

$$= \max\left\{ \frac{\sqrt{f_c'}}{4 \text{ x } f_y} \times b \times d \;;\; \frac{1.4}{f_y} \times b \times d \right\}$$

$$= \max\left\{ \frac{\sqrt{25}}{4 \text{ x } 420} \times 300 \times 342 \;;\; \frac{1.4}{420} \times 300 \times 342 \right\}$$

$$= \max\left\{ \begin{matrix} 305.4 \text{ mm}^2 \\ 342.0 \text{ mm}^2 \end{matrix} \right\}$$

$= 342.0$ mm² < 603.2 mm² OK

Tinggi Blok Beton $a = \dfrac{A_s \times f_y}{0.85 \times f_c' \times b} = \dfrac{603.2 \times 420}{0.85 \times 25 \times 300}$

(SNI 2847:2019 pasal 22.2.2.4.1)

$= 39.74$ mm

Tinggi Daerah Tekan Beton $c = \dfrac{a}{\beta_1} = \dfrac{39.74}{0.85} = 46.75$ mm

(SNI 2847:2019 pasal 22.2.2.4.1)

Regangan Tulangan Terluar $\varepsilon_{st} = \dfrac{d - c}{c} \text{ x } 0.003 = \dfrac{342 - 46.75}{46.75} \times 0.003$

$= 0.0189$

Faktor Reduksi $\Phi = 0.65 \le 0.65 + \dfrac{\varepsilon_{st} - \varepsilon_{sy}}{0.003} \times 0.25 \le 0.9$

(SNI 2847:2019 tabel 21.2.2)

$= 0.65 \le 0.65 + \dfrac{0.019 - 0.0021}{0.003} \times 0.25$

$= 0.90$

Kapasitas Momen $\Phi M_n = \Phi \times \{ A_{s,1} \times f_y \times (d - a / 2) + A_{s,2} \times f_y \times (d_2 - a / 2) \}$

$$= 0.90 \times \left\{ \begin{matrix} 603.2 \times 420 \times \left(342 - \dfrac{39.739}{2} \right) \\ + \quad 0.0 \times 420 \times \left(292 - \dfrac{39.739}{2} \right) \end{matrix} \right\}$$

$= 0.90 \times \{ 81.608 + 0.000 \}$

$= 73.447$ kNm > 11.804 kNm OK

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4 Desain Geser

4.1 Geser Tumpuan

Jumlah Kaki $n_{vs} = 2$

Luas Tulangan Sengkang $A_v = n \times \pi/4 \times d_s^2 = 2 \times \pi/4 \times 10 \text{ ^2}$

$= 157.0796 \text{ mm}^2$

Spasi Sengkang $s_s = 85 \text{ mm}$

Tahanan Geser Beton $V_c = 0.17 \times \sqrt{f_c'} \times b \times d$

(SNI 2847:2019 pasal 22.5.5.1) $= 0.17 \times \sqrt{25} \times 300 \times 342$

$= 87210 \text{ N}$

Batas Penentu Spasi Maksimum $Batas = 0.33 \times \sqrt{f_c'} \times b \times d$

(SNI 2847:2019 tabel 9.7.6.2.2) $= 0.33 \times \sqrt{25} \times 300 \times 342$

$= 169290 \text{ N} < 199788.5 \text{ N}$

Spasi Maksimum $s_{max} = \min \begin{Bmatrix} d/4 \\ 300 \end{Bmatrix}$

(SNI 2847:2019 tabel 9.7.6.2.2)

$= \min \begin{Bmatrix} 342/4 \\ 300 \end{Bmatrix}$

$= \min \begin{Bmatrix} 85.5 \\ 300 \end{Bmatrix}$

$= 85.5 \text{ mm} > 85 \text{ mm}$ OK

Tahanan Geser Baja $V_s = \min \left\{ \begin{array}{l} \dfrac{A_v \times f_{yv} \times d}{s} \\ 0.66 \times \sqrt{f_c'} \times b \times d \end{array} \right.$

(SNI 2847:2019 pasal 22.10.5.3)

$= \min \left\{ \begin{array}{l} \dfrac{157 \times 420 \times 342}{85} \\ 0.66 \times \sqrt{25} \times 300 \times 342 \end{array} \right.$

$= \min \begin{Bmatrix} 265446 \\ 338580 \end{Bmatrix}$

$= 265446 \text{ N}$

Faktor Reduksi $\Phi = 0.75$

(SNI 2847:2019 pasal 12.5.3.2)

Kapasitas Geser $\Phi V_n = \Phi \times (V_c + V_s)$

$= 0.75 \times (87.21 + 265.4461)$

$= 264.4921 \text{ kN} > 215.2489 \text{ kN}$ OK

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4.2 Geser Lapangan

Jumlah Kaki n_{vm} = 2

Luas Tulangan Sengkang A_v = $n \times \pi/4 \times d_s^2$ = 2 × π/4 × 10 ^2

= 157.0796 mm^2

Spasi Sengkang s_m = 85 mm

Tahanan Geser Beton V_c = $0.17 \times \sqrt{f_c'} \times b \times d$

(SNI 2847:2019 pasal 22.5.5.1) = $0.17 \times \sqrt{25} \times 300 \times 342$

= 87210 N

Batas Penentu Spasi Maksimum *Batas* = $0.33 \times \sqrt{f_c'} \times b \times d$

(SNI 2847:2019 tabel 9.7.6.2.2) = $0.33 \times \sqrt{25} \times 300 \times 342$

= 169290 N < 198039.7 N

Spasi Maksimum s_{max} = $\min \begin{Bmatrix} d/4 \\ 300 \end{Bmatrix}$

(SNI 2847:2019 tabel 9.7.6.2.2)

= $\min \begin{Bmatrix} 342/4 \\ 300 \end{Bmatrix}$

= $\min \begin{Bmatrix} 85.5 \\ 300 \end{Bmatrix}$

= 85.5 mm > 85 mm OK

Tahanan Geser Baja V_s = $\min \left\{ \begin{matrix} \frac{A_v \times f_{yv} \times d}{s} \\ 0.66 \times \sqrt{f_c'} \times b \times d \end{matrix} \right\}$

(SNI 2847:2019 pasal 22.10.5.3)

= $\min \left\{ \begin{matrix} \frac{157 \times 420 \times 342}{85} \\ 0.66 \times \sqrt{25} \times 300 \times 342 \end{matrix} \right\}$

= $\min \begin{Bmatrix} 265446 \\ 338580 \end{Bmatrix}$

= 265446 N

Faktor Reduksi Φ = 0.75

(SNI 2847:2019 pasal 12.5.3.2)

Kapasitas Geser ΦV_n = $\Phi \times (V_c + V_s)$

= $0.75 \times (87.21 + 265.4461)$

= 264.4921 kN > 213.9373 kN OK

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5 Desain Torsi

5.1 Parameter Penampang untuk Perhitungan Torsi

Luas Penampang Penuh — $A_{cp} = b \times h = 300 \times 400$

$= 120000 \text{ mm}^2$

Keliling Penampang Penuh — $P_{cp} = 2 \times (b + h) = 2 \times (300 + 400)$

$= 1400 \text{ mm}$

Lebar Penampang Inti — $x_o = b - 2 \times c_c - d_s$

(SNI 2847:2019 pasal 22.7.6.1.1)

$= 300 - 2 \times 40 - 10$

$= 210 \text{ mm}$

Tinggi Penampang Inti — $y_o = h - 2 \times c_c - d_s$

(SNI 2847:2019 pasal 22.7.6.1.1)

$= 400 - 2 \times 40 - 10$

$= 310 \text{ mm}$

Luas Penampang Inti — $A_{oh} = x_o \times y_o = 210 \times 310$

(SNI 2847:2019 pasal 22.7.6.1.1)

$= 65100 \text{ mm}^2$

Luas Efektif Penampang Inti — $A_o = 0.85 \times A_{oh} = 0.85 \times 65100$

(SNI 2847:2019 pasal 22.7.6.1.1)

$= 55335 \text{ mm}^2$

Keliling Penampang Inti — $P_h = 2 \times x_o + y_o = 2 \times 210 + 310$

(SNI 2847:2019 pasal 22.7.6.1.1)

$= 1040 \text{ mm}$

5.2 Pengecekan Kebutuhan Tulangan Torsi

Tahanan Retak Torsi — $T_{cr} = 0.33 \times \sqrt{f_c'} \times \frac{A_{cp}^2}{P_{cp}}$

(SNI 2847:2019 pasal 22.7.5.1)

$= 0.33 \times \sqrt{25} \times \frac{120000 \text{ ^2}}{1400}$

$= 16.971 \text{ kNm}$

Faktor Reduksi — $\Phi = 0.75$

(SNI 2847:2019 tabel 21.2.1)

Ambang Batas Kebutuhan Tulangan Torsi

(SNI 2847:2019 tabel 22.7.4.1)

$= \frac{\Phi \times T_{cr}}{4}$

$= \frac{0.75 \times 16.971}{4}$

$= 3.182 \text{ kNm} > 1.1982 \text{ kNm}$

--> **Tidak Perlu Tulangan Torsi**

Perhitungan di bawah ini dapat diabaikan

5.3 Pengecekan Kecukupan Dimensi

Momen Torsi Pakai — T_u
(SNI 2847:2019 pasal 22.7.3.2)

$$T_u = \min \begin{cases} \Phi \times T_{cr} \\ T_u \end{cases}$$

$$= \min \begin{matrix} 0.75 \times 16.971 \\ 1.198 \end{matrix}$$

$$= \min \begin{matrix} 12.729 \\ 1.198 \end{matrix}$$

$$= 1.198 \text{ kNm}$$

Tegangan Akibat Geser + Torsi — σ_u
(SNI 2847:2019 pasal 22.7.7.1)

$$\sigma_u = \sqrt{\left(\frac{V_u}{b \times d}\right)^2 + \left(\frac{T_u \times P_h}{1.7 \times A_{oh}^2}\right)^2}$$

$$= \sqrt{\left(\frac{215.249}{300 \times 342}\right)^2 + \left(\frac{1.198 \times 1040}{1.7 \times 65100}\right)^2}$$

$$= \sqrt{\{\ 2.098^2 + 0.173^2}$$

$$= 2.105 \text{ MPa}$$

Tahanan Tegangan Geser+Torsi Beton — σ_n
(SNI 2847:2019 pasal 22.7.7.1)

$$= \Phi \left(\frac{V_c}{b \times d} + 0.66 \times \sqrt{f_c'}\right)$$

$$= 0.75 \left(\frac{87210}{300 \times 342} + 0.66 \times \sqrt{25}\right)$$

$$= 3.113 \text{ MPa} > 2.105 \text{ MPa} \quad -$$

5.4 Tulangan Transversal Torsi

Spasi Maksimum — s_{max}
(SNI 2847:2019 pasal 9.7.6.3.3)

$$= \min \begin{matrix} P_h \\ 8 \\ d_b \\ 0.042 \\ 300 \end{matrix}$$

$$= \min \begin{matrix} 1040 \\ 8 \\ 16 \\ 0.042 \\ 300 \end{matrix}$$

$$= \min \begin{matrix} 130 \\ 380.9524 \\ 300 \end{matrix}$$

$$= 130 \text{ mm} > 85 \text{ mm} \quad - \quad \text{(tumpuan)}$$

$$> 85 \text{ mm} \quad - \quad \text{(lapangan)}$$

Kebutuhan Tulangan Transversal Torsi — A_t/s
(SNI 2847:2019 pasal 22.7.6.1)

$$\frac{A_t}{s} = \frac{T_u}{2 \times \Phi \times A_o \times f_{yv}}$$

$$= \frac{1.198 \times 10^{6}}{2 \times \{0.75 \times 55335\} \times 420}$$

$$= 0.034 \ \text{mm}^2/\text{mm}$$

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Kebutuhan Tulangan Geser Tumpuan

$$A_v/s = \frac{\left(\frac{V_u}{\Phi} - V_c\right)}{f_{yv} \times d}$$

$$= \frac{\left(\frac{215.2489}{0.75} - 87\right)}{420 \times 342}$$

$$= 1.391 \text{ mm}^2/\text{mm}$$

Kebutuhan Tulangan Geser Lapangan

$$A_v/s = \frac{\left(\frac{V_u}{\Phi} - V_c\right)}{f_{yv} \times d}$$

$$= \frac{\left(\frac{213.9373}{0.75} - 87\right)}{420 \times 342}$$

$$= 1.379 \text{ mm}^2/\text{mm}$$

Kebutuhan Tulangan Geser+Torsi Tumpuan

(SNI 2847:2019 pasal 9.5.4.3)

$$A_{v+t}/s = 2 \times A_t/s + A_v/s$$

$$= 2 \times 0.034 + 1.391$$

$$= 1.460 \text{ mm}^2/\text{mm} < 1.848 \text{ mm}^2/\text{mm} \text{ -}$$

Kebutuhan Tulangan Geser+Torsi Lapangan

(SNI 2847:2019 pasal 9.5.4.3)

$$A_{v+t}/s = 2 \times A_t/s + A_v/s$$

$$= 2 \times 0.034 + 1.379$$

$$= 1.447 \text{ mm}^2/\text{mm} < 1.848 \text{ mm}^2/\text{mm} \text{ -}$$

Tulangan Transversal Minimum

(SNI 2847:2019 pasal 9.6.4.2)

$$A/s_{min} = \max \begin{Bmatrix} 0.062 \times \sqrt{f_c'} \times \frac{b}{f_{yv}} \\ 0.350 \times \frac{b}{f_{yv}} \end{Bmatrix}$$

$$A/s_{min} = \max \begin{Bmatrix} 0.062 \times \sqrt{25} \times \frac{300}{420} \\ 0.350 \times \frac{300}{420} \end{Bmatrix}$$

$$= \max \begin{Bmatrix} 0.221 \\ 0.250 \end{Bmatrix}$$

$$= 0.250 \text{ mm}^2/\text{mm} < 1.848 \text{ mm}^2/\text{mm} \text{ -}$$

$$< 1.848 \text{ mm}^2/\text{mm} \text{ -}$$

5.5 Tulangan Longitudinal Torsi

Kebutuhan Tulangan Longitudinal Torsi

(SNI 2847:2019 pasal 22.7.6.1)

$$A_l = A_t/s \times P_h \times \frac{f_{yv}}{f_y}$$

$$= 0.034 \times 1040 \times \frac{420}{420}$$

$$= 35.746 \text{ mm}^2$$

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Tulangan Longitudinal Torsi Minimum A_l

(SNI 2847:2019 pasal 9.6.4.3)

$$A_l = \min \begin{Bmatrix} 0.42 \times \sqrt{f_c'} \times \frac{A_{cp}}{f_{yv}} - A_t/s \times P_h \times \frac{f_{yv}}{f_y} \\ 0.42 \times \sqrt{f_c'} \times \frac{A_{cp}}{f_{yv}} - \frac{0.175\ b\ P_h}{f_{yv}} \times \frac{f_{yv}}{f_y} \end{Bmatrix}$$

$$= \min \begin{Bmatrix} 0.42 \times \sqrt{25} \times \frac{120000}{420} - 0.034 \times 1040 \times 1 \\ 0.42 \times \sqrt{25} \times \frac{120000}{420} - \frac{0.175 \times 300}{420} \times 1040 \times 1 \end{Bmatrix}$$

$$= \min \begin{Bmatrix} 564.25 \\ 470.00 \end{Bmatrix}$$

$$= 470.00 \text{ mm}^2$$

Ketersediaan Tulangan Longitudinal untuk Torsi $A_{s,tor} = \frac{\Phi M_n - M_u}{\Phi M_n} \times A_s$

Tumpuan Negatif	-->	$\frac{73.447 - 13.789}{73.447}$	×	603.2	=	489.943		
Tumpuan Positif	-->	$\frac{73.447 - 53.9044}{73.447}$	×	603.2	=	160.495		
Lapangan Negatif	-->	$\frac{73.447 - 10.9991}{73.447}$	×	603.2	=	512.855		
Lapangan Positif	-->	$\frac{73.447 - 11.8043}{73.447}$	×	603.2	=	506.243		
Tulangan Tengah	=	402.1239	mm^2					

Longitudinal Torsi Tumpuan	=	1052.56	mm^2	>	470.00	mm^2	-	
Longitudinal Torsi Lapangan	=	1421.22	mm^2	>	470.00	mm^2	-	

Spasi Vertikal Tulangan Longitudinal s_{vl}

(SNI 2847:2019 pasal 9.6.5.1)

$$= \frac{h - 2 \times c_c - 2 \times d_s - d_b}{2 + n_t - 1} \quad \text{(1 lapis)}$$

$$\frac{h - 2 \times c_c - 2 \times d_s - d_b - s_{12}}{2 + n_t - 1} \quad \text{(2 lapis atas/bawah)}$$

$$\frac{h - 2 \times c_c - 2 \times d_s - d_b - 2\,s_{12}}{2 + n_t - 1} \quad \text{(2 lapis atas dan bawah)}$$

Tumpuan	-->	142	mm	<	300	mm	-
Lapangan	-->	142	mm	<	300	mm	-

Spasi Horizontal Tulangan Longitudinal $s_{hl} = \frac{b - 2 \times c_c - 2 \times d_s - d_b}{n - 1}$

(SNI 2847:2019 pasal 9.6.5.1)

Tumpuan Atas	-->	92.000	mm	<	300	mm	-
Tumpuan Bawah	-->	92.000	mm	<	300	mm	-
Lapangan Atas	-->	92.000	mm	<	300	mm	-
Lapangan Bawah	-->	92.000	mm	<	300	mm	-

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6 Kesimpulan

6.1 Sketsa Balok

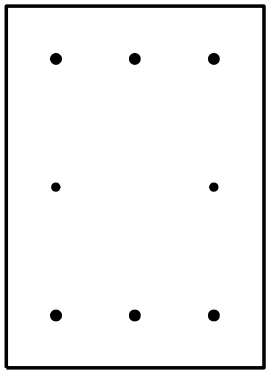
Tumpuan

300 × 400

3 D 16

2 D 16

3 D 16



Sengkang: 2 D 10 - 85

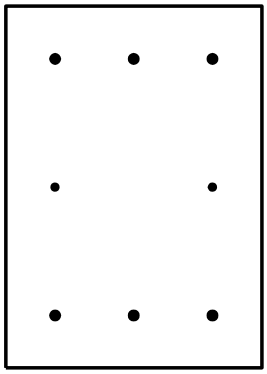
Lapangan

300 × 400

3 D 16

2 D 16

3 D 16



Sengkang: 2 D 10 - 85

6.2 Rekapitulasi Hasil Desain

No	Parameter	Cek
1	Tulangan Longitudinal Tumpuan Atas	OK
2	Tulangan Longitudinal Tumpuan Bawah	OK
3	Tulangan Longitudinal Lapangan Atas	OK
4	Tulangan Longitudinal Lapangan Bawah	OK
5	Tulangan Sengkang Tumpuan	OK
6	Tulangan Sengkang Lapangan	OK
7	Perlu Tulangan Torsi?	Tidak Perlu Tulangan Torsi
8	Kecukupan Dimensi	-
9	Tulangan Sengkang Torsi Tumpuan	-
10	Tulangan Sengkang Torsi Lapangan	-
11	Tulangan Longitudinal Torsi Tumpuan	-
12	Tulangan Longitudinal Torsi Lapangan	-

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1 Input Data

1.1 Geometri Balok

Lebar Balok	b	=	200	mm
Tinggi Balok	h	=	300	mm
Panjang Balok	L	=	3882.3	mm
Selimut Bersih	c_c	=	40	mm

1.3 Material

Kuat Tekan Beton	f_c'	=		Kuat
Leleh Baja Tulangan Longitudinal	f_y	=		Kuat
Leleh Baja Tulangan Transversal	f_{yv}	=		MPa

1.3 Diameter Tulangan

Diameter Tulangan Longitudinal	d_b	=		mm
Diameter Tulangan Pinggang	d_{bt}	=		mm
Diameter Tulangan Sengkang	d_s	=		mm

1.4 Jumlah Tulangan Longitudinal

	Tumpuan			Lapangan		
Jumlah Tulangan Atas Baris 1	n_{ts1}	=		n_{tm1}	=	
Jumlah Tulangan Atas Baris 2	n_{ts2}	=		n_{tm2}	=	
Jumlah Tulangan Bawah Baris 1	n_{bs1}	=		n_{bm1}	=	
Jumlah Tulangan Bawah Baris 2	n_{bs2}	=		n_{bm2}	=	

Spasi Tulangan Lapis 1 ke Lapis 2	s_{12}	=		mm
Jumlah Pasang Tulangan Pinggang/Tengah	n_t	=		

1.5 Tulangan Transversal/Sengkang

Jumlah Kaki Tulangan Sengkang Tumpuan	n_{vs}	=		
Jumlah Kaki Tulangan Sengkang Lapangan	n_{vm}	=		
Spasi Sengkang Tumpuan	s_s	=		mm
Spasi Sengkang Lapangan	s_m	=		mm

1.6 Gaya Dalam

Momen Negatif Tumpuan	$M_{u,tum}$ (-)	=		kNm
Momen Positif Tumpuan	$M_{u,tum}$ (+)	=		kNm
Momen Negatif Lapangan	$M_{u,lap}$ (-)	=		kNm
Momen Positif Lapangan	$M_{u,lap}$ (+)	=		kNm
Gaya Geser Tumpuan	$V_{u,tumpuan}$	=		kN
Gaya Geser Lapangan	$V_{u,lapangan}$	=		kN
Torsi	T_u	=		kNm

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2 Parameter Material dan Geometri

Faktor Material Beton β_1

(SNI 2847:2019 tabel 22.2.2.4.3)

$$= 0.65 \le 0.85 - 0.05\,\frac{f_c' - 28}{7} \le 0.85$$

$$= 0.65 \le 0.85 - 0.05\,\frac{25.0 - 28}{7} \le 0.85$$

$$= 0.850$$

Regangan Leleh Baja Tulangan ε_{sy}

$$= \frac{f_y}{E_s} = \frac{420}{2000(0} = 0.0021$$

Tinggi Efektif Balok d

$$= h - c_c - d_s - \frac{d_b}{2}$$

$$= 300 - 4 - 3 - \frac{1(}{2}$$

$$= 247 \text{ mm}$$

Lokasi Tulangan Lapis 2 d_2

$$= d - s_{12}$$

$$= 247 - 5$$

$$= 197 \text{ mm}$$

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3 Desain Lentur

3.1 Momen Negatif Tumpuan (Tulangan Tumpuan Atas)

Jumlah Tulangan Lapis 1 n_{ts1} = 3 --> $A_{s,1}$ = 235.6194 mm²

Jumlah Tulangan Lapis 2 n_{ts2} = 0 --> $A_{s,2}$ = 0 mm²

Jarak Bersih Tulangan Lapis 1 $s_{l,1}$ = 37 mm > 25 mm OK

Jarak Bersih Tulangan Lapis 2 $s_{l,2}$ = - mm > 25 mm OK

Luas Tulangan Total A_s = $A_{s,1}$ + $A_{s,2}$ = 235.6194 + 0

= 235.6 mm²

Rasio Luas Tulangan $\rho = \frac{A_s}{b \times d} = \frac{235.6}{200 \times 247} = 0.48\%$

Luas Tulangan Minimum $A_{s,min}$

(SNI 2847:2019 pasal 9.6.1.2)

$$= \max\left\{\frac{\sqrt{f_c'}}{4 \times f_y} \times b \times d \;;\; \frac{1.4}{f_y} \times b \times d\right\}$$

$$= \max\left\{\frac{\sqrt{25}}{4 \times 420} \times 200 \times 247 \;;\; \frac{1.4}{420} \times 200 \times 247\right\}$$

$$= \max\{147.0 \text{ mm}^2 \;;\; 164.7 \text{ mm}^2\}$$

= 164.7 mm² < 235.6 mm² OK

Tinggi Blok Beton $a = \frac{A_s \times f_y}{0.85 \times f_c' \times b} = \frac{235.6 \times 420}{0.85 \times 25 \times 200}$

(SNI 2847:2019 pasal 22.2.2.4.1)

= 23.28 mm

Tinggi Daerah Tekan Beton $c = \frac{a}{\beta_1} = \frac{23.28}{0.85} = 27.39$ mm

(SNI 2847:2019 pasal 22.2.2.4.1)

Regangan Tulangan Terluar $\varepsilon_{st} = \frac{d - c}{c} \times 0.003 = \frac{247 - 27.39}{27.39} \times 0.003$

= 0.0240

Faktor Reduksi $\Phi = 0.65 \le 0.65 + \frac{\varepsilon_{st} - \varepsilon_{sy}}{0.003} \times 0.25 \le 0.9$

(SNI 2847:2019 tabel 21.2.2)

$$= 0.65 \le 0.65 + \frac{0.024 - 0.0021}{0.003} \times 0.25$$

= 0.90

Kapasitas Momen $\Phi M_n = \Phi \times \{A_{s,1} \times f_y \times (d - a/2) + A_{s,2} \times f_y \times (d_2 - a/2)\}$

$$= 0.90 \times \left\{235.6 \times 420 \times \left(247 - \frac{23.285}{2}\right) + 0.0 \times 420 \times \left(197 - \frac{23.285}{2}\right)\right\}$$

$$= 0.90 \times \{23.291 + 0.000\}$$

= 20.962 kNm > 7.579 kNm OK

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3.2 Momen Positif Tumpuan (Tulangan Tumpuan Bawah)

Jumlah Tulangan Lapis 1 $n_{bs1} = 3$ --> $A_{s,1} = 235.6194$ mm²

Jumlah Tulangan Lapis 2 $n_{bs2} = 0$ --> $A_{s,2} = 0$ mm²

Jarak Bersih Tulangan Lapis 1 $s_{l,1} = 37$ mm > 25 mm OK

Jarak Bersih Tulangan Lapis 2 $s_{l,2} = -$ mm > 25 mm OK

Luas Tulangan Total $A_s = A_{s,1} + A_{s,2} = 235.6194 + 0$

$= 235.6$ mm²

Rasio Luas Tulangan $\rho = \dfrac{A_s}{b \times d} = \dfrac{235.6}{200 \times 247} = 0.48\%$

Luas Tulangan Minimum $A_{s,min}$

(SNI 2847:2019 pasal 9.6.1.2)

$$= \max\left\{\begin{array}{l}\dfrac{\sqrt{f_c'}}{4 \text{ x } f_y} \times b \times d \\ \dfrac{1.4}{f_y} \times b \times d\end{array}\right.$$

$$= \max\left\{\begin{array}{l}\dfrac{\sqrt{25}}{4 \text{ x } 420} \times 200 \times 247 \\ \dfrac{1.4}{420} \times 200 \times 247\end{array}\right.$$

$$= \max\left\{\begin{array}{l}147.0 \text{ mm}^2 \\ 164.7 \text{ mm}^2\end{array}\right.$$

$= 164.7$ mm² < 235.6 mm² OK

Tinggi Blok Beton $a = \dfrac{A_s \times f_y}{0.85 \times f_c' \times b} = \dfrac{235.6 \times 420}{0.85 \times 25 \times 200}$

(SNI 2847:2019 pasal 22.2.2.4.1)

$= 23.28$ mm

Tinggi Daerah Tekan Beton $c = \dfrac{a}{\beta_1} = \dfrac{23.28}{0.85} = 27.39$ mm

(SNI 2847:2019 pasal 22.2.2.4.1)

Regangan Tulangan Terluar $\varepsilon_{st} = \dfrac{d - c}{c} \text{ x } 0.003 = \dfrac{247 - 27.39}{27.39} \times 0.003$

$= 0.0240$

Faktor Reduksi $\Phi = 0.65 \le 0.65 + \dfrac{\varepsilon_{st} - \varepsilon_{sy}}{0.003} \times 0.25 \le 0.9$

(SNI 2847:2019 tabel 21.2.2)

$= 0.65 \le 0.65 + \dfrac{0.024 - 0.0021}{0.003} \times 0.25$

$= 0.90$

Kapasitas Momen $\Phi M_n = \Phi \times \left\{\begin{array}{l}A_{s,1} \times f_y \times (d - a/2) \\ + A_{s,2} \times f_y \times (d_2 - a/2)\end{array}\right.$

$$= 0.90 \times \left\{\begin{array}{l}235.6 \times 420 \times \left(247 - \dfrac{23.285}{2}\right) \\ + 0.0 \times 420 \times \left(197 - \dfrac{23.285}{2}\right)\end{array}\right.$$

$= 0.90 \times \{23.291 + 0.000\}$

$= 20.962$ kNm > 4.360 kNm OK

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3.3 Momen Negatif Lapangan (Tulangan Lapangan Atas)

Jumlah Tulangan Lapis 1 $n_{tm1} = 3$ --> $A_{s,1} = 235.6194$ mm²

Jumlah Tulangan Lapis 2 $n_{tm2} = 0$ --> $A_{s,2} = 0$ mm²

Jarak Bersih Tulangan Lapis 1 $s_{l,1} = 37$ mm > 25 mm OK

Jarak Bersih Tulangan Lapis 2 $s_{l,2} = -$ mm > 25 mm OK

Luas Tulangan Total $A_s = A_{s,1} + A_{s,2} = 235.6194 + 0$

$= 235.6$ mm²

Rasio Luas Tulangan $\rho = \dfrac{A_s}{b \times d} = \dfrac{235.6}{200 \times 247} = 0.48\%$

Luas Tulangan Minimum $A_{s,min}$ (SNI 2847:2019 pasal 9.6.1.2)

$$= \max\left\{ \frac{\sqrt{f_c'}}{4 \text{ x } f_y} \times b \times d \;;\; \frac{1.4}{f_y} \times b \times d \right\}$$

$$= \max\left\{ \frac{\sqrt{25}}{4 \text{ x } 420} \times 200 \times 247 \;;\; \frac{1.4}{420} \times 200 \times 247 \right\}$$

$= \max\{ 147.0 \text{ mm}^2 ; 164.7 \text{ mm}^2 \}$

$= 164.7$ mm² < 235.6 mm² OK

Tinggi Blok Beton $a = \dfrac{A_s \times f_y}{0.85 \times f_c' \times b} = \dfrac{235.6 \times 420}{0.85 \times 25 \times 200}$ (SNI 2847:2019 pasal 22.2.2.4.1)

$= 23.28$ mm

Tinggi Daerah Tekan Beton $c = \dfrac{a}{\beta_1} = \dfrac{23.28}{0.85} = 27.39$ mm (SNI 2847:2019 pasal 22.2.2.4.1)

Regangan Tulangan Terluar $\varepsilon_{st} = \dfrac{d - c}{c} \text{ x } 0.003 = \dfrac{247 - 27.39}{27.39} \times 0.003$

$= 0.0240$

Faktor Reduksi $\Phi = 0.65 \le 0.65 + \dfrac{\varepsilon_{st} - \varepsilon_{sy}}{0.003} \times 0.25 \le 0.9$ (SNI 2847:2019 tabel 21.2.2)

$= 0.65 \le 0.65 + \dfrac{0.024 - 0.0021}{0.003} \times 0.25$

$= 0.90$

Kapasitas Momen $\Phi M_n = \Phi \times \{ A_{s,1} \times f_y \times (d - a / 2) + A_{s,2} \times f_y \times (d_2 - a / 2) \}$

$$= 0.90 \times \left\{ \begin{array}{l} 235.6 \times 420 \times \left(247 - \dfrac{23.285}{2} \right) \\ + \; 0.0 \times 420 \times \left(197 - \dfrac{23.285}{2} \right) \end{array} \right\}$$

$= 0.90 \times \{ 23.291 + 0.000 \}$

$= 20.962$ kNm > 3.462 kNm OK

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3.4 Momen Positif Lapangan (Tulangan Lapangan Bawah)

Jumlah Tulangan Lapis 1 $n_{tm1} = 3$ --> $A_{s,1} = 235.6194$ mm²

Jumlah Tulangan Lapis 2 $n_{tm2} = 0$ --> $A_{s,2} = 0$ mm²

Jarak Bersih Tulangan Lapis 1 $s_{l,1} = 37$ mm > 25 mm OK

Jarak Bersih Tulangan Lapis 2 $s_{l,2} = -$ mm > 25 mm OK

Luas Tulangan Total $A_s = A_{s,1} + A_{s,2} = 235.6194 + 0$

$= 235.6$ mm²

Rasio Luas Tulangan $\rho = \dfrac{A_s}{b \times d} = \dfrac{235.6}{200 \times 247} = 0.48\%$

Luas Tulangan Minimum $A_{s,min}$

(SNI 2847:2019 pasal 9.6.1.2)

$$= \max\left\{\begin{array}{l}\dfrac{\sqrt{f_c'}}{4 \text{ x } f_y} \times b \times d \\ \dfrac{1.4}{f_y} \times b \times d\end{array}\right.$$

$$= \max\left\{\begin{array}{l}\dfrac{\sqrt{25}}{4 \text{ x } 420} \times 200 \times 247 \\ \dfrac{1.4}{420} \times 200 \times 247\end{array}\right.$$

$$= \max\left\{\begin{array}{l}147.0 \text{ mm}^2 \\ 164.7 \text{ mm}^2\end{array}\right.$$

$= 164.7$ mm² < 235.6 mm² OK

Tinggi Blok Beton $a = \dfrac{A_s \times f_y}{0.85 \times f_c' \times b} = \dfrac{235.6 \times 420}{0.85 \times 25 \times 200}$

(SNI 2847:2019 pasal 22.2.2.4.1)

$= 23.28$ mm

Tinggi Daerah Tekan Beton $c = \dfrac{a}{\beta_1} = \dfrac{23.28}{0.85} = 27.39$ mm

(SNI 2847:2019 pasal 22.2.2.4.1)

Regangan Tulangan Terluar $\varepsilon_{st} = \dfrac{d - c}{c} \text{ x } 0.003 = \dfrac{247 - 27.39}{27.39} \times 0.003$

$= 0.0240$

Faktor Reduksi $\Phi = 0.65 \le 0.65 + \dfrac{\varepsilon_{st} - \varepsilon_{sy}}{0.003} \times 0.25 \le 0.9$

(SNI 2847:2019 tabel 21.2.2)

$= 0.65 \le 0.65 + \dfrac{0.024 - 0.0021}{0.003} \times 0.25$

$= 0.90$

Kapasitas Momen $\Phi M_n = \Phi \times \left\{\begin{array}{l}A_{s,1} \times f_y \times (d - a/2) \\ + A_{s,2} \times f_y \times (d_2 - a/2)\end{array}\right.$

$$= 0.90 \times \left\{\begin{array}{l}235.6 \times 420 \times \left(247 - \dfrac{23.285}{2}\right) \\ + 0.0 \times 420 \times \left(197 - \dfrac{23.285}{2}\right)\end{array}\right.$$

$$= 0.90 \times \left\{23.291 + 0.000\right\}$$

$= 20.962$ kNm > 3.114 kNm OK

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4 Desain Geser

4.1 Geser Tumpuan

Jumlah Kaki n_{vs} = 2

Luas Tulangan Sengkang A_v = $n \times \pi/4 \times d_s^2$ = 2 × π/4 × 8 ^2

= 100.531 mm^2

Spasi Sengkang s_s = 60 mm

Tahanan Geser Beton V_c = $0.17 \times \sqrt{f_c'} \times b \times d$

(SNI 2847:2019 pasal 22.5.5.1) = $0.17 \times \sqrt{25} \times 200 \times 247$

= 41990 N

Batas Penentu Spasi Maksimum *Batas* = $0.33 \times \sqrt{f_c'} \times b \times d$

(SNI 2847:2019 tabel 9.7.6.2.2) = $0.33 \times \sqrt{25} \times 200 \times 247$

= 81510 N < 81960 N

Spasi Maksimum s_{max} = $\min \begin{Bmatrix} d/4 \\ 300 \end{Bmatrix}$

(SNI 2847:2019 tabel 9.7.6.2.2)

= $\min \begin{Bmatrix} 247/4 \\ 300 \end{Bmatrix}$

= $\min \begin{Bmatrix} 61.75 \\ 300 \end{Bmatrix}$

= 61.75 mm > 60 mm OK

Tahanan Geser Baja V_s = $\min \left\{ \dfrac{A_v \times f_{yv} \times d}{s} ; 0.66 \times \sqrt{f_c'} \times b \times d \right\}$

(SNI 2847:2019 pasal 22.10.5.3)

= $\min \left\{ \dfrac{101 \times 420 \times 247}{60} ; 0.66 \times \sqrt{25} \times 200 \times 247 \right\}$

= $\min \begin{Bmatrix} 173818 \\ 163020 \end{Bmatrix}$

= 163020 N

Faktor Reduksi Φ = 0.75

(SNI 2847:2019 pasal 12.5.3.2)

Kapasitas Geser ΦV_n = $\Phi \times (V_c + V_s)$

= $0.75 \times (41.99 + 163.02)$

= 153.7575 kN > 92.9625 kN OK

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4.2 Geser Lapangan

Jumlah Kaki — n_{vm} = 2

Luas Tulangan Sengkang — $A_v = n \times \pi/4 \times d_s^2 = 2 \times \pi/4 \times 8 \text{ ^2}$

$= 100.531 \text{ mm}^2$

Spasi Sengkang — s_m = 85 mm

Tahanan Geser Beton — $V_c = 0.17 \times \sqrt{f_c'} \times b \times d$

(SNI 2847:2019 pasal 22.5.5.1)

$= 0.17 \times \sqrt{25} \times 200 \times 247$

$= 41990$ N

Batas Penentu Spasi Maksimum — $Batas = 0.33 \times \sqrt{f_c'} \times b \times d$

(SNI 2847:2019 tabel 9.7.6.2.2)

$= 0.33 \times \sqrt{25} \times 200 \times 247$

$= 81510$ N > 81324.13 N

Spasi Maksimum — $s_{max} = \min \left\{ \begin{matrix} d / 2 \\ 600 \end{matrix} \right\}$

(SNI 2847:2019 tabel 9.7.6.2.2)

$= \min \left\{ \begin{matrix} 247 / 2 \\ 600 \end{matrix} \right\}$

$= \min \left\{ \begin{matrix} 123.5 \\ 600 \end{matrix} \right\}$

$= 123.5$ mm > 85 mm OK

Tahanan Geser Baja — $V_s = \min \left\{ \begin{matrix} \dfrac{A_v \times f_{yv} \times d}{s} \\ 0.66 \times \sqrt{f_c'} \times b \times d \end{matrix} \right\}$

(SNI 2847:2019 pasal 22.10.5.3)

$= \min \left\{ \begin{matrix} \dfrac{101 \times 420 \times 247}{85} \\ 0.66 \times \sqrt{25} \times 200 \times 247 \end{matrix} \right\}$

$= \min \left\{ \begin{matrix} 122695 \\ 163020 \end{matrix} \right\}$

$= 122695$ N

Faktor Reduksi — Φ = 0.75

(SNI 2847:2019 pasal 12.5.3.2)

Kapasitas Geser — $\Phi V_n = \Phi \times \left(V_c + V_s \right)$

$= 0.75 \times \left(41.99 + 122.6951 \right)$

$= 123.5138$ kN > 92.4856 kN OK

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5 Desain Torsi

5.1 Parameter Penampang untuk Perhitungan Torsi

Luas Penampang Penuh $A_{cp} = b \times h = 200 \times 300$

$= 60000 \text{ mm}^2$

Keliling Penampang Penuh $P_{cp} = 2 \times (b + h) = 2 \times (200 + 300)$

$= 1000 \text{ mm}$

Lebar Penampang Inti $x_o = b - 2 \times c_c - d_s$

(SNI 2847:2019 pasal 22.7.6.1.1) $= 200 - 2 \times 40 - 8$

$= 112 \text{ mm}$

Tinggi Penampang Inti $y_o = h - 2 \times c_c - d_s$

(SNI 2847:2019 pasal 22.7.6.1.1) $= 300 - 2 \times 40 - 8$

$= 212 \text{ mm}$

Luas Penampang Inti $A_{oh} = x_o \times y_o = 112 \times 212$

(SNI 2847:2019 pasal 22.7.6.1.1) $= 23744 \text{ mm}^2$

Luas Efektif Penampang Inti $A_o = 0.85 \times A_{oh} = 0.85 \times 23744$

(SNI 2847:2019 pasal 22.7.6.1.1) $= 20182.4 \text{ mm}^2$

Keliling Penampang Inti $P_h = 2 \times (x_o + y_o) = 2 \times (112 + 212)$

(SNI 2847:2019 pasal 22.7.6.1.1) $= 648 \text{ mm}$

5.2 Pengecekan Kebutuhan Tulangan Torsi

Tahanan Retak Torsi $T_{cr} = 0.33 \times \sqrt{f_c'} \times \frac{A_{cp}^2}{P_{cp}}$

(SNI 2847:2019 pasal 22.7.5.1)

$= 0.33 \times \sqrt{2} \times \frac{600000^2}{1000}$

$= 5.940 \text{ kNm}$

Faktor Reduksi $\Phi = 0.75$

(SNI 2847:2019 tabel 21.2.1)

Ambang Batas Kebutuhan Tulangan Torsi $= \Phi \times \frac{T_{cr}}{4}$

(SNI 2847:2019 tabel 22.7.4.1)

$= 0.75 \times \frac{5.940}{4}$

$= 1.114 \text{ kNm} > 0.0735 \text{ kN}$

--> **Tidak Perlu Tulangan Torsi**

Perhitungan di bawah ini dapat diabaikan

5.3 Pengecekan Kecukupan Dimensi

Momen Torsi Pakai — T_u
(SNI 2847:2019 pasal 22.7.3.2)

$$T_u = \min \begin{cases} \Phi \times T_{cr} \\ T_u \end{cases}$$

$$= \min \begin{matrix} 0.75 \times 5.940 \\ 0.074 \end{matrix}$$

$$= \min \begin{matrix} 4.455 \\ 0.074 \end{matrix}$$

$$= 0.074 \text{ kNm}$$

Tegangan Akibat Geser + Torsi — σ_u
(SNI 2847:2019 pasal 22.7.7.1)

$$\sigma_u = \sqrt{\left(\frac{V_u}{b \times d} \right)^2 + \left(\frac{T_u \times P_h}{1.7 \times A_{oh}^2} \right)^2}$$

$$= \sqrt{\left(\frac{92.963}{200 \times 247} \right)^2 + \left(\frac{0.074 \times 648}{1.7 \times 23744} \right)^2}$$

$$= \sqrt{\{ 1.882^2 + 0.050^2 }$$

$$= 1.882 \text{ MPa}$$

Tahanan Tegangan Geser+Torsi Beton — σ_n
(SNI 2847:2019 pasal 22.7.7.1)

$$\sigma_n = \Phi \left(\frac{V_c}{b \times d} + 0.66 \times \sqrt{f_c'} \right)$$

$$= 0.75 \left(\frac{41990}{200 \times 247} + 0.66 \times \sqrt{25} \right)$$

$$= 3.113 \text{ MPa} > 1.882 \text{ MPa} \quad -$$

5.4 Tulangan Transversal Torsi

Spasi Maksimum — s_{max}
(SNI 2847:2019 pasal 9.7.6.3.3)

$$s_{max} = \min \begin{matrix} P_h \\ 8 \\ d_b \\ 0.042 \\ 300 \end{matrix}$$

$$= \min \begin{matrix} 648 \\ 8 \\ 10 \\ 0.042 \\ 300 \end{matrix}$$

$$= \min \begin{matrix} 81 \\ 238.0952 \\ 300 \end{matrix}$$

$$= 81 \text{ mm} > 60 \text{ mm} \quad - \quad \text{(tumpuan)}$$

$$< 85 \text{ mm} \quad - \quad \text{(lapangan)}$$

Kebutuhan Tulangan Transversal Torsi — A_t/s
(SNI 2847:2019 pasal 22.7.6.1)

$$\frac{A_t}{s} = \frac{T_u}{2 \times \Phi \times A_o \times f_{yv}}$$

$$= \frac{0.074 \times 10^6}{}$$

$$2 \times 0.75 \times 20182.4 \times 420$$

$$= 0.006 \ mm^2/mm$$

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Kebutuhan Tulangan Geser Tumpuan

$$A_v/s = \frac{\left(\frac{V_u}{\Phi} - V_c\right)}{f_{yv} \times d}$$

$$= \frac{\left(\frac{92.9625}{0.75} - 42\right)}{420 \times 247}$$

$$= 0.790 \text{ mm}^2/\text{mm}$$

Kebutuhan Tulangan Geser Lapangan

$$A_v/s = \frac{\left(\frac{V_u}{\Phi} - V_c\right)}{f_{yv} \times d}$$

$$= \frac{\left(\frac{92.4856}{0.75} - 42\right)}{420 \times 247}$$

$$= 0.784 \text{ mm}^2/\text{mm}$$

Kebutuhan Tulangan Geser+Torsi Tumpuan *(SNI 2847:2019 pasal 9.5.4.3)*

$$A_{v+t}/s = 2 \times A_t/s + A_v/s$$

$$= 2 \times 0.006 + 0.790$$

$$= 0.802 \text{ mm}^2/\text{mm} < 1.676 \text{ mm}^2/\text{mm} \text{ -}$$

Kebutuhan Tulangan Geser+Torsi Lapangan *(SNI 2847:2019 pasal 9.5.4.3)*

$$A_{v+t}/s = 2 \times A_t/s + A_v/s$$

$$= 2 \times 0.006 + 0.784$$

$$= 0.795 \text{ mm}^2/\text{mm} < 1.183 \text{ mm}^2/\text{mm} \text{ -}$$

Tulangan Transversal Minimum *(SNI 2847:2019 pasal 9.6.4.2)*

$$A/s_{min} = \max\left\{\begin{array}{l} 0.062 \times \sqrt{f_c'} \times \frac{b}{f_{yv}} \\ 0.350 \times \frac{b}{f_{yv}} \end{array}\right.$$

$$A/s_{min} = \max\left\{\begin{array}{l} 0.062 \times \sqrt{25} \times \frac{200}{420} \\ 0.350 \times \frac{200}{420} \end{array}\right.$$

$$= \max\left\{\begin{array}{l} 0.148 \\ 0.167 \end{array}\right.$$

$$= 0.167 \text{ mm}^2/\text{mm} < 1.676 \text{ mm}^2/\text{mm} \text{ -}$$

$$< 1.183 \text{ mm}^2/\text{mm} \text{ -}$$

5.5 Tulangan Longitudinal Torsi

Kebutuhan Tulangan Longitudinal Torsi *(SNI 2847:2019 pasal 22.7.6.1)*

$$A_l = A_t/s \times P_h \times \frac{f_{yv}}{f_y}$$

$$= 0.006 \times 648 \times \frac{420}{420}$$

$$= 3.746 \text{ mm}^2$$

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Tulangan Longitudinal Torsi Minimum A_l

(SNI 2847:2019 pasal 9.6.4.3)

$$A_l = \min \begin{Bmatrix} 0.42 \times \sqrt{f_c'} \times \frac{A_{cp}}{f_{yv}} - A_t/s \times P_h \times \frac{f_{yv}}{f_y} \\ 0.42 \times \sqrt{f_c'} \times \frac{A_{cp}}{f_{yv}} - \frac{0.175\ b\ P_h}{f_{yv}} \times \frac{f_{yv}}{f_y} \end{Bmatrix}$$

$$= \min \begin{Bmatrix} 0.42 \times \sqrt{25} \times \frac{60000}{420} - 0.006 \times 648 \times 1 \\ 0.42 \times \sqrt{25} \times \frac{60000}{420} - \frac{0.175 \times 200}{420} \times 648 \times 1 \end{Bmatrix}$$

$$= \min \begin{Bmatrix} 296.25 \\ 246.00 \end{Bmatrix}$$

$$= 246.00 \text{ mm}^2$$

Ketersediaan Tulangan Longitudinal untuk Torsi $A_{s,tor} = \frac{\Phi M_n - M_u}{\Phi M_n} \times A_s$

Tumpuan Negatif	-->	$\frac{20.962 - 7.5793}{20.962}$	×	235.6	=	150.425		
Tumpuan Positif	-->	$\frac{20.962 - 4.3602}{20.962}$	×	235.6	=	186.609		
Lapangan Negatif	-->	$\frac{20.962 - 3.4623}{20.962}$	×	235.6	=	196.702		
Lapangan Positif	-->	$\frac{20.962 - 3.1135}{20.962}$	×	235.6	=	200.623		
Tulangan Tengah	=	157.0796	mm²					
Longitudinal Torsi Tumpuan	=	494.11	mm²	>	246.00	mm²	-	
Longitudinal Torsi Lapangan	=	554.40	mm²	>	246.00	mm²	-	

Spasi Vertikal Tulangan Longitudinal s_{vl}

(SNI 2847:2019 pasal 9.6.5.1)

$$= \frac{h - 2 \times c_c - 2 \times d_s - d_b}{2 + n_t - 1} \quad \text{(1 lapis)}$$

$$\frac{h - 2 \times c_c - 2 \times d_s - d_b - s_{12}}{2 + n_t - 1} \quad \text{(2 lapis atas/bawah)}$$

$$\frac{h - 2 \times c_c - 2 \times d_s - d_b - 2\,s_{12}}{2 + n_t - 1} \quad \text{(2 lapis atas dan bawah)}$$

Tumpuan	-->	97	mm	<	300	mm	-
Lapangan	-->	97	mm	<	300	mm	-

Spasi Horizontal Tulangan Longitudinal $s_{hl} = \frac{b - 2 \times c_c - 2 \times d_s - d_b}{n - 1}$

(SNI 2847:2019 pasal 9.6.5.1)

Tumpuan Atas	-->	47.000	mm	<	300	mm	-
Tumpuan Bawah	-->	47.000	mm	<	300	mm	-
Lapangan Atas	-->	47.000	mm	<	300	mm	-
Lapangan Bawah	-->	47.000	mm	<	300	mm	-

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6 Kesimpulan

6.1 Sketsa Balok

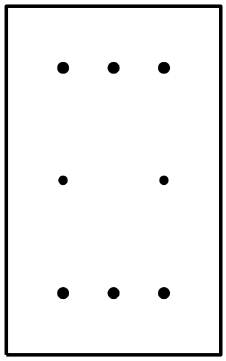
Tumpuan

200 × 300

3 D 10

2 D 10

3 D 10



Sengkang: 2 D 8 - 60

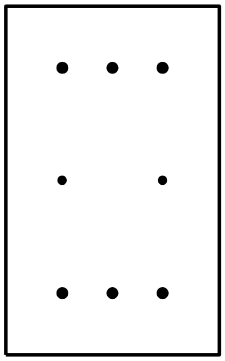
Lapangan

200 × 300

3 D 10

2 D 10

3 D 10



Sengkang: 2 D 8 - 85

6.2 Rekapitulasi Hasil Desain

No	Parameter	Cek
1	Tulangan Longitudinal Tumpuan Atas	OK
2	Tulangan Longitudinal Tumpuan Bawah	OK
3	Tulangan Longitudinal Lapangan Atas	OK
4	Tulangan Longitudinal Lapangan Bawah	OK
5	Tulangan Sengkang Tumpuan	OK
6	Tulangan Sengkang Lapangan	OK
7	Perlu Tulangan Torsi?	Tidak Perlu Tulangan Torsi
8	Kecukupan Dimensi	-
9	Tulangan Sengkang Torsi Tumpuan	-
10	Tulangan Sengkang Torsi Lapangan	-
11	Tulangan Longitudinal Torsi Tumpuan	-
12	Tulangan Longitudinal Torsi Lapangan	-

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1 Input Data

1.1 Geometri Kolom

Sisi Pendek Kolom	b	=	450	mm	d_1	=	389	mm
Sisi Panjang Kolom	h	=	450	mm	d_2	=	389	mm
Tinggi Kolom	L	=	4750	mm				
Selimut Bersih	c_c	=	40	mm				
Tinggi Balok	h_b	=	500	mm				
Tinggi Bersih Kolom	L_n	=	4250	mm				

1.3 Material

Kuat Tekan Beton	f_c'	=	25	MPa	β_1	=	0.850	
Kuat Leleh Baja Tulangan Longitudinal	f_y	=	420	MPa				
Kuat Leleh Baja Tulangan Transversal	f_{yv}	=	420	MPa				
Diameter Agregat	d_{agg}	=	25	mm				

1.3 Diameter Tulangan

Diameter Tulangan Longitudinal	d_b	=	22	mm	A_b	=	380.13	mm^2
Diameter Tulangan Sengkang	d_s	=	10	mm	A_v	=	78.54	mm^2

1.4 Tulangan Longitudinal/Utama

Jumlah Tulangan X	n_x	=	6					
Jumlah Tulangan Y	n_y	=	6					
Jumlah Total Tulangan Longitudinal	n	=	20		A_s	=	7602.65	mm^2

1.5 Tulangan Transversal/Sengkang

Jumlah Kaki Sengkang Tumpuan Arah X	$n_{vs,x}$	=	5		$A_{vs,x}$			
Jumlah Kaki Sengkang Tumpuan Arah Y	$n_{vs,y}$	=	5		$A_{vs,y}$	=	392.70	mm^2
Jumlah Kaki Sengkang Lapangan Arah X	$n_{vm,x}$	=	2		$A_{vm,x}$	=	392.70	mm^2
Jumlah Kaki Sengkang Lapangan Arah Y	$n_{vm,y}$	=	2		$A_{vm,y}$	=	157.08	mm^2
Spasi Sengkang Tumpuan	s_s	=	100	mm		=	157.08	mm^2
Spasi Sengkang Lapangan	s_m	=	130	mm				

1.6 Gaya Dalam

Aksial-Lentur

Kondisi	P	MX	MY	Mu
	(kN)	(kNm)	(kNm)	(kNm)
P Max	801.5108	23.0354	-54.7036	59.356
P Min	-15.9837	-45.8038	-91.4713	102.299
MX Max	107.6079	327.9645	56.5861	332.810
MX Min	115.1273	-321.2738	52.1412	325.477
MY Max	253.3797	-56.0408	363.3559	367.652
MY Min	252.7696	-51.2044	-360.8569	364.472

Geser

Gaya Geser Sumbu X	V_{ux}	=	187.816	kN
Gaya Geser Sumbu Y	V_{uy}	=	207.775	kN

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2 Pengecekan Syarat Geometri

Syarat Sisi Pendek --> b ≥ 300

(SNI 2847:2019 pasal 18.7.2.1) --> 450 mm > 300 mm OK

Syarat Rasio Sisi Pendek per Panjang --> $\frac{b}{h} \geq 0.4$

(SNI 2847:2019 pasal 18.7.2.1)

--> $\frac{450}{450} \geq 0.4$

--> 1 > 0.4 OK

3 Desain Aksial-Lentur

3.1 Pengecekan Syarat Rasio Tulangan

Luas Tulangan Longitudinal $A_s = n \times A_b$

= 20 × 380.1327

= 7602.654 mm²

Luas Penampang $A_g = b \times h$

= 450 × 450

= 202500 mm²

Rasio Tulangan $\rho = \frac{A_s}{A_g} = \frac{7602.654}{202500} = 3.75\%$

(SNI 2847:2019 pasal 18.7.4.1)

1% < 3.75% < 6% OK

Spasi Bersih Antar Tulangan s_h = 43.6 mm > 33.33333 mm OK

(SNI 2847:2019 pasal 25.2)

3.2 Pengecekan Kapasitas Aksial-Lentur

Tabel Rekapitulasi

Kondisi	Pu (kN)	Mux (kNm)	Muy (kNm)	ΦMnx (kNm)	ΦMny (kNm)	Rasio Kapasitas	Cek
P Max	801.5108	23.0354	-54.7036	195.8	261.9	0.182	OK
P Min	-15.9837	-45.8038	-91.4713	343.3	139.1	0.276	OK
MX Max	107.6079	327.9645	56.5861	324.8	159.0	0.920	OK
MX Min	115.1273	-321.2738	52.1412	274.7	208.5	0.944	OK
MY Max	253.3797	-56.0408	363.3559	26.9	440.2	0.834	OK
MY Min	252.7696	-51.2044	-360.8569	171.5	309.1	0.900	OK

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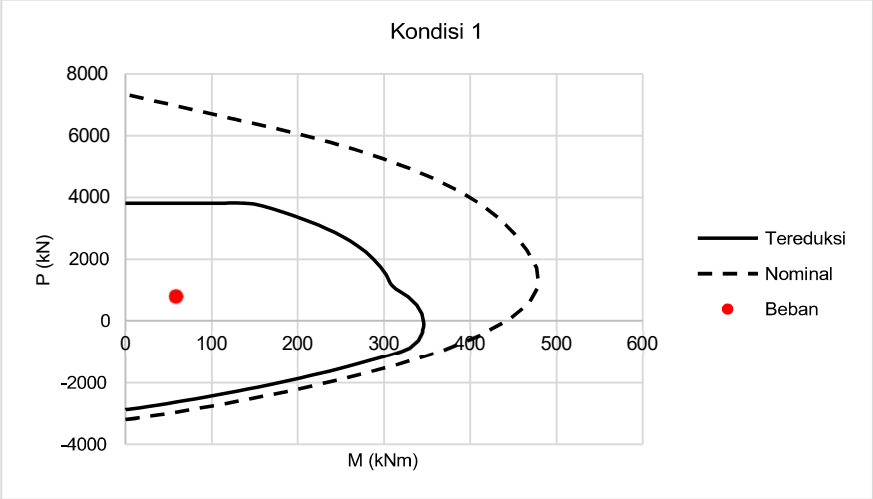
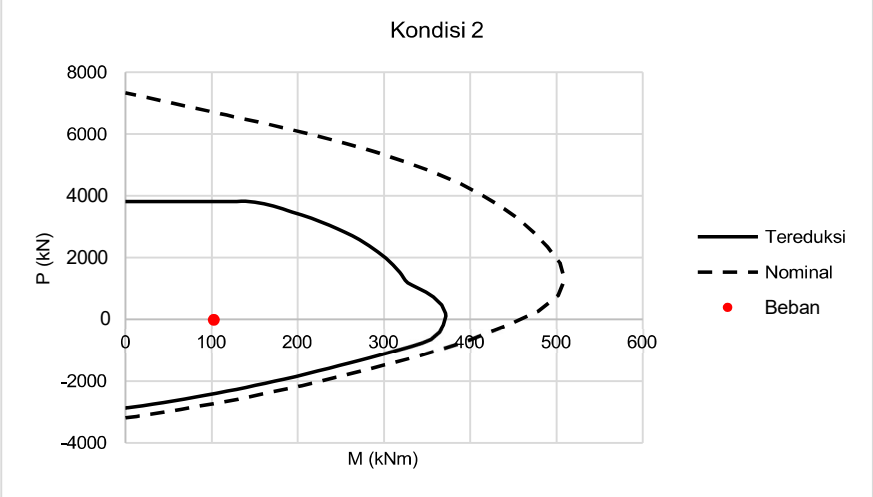
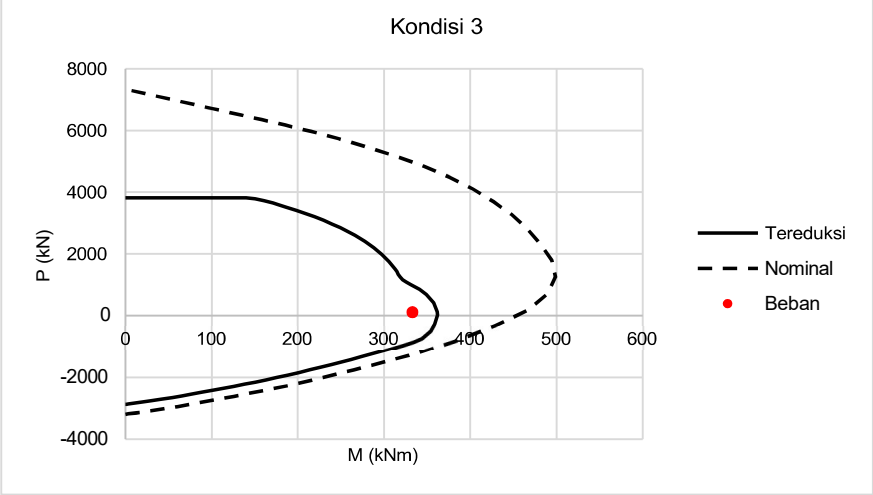
Diagram Interaksi







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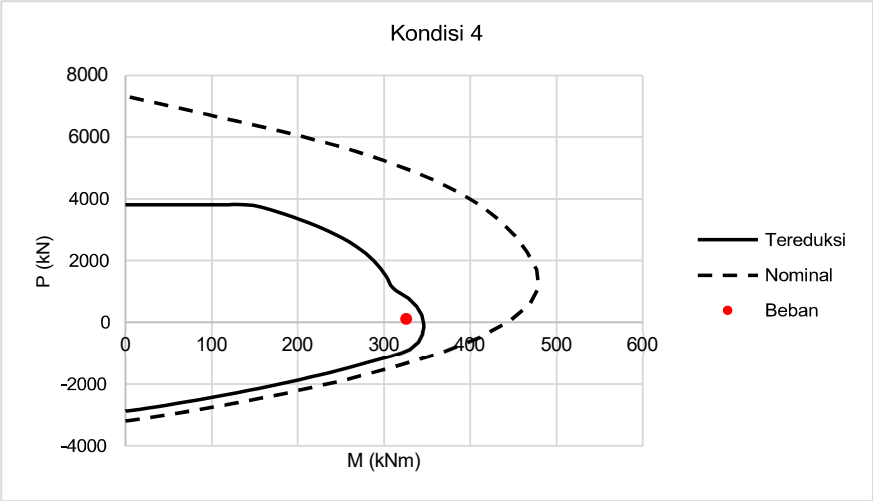

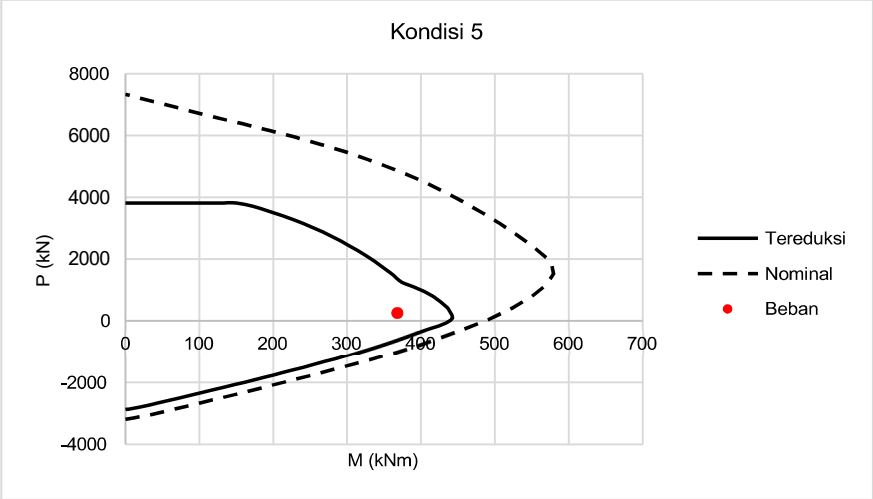

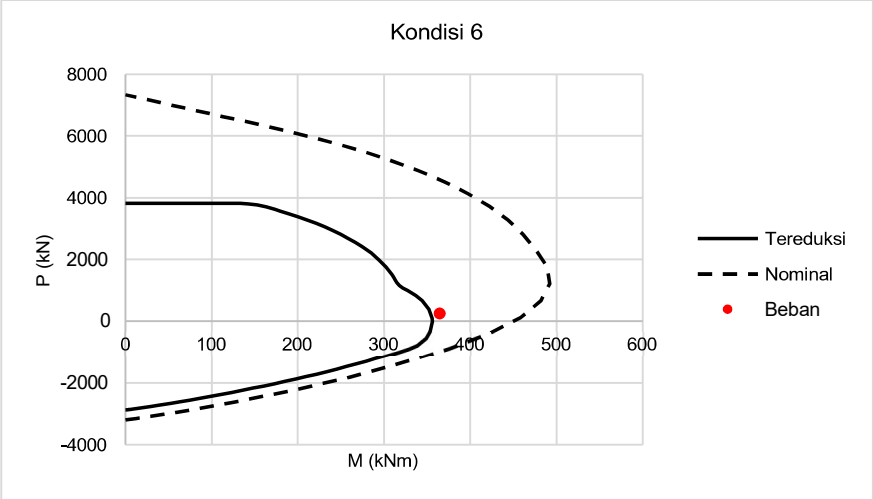

3.3 Pengecekan Syarat Kolom Kuat-Balok Lemah/*Strong Column Weak Beam* (SCWB)

Momen Nominal Kolom Sumbu X	$M_{nk,X}$	=	424.2	kNm
Momen Nominal Kolom Sumbu Y	$M_{nk,Y}$	=	383.8	kNm
Momen Nominal Tumpuan (-) Balok Arah Y	$M_{nb,Y}^{-}$	=	172.6	kNm
Momen Nominal Tumpuan (+) Balok Arah Y	$M_{nb,Y}^{+}$	=	106.9	kNm
Momen Nominal Tumpuan (-) Balok Arah X	$M_{nb,X}^{-}$	=	172.6	kNm
Momen Nominal Tumpuan (+) Balok Arah X	$M_{nb,X}^{+}$	=	106.9	kNm

Pengecekan SCWB Momen X Kolom --> $2\,M_{nk,X} > 1.2 \times M_{nb,Y}^{-} + M_{nb,Y}^{+}$

(SNI 2847:2019 pasal 18.7.3.2)

$848.5 > 1.2 \times 172.6 + 106.9$

$848.5 > 335.502$ OK

Pengecekan SCWB Momen Y Kolom --> $2\,M_{nk,Y} > 1.2 \times M_{nb,X}^{-} + M_{nb,X}^{+}$

(SNI 2847:2019 pasal 18.7.3.2)

$767.6 > 1.2 \times 172.6 + 106.9$

$767.6 > 335.502$ OK

4 Desain Geser

4.1 Desain Geser Tumpuan

Momen Probable Kolom Sumbu X $M_{pr,X}$ = 572.2 kNm

Momen Probable Kolom Sumbu Y $M_{pr,Y}$ = 572.2 kNm

Gaya Geser Probable Sumbu X $V_{pr,X}$

(SNI 2847:2019 pasal 18.7.6.1)

$$= \frac{2 \times M_{pr,Y}}{L_n}$$

$$= \frac{2 \times 572.2}{4250}$$

$$= 269253.5 \text{ N}$$

Gaya Geser Probable Sumbu Y $V_{pr,Y}$

(SNI 2847:2019 pasal 18.7.6.1)

$$= 2 \times \frac{M_{pr,X}}{L_n}$$

$$= 2 \times \frac{572.2}{4250}$$

$$= 269253.5 \text{ N}$$

Gaya Geser Pakai Sumbu X $V_{u,X}$ = MAX V_{ux} ; $V_{pr,X}$

= MAX 187816.3 ; 269253.5

= 269253.5 N

Gaya Geser Pakai Sumbu Y $V_{u,Y}$ = MAX V_{uy} ; $V_{pr,Y}$

= MAX 207774.8 ; 269253.5

= 269253.5 N

Kapasitas Geser Beton Sumbu X $V_{c,X}$

(SNI 2847:2019 pasal 22.5.5.1)

$$= 0.17 \times 1 + \frac{N_u}{14\,A_g} \times \sqrt{f_c'} \times h \times d_2$$

$$= 0.17 \times 1 + \frac{0}{14 \times 202500} \times \sqrt{25} \times 450 \times 389$$

$$= 148792.5 \text{ N}$$

Kapasitas Geser Beton Sumbu Y $V_{c,Y}$ = 0.17 × 1 + $\frac{N_u}{14\,A_g}$

(SNI 2847:2019 pasal 22.5.5.1)

$\times \sqrt{f_c'} \times b \times d_1$

$= 0.17 \times 1 + \frac{0}{14} \times \sqrt{25} \times 450 \times 202500 \times 389$

$= 148792.5$ N

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Kapasitas Geser Baja Tulangan Sumbu X $V_{s,X} = \frac{A_{vs,X} \times f_{yv} \times d_2}{s}$

(SNI 2847:2019 pasal 22.5.10.5.3)

$= \frac{392.70 \times 420 \times 389}{100}$

$= 641591.8$ N

Kapasitas Geser Baja Tulangan Sumbu Y $V_{s,X} = \frac{A_{vs,Y} \times f_{yv} \times d_1}{s}$

(SNI 2847:2019 pasal 22.5.10.5.3)

$= \frac{392.70 \times 420 \times 389}{100}$

$= 641591.8$ N

Faktor Reduksi $\Phi = 0.75$

(SNI 2847:2019 tabel 21.2.1)

Kapasitas Nominal Kolom Sumbu X $V_{n,X} = \Phi \times \left(V_{c,X} + V_{s,X} \right)$

(SNI 2847:2019 pasal 22.5.10.1)

$= 0.75 \times \left(148792.5 + 641591.8 \right)$

$= 592788.2$ N > 269253.5 N OK

Kapasitas Nominal Kolom Sumbu Y $V_{n,Y} = \Phi \times \left(V_{c,Y} + V_{s,Y} \right)$

(SNI 2847:2019 pasal 22.5.10.1)

$= 0.75 \times \left(148792.5 + 641591.8 \right)$

$= 592788.2$ N > 269253.5 N OK

4.2 Desain Geser Lapangan

Kapasitas Geser Beton Sumbu X $V_{c,X} = 148792.5$ N

Kapasitas Geser Beton Sumbu Y $V_{c,Y} = 148792.5$ N

Kapasitas Geser Baja Tulangan Sumbu X $V_{s,X} = \frac{A_{vm,X} \times f_{yv} \times d_2}{s_n}$

(SNI 2847:2019 pasal 22.5.10.5.3)

$= \frac{157.08 \times 420 \times 389}{130}$

$= 197412.8$ N

Kapasitas Geser Baja Tulangan Sumbu Y $V_{s,X} = \frac{A_{vm,Y} \times f_{yv} \times d_1}{s_n}$

(SNI 2847:2019 pasal 22.5.10.5.3)

$= \frac{157.08 \times 420 \times 389}{130}$

$= 197412.8$ N

Faktor Reduksi $\Phi = 0.75$

Kapasitas Nominal Kolom Sumbu X $V_{n,X} = \Phi \times \left(V_{c,X} + V_{s,X} \right)$

(SNI 2847:2019 pasal 22.5.10.1)

$= 0.75 \times \left(148792.5 + 197412.8 \right)$

$= 259654$ N > 187816.3 N OK

Kapasitas Nominal Kolom Sumbu Y $V_{n,Y} = \Phi \times \left(V_{c,Y} + V_{s,Y} \right)$

(SNI 2847:2019 pasal 22.5.10.1)

$= 0.75 \times \left(148792.5 + 197412.8 \right)$

$= 259654$ N > 207774.8 N OK

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	Revision	: -

5 Pengecekan Confinement, Jarak Antar Kaki Sengkang, dan Spasi Sengkang

5.1 Tulangan Sengkang Tumpuan Minimum

Luas per Spasi Sengkang X Terpasang $\frac{A_{sh,x}}{s} = \frac{A_{vs,x}}{s_s} = \frac{392.6991}{100} = 3.927$ mm²/mm

Luas per Spasi Sengkang Y Terpasang $\frac{A_{sh,y}}{s} = \frac{A_{vs,y}}{s_s} = \frac{392.6991}{100} = 3.927$ mm²/mm

Lebar Inti Beton $b_c = b - 2\,c_c - d_s = 360$ mm

Panjang Inti Beton $h_c = h - 2\,c_c - d_s = 360$ mm

Luas Inti Beton $A_{ch} = b_c \times h_c = 129600$ mm²

$P_u > 0.3\,A_g\,f_c'$ atau $f_c' > 70\ MPa$? --> Tidak

(SNI 2847:2019 tabel 18.7.5.4)

Faktor Kekuatan Beton $k_f = \frac{f_c'}{175} + 0.6 \geq 1 = \frac{25}{175} + 0.6 \geq 1$

(SNI 2847:2019 pasal 18.7.5.4)

$= 1$

Faktor Keefektifan Pengekangan $k_n = \frac{n}{n-2} = \frac{20}{20-2} = 1.111$

(SNI 2847:2019 pasal 18.7.5.4)

Tulangan Transversal Pengekang Perlu

(SNI 2847:2019 tabel 18.7.5.4)

$$= \begin{cases} 0.09 \times \frac{f_c'}{f_{yv}} \\ 0.3 \times \left(\frac{A_g}{A_{ch}} - 1\right) \times \frac{f_c'}{f_{yv}} \\ 0.2 \times k_f \times k_n \times \frac{P_u}{f_{yv} \times A_{ch}} \end{cases}$$

$$= \begin{cases} 0.09 \times \frac{25}{420} \\ 0.3 \times \left(\frac{202500}{129600} - 1\right) \times \frac{25}{420} \\ 0.2 \times 1 \times 1.111 \times \frac{801510.8}{420 \times 129600} \end{cases}$$

$$= \begin{cases} 0.005357 \\ 0.010045 \\ 0.003272 \end{cases}$$

$= 0.010045$

Tulangan Transversal Pengekang X $= \frac{A_{sh,x}}{s\,h_c}$

(SNI 2847:2019 tabel 18.7.5.4)

$= 0.010908 > 0.010045$ OK

Tulangan Transversal Pengekang Y $= \frac{A_{sh,y}}{s\,b_c}$

(SNI 2847:2019 tabel 18.7.5.4)

$= 0.010908 > 0.010045$ OK

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5.2 Tulangan Sengkang Lapangan Minimum

Luas per Spasi Sengkang X Terpasang

$$\frac{A_{v,x}}{s} = \frac{A_{vm,x}}{s_m} = \frac{157.0796}{130} = 1.208 \text{ mm}^2/\text{mm}$$

Luas per Spasi Sengkang Y Terpasang

$$\frac{A_{v,y}}{s} = \frac{A_{vm,y}}{s_m} = \frac{157.0796}{130} = 1.208 \text{ mm}^2/\text{mm}$$

Luas per Spasi Sengkang X Perlu

(SNI 2847:2019 pasal 10.6.2.2)

$$\frac{A_{v,x}}{s} > \begin{cases} 0.062 \times \sqrt{f_c'} \times \frac{h}{f_{yv}} \\ 0.35 \times \frac{h}{f_{yv}} \end{cases}$$

$$1.208 > \begin{cases} 0.062 \times \sqrt{25} \times \frac{450}{420} \\ 0.3 \times \frac{450}{420} \end{cases}$$

$$1.208 > \begin{cases} 0.332 \\ 0.321 \end{cases}$$

$$1.208 > 0.332 \text{ mm}^2/\text{mm} \quad \text{OK}$$

Luas per Spasi Sengkang Y Perlu

(SNI 2847:2019 pasal 10.6.2.2)

$$\frac{A_{v,y}}{s} > \begin{cases} 0.062 \times \sqrt{f_c'} \times \frac{b}{f_{yv}} \\ 0.35 \times \frac{b}{f_{yv}} \end{cases}$$

$$1.208 > \begin{cases} 0.062 \times \sqrt{25} \times \frac{450}{420} \\ 0.3 \times \frac{450}{420} \end{cases}$$

$$1.208 > \begin{cases} 0.332 \\ 0.321 \end{cases}$$

$$1.208 > 0.332 \text{ mm}^2/\text{mm} \quad \text{OK}$$

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5.3 Spasi dan Jarak Antar Kaki Sengkang Maksimum

Spasi Sengkang Tumpuan Maximum — $s_{s,max}$

(SNI 2847:2019 pasal 18.7.5.3)

$$= \left\{ \begin{array}{l} \dfrac{b}{4} \\ 6\ d_b \\ 100 \le 100 + \dfrac{350 - x_{i,max}}{3} \le 150 \end{array} \right\}$$

$$= \left\{ \begin{array}{l} \dfrac{450}{4} \\ 6 \times 22 \\ 100 \le 100 + \dfrac{350 - 131.2}{3} \le 150 \end{array} \right\}$$

$$= \left\{ \begin{array}{l} 112.5 \\ 132 \\ 150 \end{array} \right\}$$

$= 112.5$ mm $>$ 100 mm OK

Spasi Sengkang Lapangan Maximum — $s_{s,max}$

(SNI 2847:2019 pasal 18.7.5.5)

$$= \left\{ \begin{array}{l} 6\ d_b \\ 150 \end{array} \right\}$$

$$= \left\{ \begin{array}{l} 6 \times 22 \\ 150 \end{array} \right\}$$

$$= \left\{ \begin{array}{l} 132 \\ 150 \end{array} \right\}$$

$= 132$ mm $>$ 130 mm OK

Jarak Antar Kaki Sengkang Max — $x_{i,max} \le 350$ mm

(SNI 2847:2019 pasal 18.7.5.2)

Jarak Antar Kaki Tumpuan Maximum — $x_{sx} = 131.2$ mm $<$ 350 mm OK

(SNI 2847:2019 pasal 18.7.5.2) — $x_{sy} = 131.2$ mm $<$ 350 mm OK

Jumlah Tul. Longitudinal yang Terkekang — $n_{cx} = 5 > 3$ OK

(SNI 2847:2019 pasal 18.7.5.2) — $n_{cy} = 5 > 3$ OK

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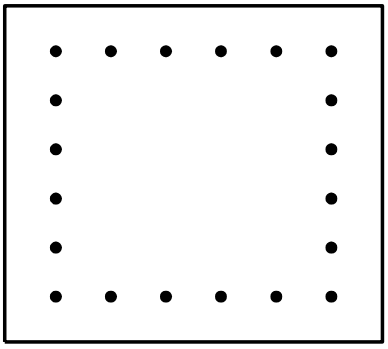
6 Kesimpulan

6.1 Sketsa Kolom



Dimensi : 450 × 450
Longitudinal : 20 D22 (3.75%)
Sengkang Tumpuan : 5 / 5 D10-100
Sengkang Lapangan : 2 / 2 D10-130
Panjang Tumpuan Min. : 708.3 mm (kedua ujung)

6.2 Rekapitulasi Hasil Desain

No	Parameter	Cek
1	Syarat Geometri	OK
2	Rasio Tulangan Lentur	OK
3	Kapasitas Aksial-Lentur	OK
4	Syarat Kolom Kuat-Balok Lemah	OK
5	Kapasitas Geser Tumpuan	OK
6	Kapasitas Geser Lapangan	OK
7	Tulangan Sengkang Tumpuan	OK
8	Tulangan Sengkang Lapangan	OK
9	Spasi Sengkang Tumpuan	OK
10	Spasi Sengkang Lapangan	OK
11	Jarak Antar Kaki Sengkang	OK
12	Jumlah Tul. Longitudinal Terkekang	OK

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1 Input Data

1.1 Geometri Kolom

Sisi Pendek Kolom	b	=	300	mm	d_1	=	253.5	mm
Sisi Panjang Kolom	h	=	300	mm	d_2	=	253.5	mm
Tinggi Kolom	L	=	3000	mm				
Selimut Bersih	c_c	=	30	mm				
Tinggi Balok	h_b	=	500	mm				
Tinggi Bersih Kolom	L_n	=	2500	mm				

1.3 Material

Kuat Tekan Beton	f_c'	=	25	MPa (K-300)	β_1	=	0.850	
Kuat Leleh Baja Tulangan Longitudinal	f_y	=	420	MPa (BjTS 420)				
Kuat Leleh Baja Tulangan Transversal	f_{yv}	=	420	MPa (BjTS 420)				

1.3 Diameter Tulangan

Diameter Tulangan Longitudinal	d_b	=	13	mm	A_b	=	132.73	mm^2
Diameter Tulangan Sengkang	d_s	=	10	mm	A_v	=	78.54	mm^2

1.4 Tulangan Longitudinal/Utama

Jumlah Tulangan X	n_x	=	6					
Jumlah Tulangan Y	n_y	=	6					
Jumlah Total Tulangan Longitudinal	n	=	20		A_s	=	2654.65	mm^2

1.5 Tulangan Transversal/Sengkang

Jumlah Kaki Sengkang Tumpuan Arah X	$n_{vs,x}$	=	2		$A_{vs,x}$	=	157.08	mm^2
Jumlah Kaki Sengkang Tumpuan Arah Y	$n_{vs,y}$	=	2		$A_{vs,y}$	=	157.08	mm^3
Jumlah Kaki Sengkang Lapangan Arah X	$n_{vm,x}$	=	2		$A_{vm,x}$	=	157.08	mm^4
Jumlah Kaki Sengkang Lapangan Arah Y	$n_{vm,y}$	=	2		$A_{vm,y}$	=	157.08	mm^5
Spasi Sengkang Tumpuan	s_s	=	100	mm				
Spasi Sengkang Lapangan	s_m	=	125	mm				

1.6 Gaya Dalam

Aksial-Lentur

Kondisi	P	MX	MY	Mu
	(kN)	(kNm)	(kNm)	(kNm)
P Max	290.9923	87.1281	-22.0179	89.867
P Min	-7.4277	14.3939	-79.2299	80.527
MX Max	290.9923	87.1281	-22.0179	89.867
MX Min	289.5712	-86.7688	-22.3579	89.603
MY Max	-7.2956	-13.8296	79.2299	80.428
MY Min	-7.4277	14.3939	-79.2299	80.527

Geser

Gaya Geser Sumbu X	V_{ux}	=	79.0306	kN
Gaya Geser Sumbu Y	V_{uy}	=	60.6217	kN

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3 Desain Aksial-Lentur

3.1 Pengecekan Syarat Rasio Tulangan

Luas Tulangan Longitudinal $A_s = n \times A_b$

$= 20 \times 132.7323$

$= 2654.646$ mm²

Luas Penampang $A_g = b \times h$

$= 300 \times 300$

$= 90000$ mm²

Rasio Tulangan $\rho = A_s = 2654.646 = 2.95\%$

(SNI 2847:2019 pasal 10.6.1.1) $A_g \quad 90000$

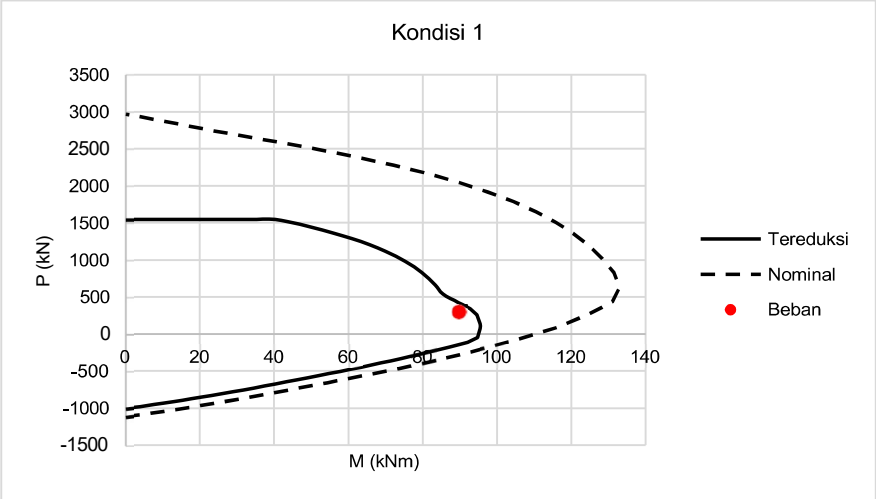
$1\% < 2.95\% < 8\%$ OK

3.2 Pengecekan Kapasitas Aksial-Lentur

Tabel Rekapitulasi

Kondisi	P	MX	MY	φMn / Mu	c	dt	εst	φ	Cek
	(kN)	(kNm)	(kNm)		(mm)	(mm)			
P Max	290.9923	87.1281	-22.0179	1.046	154.6	307.9	0.0030	0.724	OK
P Min	-7.4277	14.3939	-79.2299	1.221	111.6	294.7	0.0049	0.887	OK
MX Max	290.9923	87.1281	-22.0179	1.046	154.6	307.9	0.0030	0.724	OK
MX Min	289.5712	-86.7688	-22.3579	1.046	155.0	308.7	0.0030	0.724	OK
MY Max	-7.2956	-13.8296	79.2299	1.227	110.6	293.3	0.0050	0.889	OK
MY Min	-7.4277	14.3939	-79.2299	1.221	111.6	294.7	0.0049	0.887	OK

Diagram Interaksi



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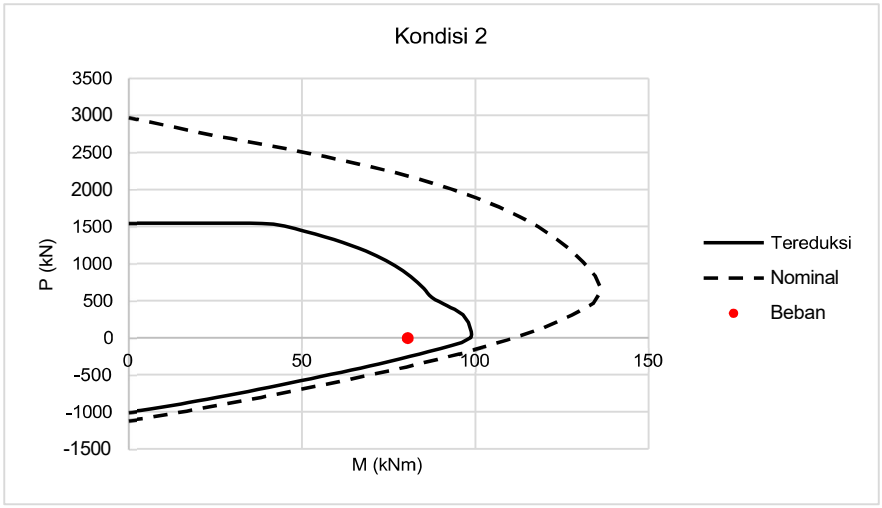
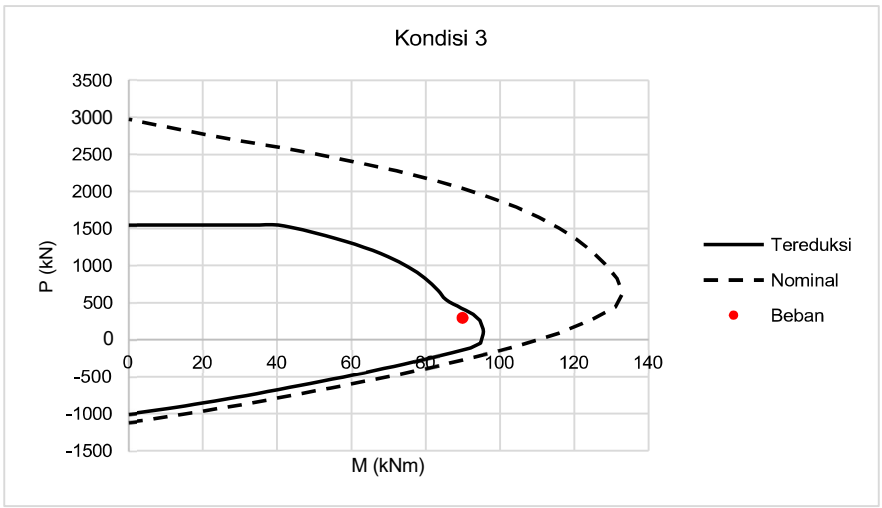
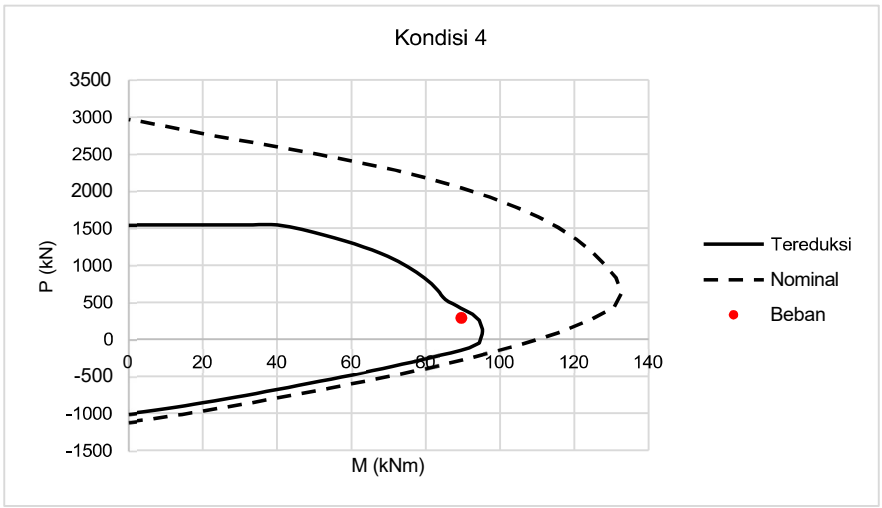
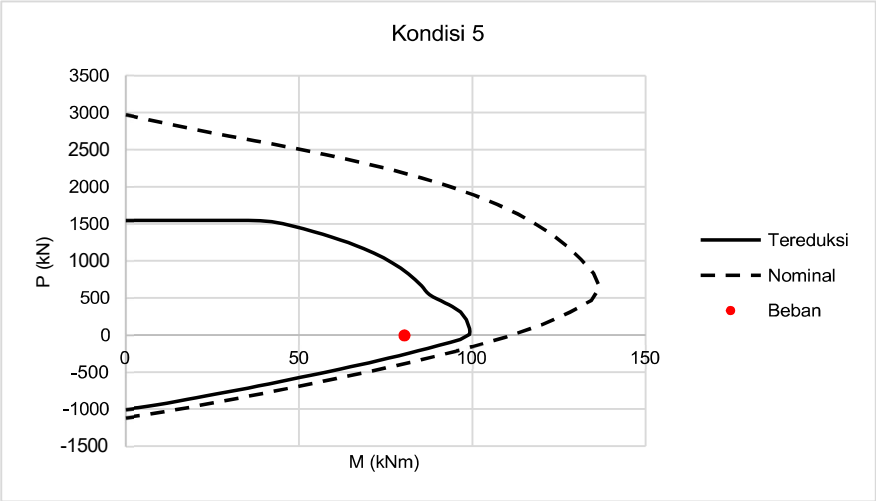
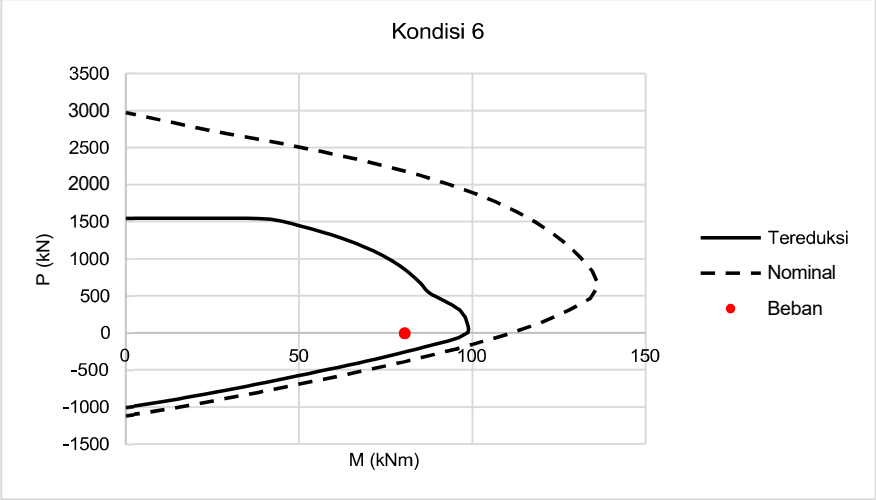
	Revision	: -











4 Desain Geser

4.1 Desain Geser Tumpuan

Kapasitas Geser Beton Sumbu X

(SNI 2847:2019 pasal 22.5.6.1)

$$V_{c,X} = 0.17 \times \left(1 + \frac{N_u}{14\,A_g}\right) \times \sqrt{f_c'} \times h \times d_2$$

$$= 0.17 \times \left(1 + \frac{0}{14 \times 90000}\right) \times \sqrt{25} \times 300 \times 253.5$$

$$= 64642.5 \text{ N}$$

Kapasitas Geser Beton Sumbu Y

(SNI 2847:2019 pasal 22.5.6.1)

$$V_{c,Y} = 0.17 \times \left(1 + \frac{N_u}{14\,A_g}\right) \times f_c' \times b \times d_1$$

$$= 0.17 \times \left(1 + \frac{0}{14 \times 90000}\right) \times \sqrt{25} \times 300 \times 253.5$$

$$= 64642.5 \text{ N}$$

Kapasitas Geser Baja Tulangan Sumbu X

(SNI 2847:2019 pasal 22.5.10.5.3)

$$V_{s,X} = \frac{A_{vs,X} \times f_{yv} \times d_2}{s_s}$$

$= \frac{157.08 \times 420 \times 253.5}{100}$

$= 167242.7$ N

Kapasitas Geser Baja Tulangan Sumbu Y — $V_{s,X} = \frac{A_{vs,Y} \times f_{yv} \times d_1}{s_s}$

(SNI 2847:2019 pasal 22.5.10.5.3)

$= \frac{157.08 \times 420 \times 253.5}{100}$

$= 167242.7$ N

Faktor Reduksi — $\Phi = 0.75$

(SNI 2847:2019 tabel 21.2.1)

Kapasitas Nominal Kolom Sumbu X — $V_{n,X} = \Phi \times \left(V_{c,X} + V_{s,X} \right)$

(SNI 2847:2019 pasal 22.5.10.1)

$= 0.75 \times \left(64642.5 + 167242.7 \right)$

$= 173913.9$ N > 79030.6 N OK

Kapasitas Nominal Kolom Sumbu Y — $V_{n,Y} = \Phi \times \left(V_{c,Y} + V_{s,Y} \right)$

(SNI 2847:2019 pasal 22.5.10.1)

$= 0.75 \times \left(64642.5 + 167242.7 \right)$

$= 173913.9$ N > 60621.7 N OK

4.2 Desain Geser Lapangan

Kapasitas Geser Beton Sumbu X — $V_{c,X} = 64642.5$ N

Kapasitas Geser Beton Sumbu Y — $V_{c,Y} = 64642.5$ N

Kapasitas Geser Baja Tulangan Sumbu X — $V_{s,X} = \frac{A_{vm,X} \times f_{yv} \times d_2}{s_m}$

(SNI 2847:2019 pasal 22.5.10.5.3)

$= \frac{157.08 \times 420 \times 253.5}{125}$

$= 133794.1$ N

Kapasitas Geser Baja Tulangan Sumbu Y — $V_{s,X} = \frac{A_{vm,Y} \times f_{yv} \times d_1}{s_m}$

(SNI 2847:2019 pasal 22.5.10.5.3)

$= \frac{157.08 \times 420 \times 253.5}{125}$

$= 133794.1$ N

Faktor Reduksi — $\Phi = 0.75$

Kapasitas Nominal Kolom Sumbu X — $V_{n,X} = \Phi \times \left(V_{c,X} + V_{s,X} \right)$

(SNI 2847:2019 pasal 22.5.10.1)

$= 0.75 \times \left(64642.5 + 133794.1 \right)$

$= 148827.5$ N > 79030.6 N OK

Kapasitas Nominal Kolom Sumbu Y — $V_{n,Y} = \Phi \times \left(V_{c,Y} + V_{s,Y} \right)$

(SNI 2847:2019 pasal 22.5.10.1)

$= 0.75 \times \left(64642.5 + 133794.1 \right)$

$= 148827.5$ N > 60621.7 N OK

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5 Pengecekan Confinement, Jarak Antar Kaki Sengkang, dan Spasi Sengkang

5.1 Tulangan Sengkang Tumpuan Minimum

Luas per Spasi Sengkang X Terpasang

$$\frac{A_{v,x}}{s} = \frac{A_{vs,x}}{s_s} = \frac{157.0796}{100} = 1.571 \text{ mm}^2/\text{mm}$$

Luas per Spasi Sengkang Y Terpasang

$$\frac{A_{v,y}}{s} = \frac{A_{vm,y}}{s_m} = \frac{157.0796}{100} = 1.571 \text{ mm}^2/\text{mm}$$

Luas per Spasi Sengkang X Perlu

(SNI 2847:2019 pasal 10.6.2.2)

$$\frac{A_{v,x}}{s} > \begin{cases} 0.062 \times \sqrt{f_c'} \times \frac{h}{f_y} \\ 0.35 \times \frac{h}{f_y} \end{cases}$$

$$1.571 > \begin{cases} 0.062 \times \sqrt{25} \times \frac{300}{420} \\ 0.3 \times \frac{300}{420} \end{cases}$$

$$1.571 > \begin{cases} 0.221 \\ 0.214 \end{cases}$$

$$1.571 > 0.221 \text{ mm}^2/\text{mm} \quad \text{OK}$$

Luas per Spasi Sengkang Y Perlu

(SNI 2847:2019 pasal 10.6.2.2)

$$\frac{A_{v,y}}{s} > \begin{cases} 0.062 \times \sqrt{f_c'} \times \frac{b}{f_y} \\ 0.35 \times \frac{b}{f_y} \end{cases}$$

$$1.571 > \begin{cases} 0.062 \times \sqrt{25} \times \frac{300}{420} \\ 0.3 \times \frac{300}{420} \end{cases}$$

$$1.571 > \begin{cases} 0.221 \\ 0.214 \end{cases}$$

$$1.571 > 0.221 \text{ mm}^2/\text{mm} \quad \text{OK}$$

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5.2 Tulangan Sengkang Lapangan Minimum

Luas per Spasi Sengkang X Terpasang

$$\frac{A_{v,x}}{s} = \frac{A_{vm,x}}{s_m} = \frac{157.0796}{125} = 1.257 \text{ mm}^2/\text{mm}$$

Luas per Spasi Sengkang Y Terpasang

$$\frac{A_{v,y}}{s} = \frac{A_{vm,y}}{s_m} = \frac{157.0796}{125} = 1.257 \text{ mm}^2/\text{mm}$$

Luas per Spasi Sengkang X Perlu

(SNI 2847:2019 pasal 10.6.2.2)

$$\frac{A_{v,x}}{s} > \begin{cases} 0.062 \times \sqrt{f_c'} \times \frac{h}{f_y} \\ 0.35 \times \frac{h}{f_y} \end{cases}$$

$$1.257 > \begin{cases} 0.062 \times \sqrt{25} \times \frac{300}{420} \\ 0.3 \times \frac{300}{420} \end{cases}$$

$$1.257 > \begin{cases} 0.221 \\ 0.214 \end{cases}$$

$$1.257 > 0.221 \text{ mm}^2/\text{mm} \quad \text{OK}$$

Luas per Spasi Sengkang Y Perlu

(SNI 2847:2019 pasal 10.6.2.2)

$$\frac{A_{v,y}}{s} > \begin{cases} 0.062 \times \sqrt{f_c'} \times \frac{b}{f_y} \\ 0.35 \times \frac{b}{f_y} \end{cases}$$

$$1.257 > \begin{cases} 0.062 \times \sqrt{25} \times \frac{300}{420} \\ 0.3 \times \frac{300}{420} \end{cases}$$

$$1.257 > \begin{cases} 0.221 \\ 0.214 \end{cases}$$

$$1.257 > 0.221 \text{ mm}^2/\text{mm} \quad \text{OK}$$

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5.3 Spasi Sengkang Maksimum

5.3.1 Spasi Sengkang Tumpuan Maksimum

Rasio Kebutuhan Tulangan Sengkang Tumpuan = $\frac{V_{s,perlu}}{\sqrt{f_c'} \times b \times d_1}$ = $\frac{40731.63}{380250}$ = 0.107 < 0.33

(SNI 2847:2019 pasal 10.7.6.5.2)

Spasi Sengkang Tumpuan Maksimum $s_{s,max}$ = $\left\{\begin{matrix} d / 2 \\ 3\,h / 4 \\ 600 \end{matrix}\right\}$

(SNI 2847:2019 pasal 10.7.6.5.2)

= $\left\{\begin{matrix} 253.5 / 2 \\ 3 \times 300 / 4 \\ 600 \end{matrix}\right\}$

= $\left\{\begin{matrix} 126.75 \\ 225 \\ 600 \end{matrix}\right\}$

= 126.8 mm > 100 mm OK

5.3.1 Spasi Sengkang Lapangan Maksimum

Rasio Kebutuhan Tulangan Sengkang Lapangan = $\frac{V_{s,perlu}}{\sqrt{f_c'} \times b \times d_1}$ = $\frac{40731.63}{380250}$ = 0.107 < 0.33

(SNI 2847:2019 pasal 10.7.6.5.2)

Spasi Sengkang Lapangan Maksimum $s_{m,max}$ = $\left\{\begin{matrix} d / 2 \\ 3\,h / 4 \\ 600 \end{matrix}\right\}$

(SNI 2847:2019 pasal 10.7.6.5.2)

= $\left\{\begin{matrix} 253.5 / 2 \\ 3 \times 300 / 4 \\ 600 \end{matrix}\right\}$

= $\left\{\begin{matrix} 126.75 \\ 225 \\ 600 \end{matrix}\right\}$

= 126.8 mm > 125 mm OK

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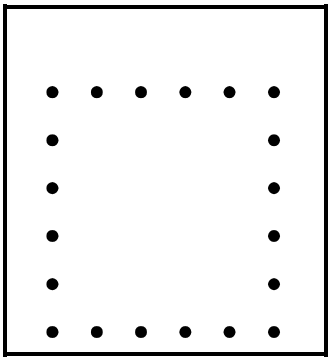
6 Kesimpulan

6.1 Sketsa Kolom



Dimensi : 300 × 300

Longitudinal : 20 D13
Sengkang Tumpuan : 2 / 2 D10-100
Sengkang Lapangan : 2 / 2 D10-125

6.2 Rekapitulasi Hasil Desain

No	Parameter	Cek
1	Rasio Tulangan Lentur	OK
2	Kapasitas Aksial-Lentur	OK
3	Kapasitas Geser Tumpuan	OK
4	Kapasitas Geser Lapangan	OK
5	Tulangan Sengkang Tumpuan	OK
6	Tulangan Sengkang Lapangan	OK
7	Spasi Sengkang Tumpuan	OK
8	Spasi Sengkang Lapangan	OK

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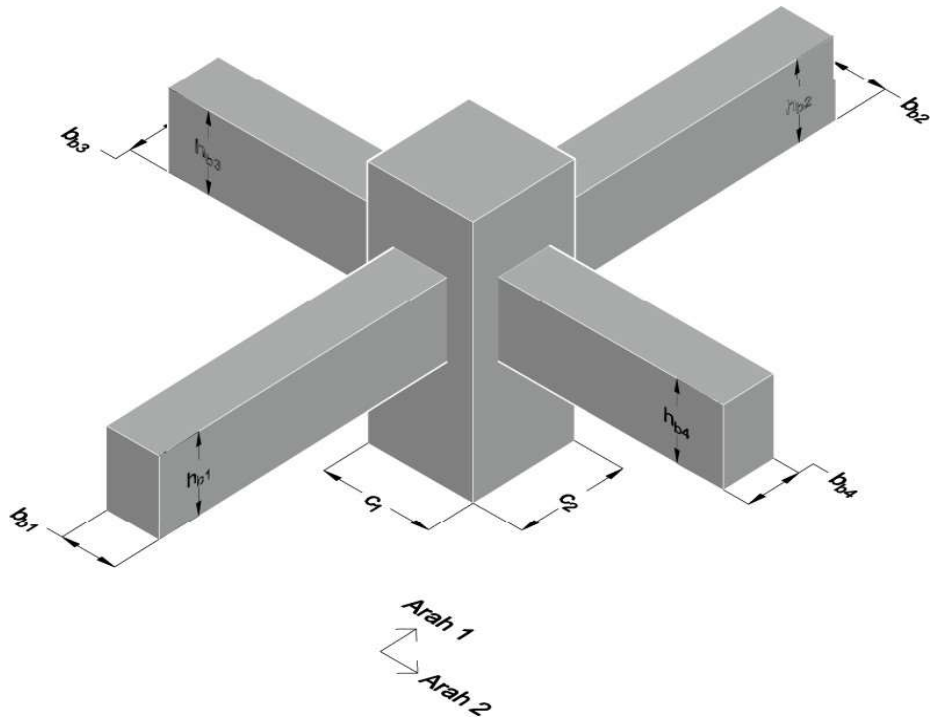
1 Input Data



1.1 Kolom

Lebar Sisi 1	c_1	=	450	mm	d_1	=	389	mm
Lebar SIsi 2	c_2	=	450	mm	d_2	=	389	mm
Panjang Kolom	L_k	=	4000	mm				
Selimut Bersih	$c_{c,k}$	=	40	mm				
Tinggi Balok Terbesar	h_b	=	500	mm				
Panjang Bersih Kolom	$L_{n,k}$	=	3500	mm				
Kuat Tekan Beton	$f_c'_{,k}$	=	25	MPa	β_1	=	0.850	
Kuat Leleh Tulangan Longitudinal	$f_{y,k}$	=	420	MPa				
Diameter Tulangan Longitudinal	$d_{b,k}$	=	22	mm	A_b	=	380.13	mm^2
Diameter Tulangan Sengkang	$d_{s,k}$	=	10	mm	A_v	=	78.54	mm^2
Jumlah Tulangan Longitudinal X	n_x	=	6					
Jumlah Tulangan Longitudinal Y	n_y	=	6					
Jumlah Total Tulangan Longitudinal	n_k	=	20		A_s	=	7602.65	mm^2

1.2 Tulangan Transversal Joint

Jumlah Kaki Sengkang Arah X	$n_{v,x}$	=	5		$A_{v,x}$	=	392.70	mm^2
Jumlah Kaki Sengkang Arah Y	$n_{v,y}$	=	5		$A_{v,y}$	=	392.70	mm^2
Spasi Sengkang	s	=	100	mm				
Kuat Leleh Tulangan Transversal	f_{yv}	=	420	MPa				

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1.3 Balok 1

Lebar Balok	b_{b1}	=	300	mm					
Tinggi Balok	h_{b1}	=	500	mm					
Panjang Balok	L_{b1}	=	4000	mm	$L_{n,b1}$	=	3550	mm	
Selimut Bersih Balok	$c_{c,b1}$	=	40	mm					
Eksentrisitas Balok terhadap Kolom	x_{1a}	=	75	mm	$x_{1,min}$	=	75	mm	
	x_{1b}	=	75	mm					
Kuat Tekan Beton	$f_c'_{b1}$	=	25	MPa	β_1	=	0.850		
Kuat Leleh Tul. Longitudinal	$f_{y,b1}$	=	420	MPa					
Diameter Tulangan Longitudinal	$d_{b,b1}$	=	16	mm	A_b	=	201.06	mm^2	
Diameter Tulangan Sengkang	$d_{s,b1}$	=	10	mm					
Jumlah Tulangan Atas Tumpuan Baris 1	$n_{t1,b1}$	=	5		$A_{st1,b1}$	=	1005.31	mm^2	
Jumlah Tulangan Atas Tumpuan Baris 2	$n_{t2,b1}$	=	0		$A_{st2,b1}$	=	0.00	mm^2	
Jumlah Tulangan Bawah Tumpuan Baris 1	$n_{b1,b1}$	=	3		$A_{sb1,b1}$	=	603.19	mm^2	
Jumlah Tulangan Bawah Tumpuan Baris 2	$n_{b2,b1}$	=	0		$A_{sb2,b1}$	=	0.00	mm^2	
Spasi Tulangan Lapis 1 ke Lapis 2	$s_{12,b1}$	=	50	mm	$d_{1,b1}$	=	442	mm	
					$d_{2,b1}$	=	392	mm	
Gaya Geser Gravitasi Tumpuan	$V_{g,tum,b1}$	=	145.12	kN					

1.4 Balok 2

Lebar Balok	b_{b2}	=	300	mm					
Tinggi Balok	h_{b2}	=	500	mm					
Panjang Balok	L_{b2}	=	4000	mm	$L_{n,b2}$	=	3550	mm	
Selimut Bersih Balok	$c_{c,b2}$	=	40	mm					
Eksentrisitas Balok terhadap Kolom	x_{2a}	=	75	mm	$x_{2,min}$	=	75	mm	
	x_{2b}	=	75	mm					
Kuat Tekan Beton	$f_c'_{b2}$	=	25	MPa	β_1	=	0.850		
Kuat Leleh Tul. Longitudinal	$f_{y,b2}$	=	420	MPa					
Diameter Tulangan Longitudinal	$d_{b,b2}$	=	16	mm	A_b	=	201.06	mm^2	
Diameter Tulangan Sengkang	$d_{s,b2}$	=	10	mm					
Jumlah Tulangan Atas Tumpuan Baris 1	$n_{t1,b2}$	=	5		$A_{st1,b2}$	=	1005.31	mm^2	
Jumlah Tulangan Atas Tumpuan Baris 2	$n_{t2,b2}$	=	0		$A_{st2,b2}$	=	0.00	mm^2	
Jumlah Tulangan Bawah Tumpuan Baris 1	$n_{b1,b2}$	=	3		$A_{sb1,b2}$	=	603.19	mm^2	
Jumlah Tulangan Bawah Tumpuan Baris 2	$n_{b2,b2}$	=	0		$A_{sb2,b2}$	=	0.00	mm^2	
Spasi Tulangan Lapis 1 ke Lapis 2	$s_{12,b2}$	=	50	mm	$d_{1,b2}$	=	442	mm	
					$d_{2,b2}$	=	392	mm	

Gaya Geser Gravitasi Tumpuan	$V_{g\ ,\ tum,b2}$	=	145.12	kN

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1.5 Balok 3

Lebar Balok	b_{b3}	=	300	mm					
Tinggi Balok	h_{b3}	=	500	mm					
Panjang Balok	L_{b3}	=	4000	mm	$L_{n,b3}$	=	3550	mm	
Selimut Bersih Balok	$c_{c,b3}$	=	40	mm					
Eksentrisitas Balok terhadap Kolom	x_{3a}	=	75	mm	$x_{3,min}$	=	75	mm	
	x_{3b}	=	75	mm					
Kuat Tekan Beton	$f_c'_{b3}$	=	25	MPa	β_1	=	0.850		
Kuat Leleh Tul. Longitudinal	$f_{y,b3}$	=	420	MPa					
Diameter Tulangan Longitudinal	$d_{b,b3}$	=	16	mm	A_b	=	201.06	mm^2	
Diameter Tulangan Sengkang	$d_{s,b3}$	=	10	mm					
Jumlah Tulangan Atas Tumpuan Baris 1	$n_{t1,b3}$	=	5		$A_{st1,b3}$	=	1005.31	mm^2	
Jumlah Tulangan Atas Tumpuan Baris 2	$n_{t2,b3}$	=	0		$A_{st2,b3}$	=	0.00	mm^2	
Jumlah Tulangan Bawah Tumpuan Baris 1	$n_{b1,b3}$	=	3		$A_{sb1,b3}$	=	603.19	mm^2	
Jumlah Tulangan Bawah Tumpuan Baris 2	$n_{b2,b3}$	=	0		$A_{sb2,b3}$	=	0.00	mm^2	
Spasi Tulangan Lapis 1 ke Lapis 2	$s_{12,b3}$	=	50	mm	$d_{1,b3}$	=	442	mm	
					$d_{2,b3}$	=	392	mm	
Gaya Geser Gravitasi Tumpuan	$V_{g,tum,b3}$	=	145.12	kN					

1.6 Balok 4

Lebar Balok	b_{b4}	=	300	mm					
Tinggi Balok	h_{b4}	=	500	mm					
Panjang Balok	L_{b4}	=	4000	mm	$L_{n,b4}$	=	3550	mm	
Selimut Bersih Balok	$c_{c,b4}$	=	40	mm					
Eksentrisitas Balok terhadap Kolom	x_{4a}	=	75	mm	$x_{4,min}$	=	75	mm	
	x_{4b}	=	75	mm					
Kuat Tekan Beton	$f_c'_{b4}$	=	25	MPa	β_1	=	0.850		
Kuat Leleh Tul. Longitudinal	$f_{y,b4}$	=	420	MPa					
Diameter Tulangan Longitudinal	$d_{b,b4}$	=	16	mm	A_b	=	201.06	mm^2	
Diameter Tulangan Sengkang	$d_{s,b4}$	=	10	mm					
Jumlah Tulangan Atas Tumpuan Baris 1	$n_{t1,b4}$	=	5		$A_{st1,b4}$	=	1005.31	mm^2	
Jumlah Tulangan Atas Tumpuan Baris 2	$n_{t2,b4}$	=	0		$A_{st2,b4}$	=	0.00	mm^2	
Jumlah Tulangan Bawah Tumpuan Baris 1	$n_{b1,b4}$	=	3		$A_{sb1,b4}$	=	603.19	mm^2	
Jumlah Tulangan Bawah Tumpuan Baris 2	$n_{b2,b4}$	=	0		$A_{sb2,b4}$	=	0.00	mm^2	
			50						

Spasi Tulangan Lapis 1 ke Lapis 2	$s_{12,b4}$	=		mm	$d_{1,b4}$	=	442 mm
					$d_{2,b4}$	=	392 mm
Gaya Geser Gravitasi Tumpuan	$V_{g\,,\,tum,b4}$	=	145.12	kN			

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2 Dimensi Joint

Lebar Joint Sisi 1 — b_{j1}

(SNI 2847:2019 pasal 18.8.4.3)

$$b_{j1} = \text{mir} \begin{Bmatrix} b_{b1} + c_2 \\ b_{b2} + c_2 \\ b_{b1} + 2 \times x_{1,min} \\ b_{b2} + 2 \times x_{2,min} \end{Bmatrix}$$

$$= \text{mir} \begin{Bmatrix} 300 + 450 \\ 300 + 450 \\ 300 + 2 \times 75 \\ 300 + 2 \times 75 \end{Bmatrix}$$

$$= \text{mir} \begin{Bmatrix} 750 \\ 750 \\ 450 \\ 450 \end{Bmatrix}$$

$$= 450 \text{ mm}$$

Lebar Joint Sisi 2 — b_{j2}

(SNI 2847:2019 pasal 18.8.4.3)

$$b_{j2} = \text{mir} \begin{Bmatrix} b_{b3} + c_1 \\ b_{b4} + c_1 \\ b_{b3} + 2 \times x_{3,min} \\ b_{b4} + 2 \times x_{4,min} \end{Bmatrix}$$

$$= \text{mir} \begin{Bmatrix} 300 + 450 \\ 300 + 450 \\ 300 + 2 \times 75 \\ 300 + 2 \times 75 \end{Bmatrix}$$

$$= \text{mir} \begin{Bmatrix} 750 \\ 750 \\ 450 \\ 450 \end{Bmatrix}$$

$$= 450 \text{ mm}$$

Luas Joint (Arah Gempa 1) — A_{j1}

$$A_{j1} = b_{j1} \times c_2$$

$$= 450 \times 450$$

$$= 202500 \text{ mm}^2$$

Luas Joint (Arah Gempa 2) — A_{j2}

$$A_{j2} = b_{j2} \times c_1$$

$$= 450 \times 450$$

$$= 202500 \text{ mm}^2$$

Tinggi Joint Minimum — $h_{j,min}$

$$h_{j,min} = \frac{h_b}{2} = \frac{500}{2} = 250 < 450 \quad \text{OK}$$

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3 Kuat Geser Joint

Jumlah Balok Merangka		=	4
Jumlah Balok Mengekang		=	0
Ada Balok Berlawanan Sisi yang Mengekang?		=	Tidak
Konfigurasi Joint		=	3
Faktor Pengali Kekuatan Geser Joint	c	=	1
(SNI 2847:2019 pasal 18.8.4.1)			
Kuat Geser Nominal Joint Gempa Arah 1	$V_{n,1}$	=	$c \times \sqrt{f_c'} \times A_{j1}$
(SNI 2847:2019 pasal 18.8.4.1)		=	1 × √ 25 × 202500
		=	1012500 N
Kuat Geser Nominal Joint Gempa Arah 2	$V_{n,2}$	=	$c \times \sqrt{f_c'} \times A_{j2}$
(SNI 2847:2019 pasal 18.8.4.1)		=	1 × √ 25 × 202500
		=	1012500 N
Faktor Reduksi Geser Joint	Φ	=	0.85
(SNI 2847:2019 pasal 21.2.4.3)			
Kuat Geser Tereduksi Joint Gempa Arah 1	$\Phi V_{n,1}$	=	860625 N
Kuat Geser Tereduksi Joint Gempa Arah 2	$\Phi V_{n,2}$	=	860625 N

4 Gaya Geser Joint

4.1 Gaya Geser Kontribusi Balok

Gaya Akibat Tulangan Atas Balok 1	$F_{st,b1}$	=	$(A_{st1,b1} + A_{st2,b1}) \times 1.25 f_{y,b1}$
(SNI 2847:2019 pasal 18.8.2.1)		=	(1005.31 + 0.00) × 1.25 × 420
		=	527787.5658 N
Gaya Akibat Tulangan Bawah Balok 1	$F_{sb,b1}$	=	$(A_{sb1,b1} + A_{sb2,b1}) \times 1.25 f_{y,b1}$
(SNI 2847:2019 pasal 18.8.2.1)		=	(603.19 + 0.00) × 1.25 × 420
		=	316672.5395 N
Gaya Akibat Tulangan Atas Balok 2	$F_{st,b2}$	=	$(A_{st1,b2} + A_{st2,b2}) \times 1.25 f_{y,b2}$
(SNI 2847:2019 pasal 18.8.2.1)		=	(1005.31 + 0.00) × 1.25 × 420
		=	527787.5658 N
Gaya Akibat Tulangan Bawah Balok 2	$F_{sb,b2}$	=	$(A_{sb1,b2} + A_{sb2,b2}) \times 1.25 f_{y,b2}$
(SNI 2847:2019 pasal 18.8.2.1)		=	(603.19 + 0.00) × 1.25 × 420
		=	316672.5395 N
Gaya Akibat Tulangan Atas Balok 3	$F_{st,b3}$	=	$(A_{st1,b3} + A_{st2,b3}) \times 1.25 f_{y,b3}$
(SNI 2847:2019 pasal 18.8.2.1)		=	(1005.31 + 0.00) × 1.25 × 420
		=	527787.5658 N
Gaya Akibat Tulangan Bawah Balok 3	$F_{sb,b3}$	=	$(A_{sb1,b3} + A_{sb2,b3}) \times 1.25 f_{y,b3}$
(SNI 2847:2019 pasal 18.8.2.1)		=	(603.19 + 0.00) × 1.25 × 420
		=	316672.5395 N
Gaya Akibat Tulangan Atas Balok 4	$F_{st,b4}$	=	$(A_{st1,b4} + A_{st2,b4}) \times 1.25 f_{y,b4}$
(SNI 2847:2019 pasal 18.8.2.1)		=	(1005.31 + 0.00) × 1.25 × 420
		=	527787.5658 N
Gaya Akibat Tulangan Bawah Balok 4	$F_{sb,b4}$	=	$(A_{sb1,b4} + A_{sb2,b4}) \times 1.25 f_{y,b4}$
(SNI 2847:2019 pasal 18.8.2.1)		=	(603.19 + 0.00) × 1.25 × 420
		=	316672.5395 N

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4.2 Gaya Geser Kolom - Metode Column Hinging

4.2.1 Momen Probable Balok

Tinggi Blok Beton Probable Negatif Balok 1

$$a_{pr}^{-}{}_{b1} = \frac{\left(A_{st1,b1} + A_{st2,b1}\right) \times 1.25\ f_{y,b1}}{0.85 \times f_c'{}_{b1} \times b_{b1}}$$

$$= \frac{527787.5658}{0.85 \times 25 \times 300}$$

$$= 82.79021 \text{ mm}$$

Momen Probable Negatif Balok 1

$$M_{pr}^{-}{}_{b1} = A_{st1,b1} \times 1.25\ f_{y,b1} \times \left(d_{1,b1} - \frac{a_{pr}^{-}{}_{b1}}{2}\right) + A_{st2,b1} \times 1.25\ f_{y,b1} \times \left(d_{2,b1} - \frac{a_{pr}^{-}{}_{b1}}{2}\right)$$

$$= 1005.31 \times 1.25 \times 420 \times \left(442 - \frac{82.79}{2}\right) + 0.00 \times 1.25 \times 420 \times \left(392 - \frac{82.79}{2}\right)$$

$$= 211434283.3 \text{ Nmm}$$

Tinggi Blok Beton Probable Positif Balok 1

$$a_{pr}^{+}{}_{b1} = \frac{\left(A_{sb1,b1} + A_{sb2,b1}\right) \times 1.25\ f_{y,b1}}{0.85 \times f_c'{}_{b1} \times b_{b1}}$$

$$= \frac{316672.5395}{0.85 \times 25 \times 300}$$

$$= 49.67412 \text{ mm}$$

Momen Probable Positif Balok 1

$$M_{pr}^{+}{}_{b1} = A_{sb1,b1} \times 1.25\ f_{y,b1} \times \left(d_{1,b1} - \frac{a_{pr}^{+}{}_{b1}}{2}\right) + A_{sb2,b1} \times 1.25\ f_{y,b1} \times \left(d_{2,b1} - \frac{a_{pr}^{+}{}_{b1}}{2}\right)$$

$$= 603.19 \times 1.25 \times 420 \times \left(442 - \frac{49.674}{2}\right) + 0.00 \times 1.25 \times 420 \times \left(392 - \frac{49.674}{2}\right)$$

$$= 132104047 \text{ Nmm}$$

Tinggi Blok Beton Probable Negatif Balok 2

$$a_{pr}^{-}{}_{b2} = \frac{\left(A_{st1,b2} + A_{st2,b2}\right) \times 1.25\ f_{y,b2}}{0.85 \times f_c'{}_{b2} \times b_{b2}}$$

$$= \frac{527787.5658}{0.85 \times 25 \times 300}$$

$$= 82.79021 \text{ mm}$$

Momen Probable Negatif Balok 2

$$M_{pr}^{-}{}_{b2} = A_{st1,b2} \times 1.25\ f_{y,b2} \times \left(d_{1,b2} - \frac{a_{pr}^{-}{}_{b2}}{2}\right) + A_{st2,b2} \times 1.25\ f_{y,b2} \times \left(d_{2,b2} - \frac{a_{pr}^{-}{}_{b2}}{2}\right)$$

$$= 1005.31 \times 1.25 \times 420 \times \left(442 - \frac{82.79}{2}\right) + 0.00 \times 1.25 \times 420 \times \left(392 - \frac{82.79}{2}\right)$$

$$= 211434283.3 \text{ Nmm}$$

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Tinggi Blok Beton Probable Positif Balok 2

$$a_{pr}^{+}{}_{b2} = \frac{\left(A_{sb1,b2} + A_{sb2,b2}\right) \times 1.25\ f_{y,b2}}{0.85 \times f_c'{}_{b2} \times b_{b2}}$$

$$= \frac{316672.5395}{0.85 \times 25 \times 300}$$

$$= 49.67412 \text{ mm}$$

Momen Probable Positif Balok 2

$$M_{pr}^{+}{}_{b2} = A_{sb1,b2} \times 1.25\ f_{y,b2} \times \left(d_{1,b2} - \frac{a_{pr}^{+}{}_{b2}}{2}\right) + A_{sb2,b2} \times 1.25\ f_{y,b2} \times \left(d_{2,b2} - \frac{a_{pr}^{+}{}_{b2}}{2}\right)$$

$$= 603.19 \times 1.25 \times 420 \times \left(442 - \frac{49.674}{2}\right) + 0.00 \times 1.25 \times 420 \times \left(392 - \frac{49.674}{2}\right)$$

$$= 132104047 \text{ Nmm}$$

Tinggi Blok Beton Probable Negatif Balok 3

$$a_{pr}^{-}{}_{b3} = \frac{\left(A_{st1,b3} + A_{st2,b3}\right) \times 1.25\ f_{y,b3}}{0.85 \times f_c'{}_{b3} \times b_{b3}}$$

$$= \frac{527787.5658}{0.85 \times 25 \times 300}$$

$$= 82.79021 \text{ mm}$$

Momen Probable Negatif Balok 3

$$M_{pr}^{-}{}_{b3} = A_{st1,b3} \times 1.25\ f_{y,b3} \times \left(d_{1,b3} - \frac{a_{pr}^{-}{}_{b3}}{2}\right) + A_{st2,b3} \times 1.25\ f_{y,b3} \times \left(d_{2,b3} - \frac{a_{pr}^{-}{}_{b3}}{2}\right)$$

$$= 1005.31 \times 1.25 \times 420 \times \left(442 - \frac{82.79}{2}\right) + 0.00 \times 1.25 \times 420 \times \left(392 - \frac{82.79}{2}\right)$$

$$= 211434283.3 \text{ Nmm}$$

Tinggi Blok Beton Probable Positif Balok 3

$$a_{pr}^{+}{}_{b3} = \frac{\left(A_{sb1,b3} + A_{sb2,b3}\right) \times 1.25\ f_{y,b3}}{0.85 \times f_c'{}_{b3} \times b_{b3}}$$

$$= \frac{316672.5395}{0.85 \times 25 \times 300}$$

$$= 49.67412 \text{ mm}$$

Momen Probable Positif Balok 3

$$M_{pr}^{+}{}_{b3} = A_{sb1,b3} \times 1.25\ f_{y,b3} \times \left(d_{1,b3} - \frac{a_{pr}^{+}{}_{b3}}{2}\right) + A_{sb2,b3} \times 1.25\ f_{y,b3} \times \left(d_{2,b3} - \frac{a_{pr}^{+}{}_{b3}}{2}\right)$$

$$= 603.19 \times 1.25 \times 420 \times \left(442 - \frac{49.674}{2}\right) + 0.00 \times 1.25 \times 420 \times \left(392 - \frac{49.674}{2}\right)$$

$$= 132104047 \text{ Nmm}$$

Tinggi Blok Beton Probable Negatif Balok 4

$$a_{pr}^{-}{}_{b4} = \frac{\left(A_{st1,b4} + A_{st2,b4}\right) \times 1.25\ f_{y,b4}}{0.85 \times f_c'{}_{b4} \times b_{b4}}$$

$$= \frac{527787.5658}{0.85 \times 25 \times 300}$$

$$= 82.79021 \text{ mm}$$

Momen Probable Negatif Balok 4

$$M_{pr}^{-}{}_{b4} = A_{st1,b4} \times 1.25\ f_{y,b4} \times \left(d_{1,b4} - \frac{a_{pr}^{-}{}_{b4}}{2}\right) + A_{st2,b4} \times 1.25\ f_{y,b4} \times \left(d_{2,b4} - \frac{a_{pr}^{-}{}_{b4}}{2}\right)$$

$$= 1005.31 \times 1.25 \times 420 \times \left(442 - \frac{82.79}{2}\right) + 0.00 \times 1.25 \times 420 \times \left(392 - \frac{82.79}{2}\right)$$

$$= 211434283.3 \text{ Nmm}$$

Tinggi Blok Beton Probable Positif Balok 4

$$a_{pr}^{+}{}_{b4} = \frac{\left(A_{sb1,b4} + A_{sb2,b4}\right) \times 1.25\ f_{y,b4}}{0.85 \times f_c'{}_{b4} \times b_{b4}}$$

$$= \frac{316672.5395}{0.85 \times 25 \times 300}$$

$$= 49.67412 \text{ mm}$$

Momen Probable Positif Balok 4

$$M_{pr}^{+}{}_{b4} = A_{sb1,b4} \times 1.25\ f_{y,b4} \times \left(d_{1,b4} - \frac{a_{pr}^{+}{}_{b4}}{2}\right) + A_{sb2,b4} \times 1.25\ f_{y,b4} \times \left(d_{2,b4} - \frac{a_{pr}^{+}{}_{b4}}{2}\right)$$

$$= 603.19 \times 1.25 \times 420 \times \left(442 - \frac{49.674}{2}\right) + 0.00 \times 1.25 \times 420 \times \left(392 - \frac{49.674}{2}\right)$$

$$= 132104047 \text{ Nmm}$$

4.2.2 Gaya Geser Balok

Gaya Geser Probable Balok 1

$$V_{pr,b1} = \frac{M_{pr}^{-}{}_{b1} + M_{pr}^{+}{}_{b1}}{L_{n,b1}} = \frac{211434283.3 + 132104047}{3550}$$

$$= 96771.36065 \text{ N}$$

Gaya Geser Desain Balok 1

$$V_{e,b1} = V_{g,tum,b1} + V_{pr,b1} = 145120 + 96771.36065$$

$$= 241891.3607 \text{ N}$$

Gaya Geser Probable Balok 2

$$V_{pr,b2} = \frac{M_{pr}^{-}{}_{b2} + M_{pr}^{+}{}_{b2}}{L_{n,b2}} = \frac{211434283.3 + 132104047}{3550}$$

$$= 96771.36065 \text{ N}$$

Gaya Geser Desain Balok 2

$$V_{e,b2} = V_{g,tum,b2} + V_{pr,b2} = 145120 + 96771.36065$$

$$= 241891.3607 \text{ N}$$

Gaya Geser Probable Balok 3

$$V_{pr,b3} = \frac{M_{pr}^{-}{}_{b3} + M_{pr}^{+}{}_{b3}}{L_{n,b3}} = \frac{211434283.3 + 132104047}{3550}$$

$$= 96771.36065 \text{ N}$$

Gaya Geser Desain Balok 3

$$V_{e,b3} = V_{g,tum,b3} + V_{pr,b3} = 145120 + 96771.36065$$

$$= 241891.3607 \text{ N}$$

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	Company	: -
	Revision	: -

Gaya Geser Probable Balok 4 $V_{pr,b4} = \frac{M_{pr}^{-}{}_{b4} + M_{pr}^{+}{}_{b4}}{L_{n,b4}} = \frac{211434283.3 + 132104047}{3550}$

$= 96771.36065$ N

Gaya Geser Desain Balok 4 $V_{e,b4} = V_{g,tum,b4} + V_{pr,b4} = 145120 + 96771.36065$

$= 241891.3607$ N

4.2.3 Gaya Geser Kolom

Gaya Geser Kolom Gempa Arah 1+ $V_{col,1+} = \frac{\left(M_{pr}^{-}{}_{b1} + M_{pr}^{+}{}_{b2}\right) + \left(V_{e,b1} + V_{e,b2}\right) \times c_2 / 2}{L_{n,k}}$

$= 129254.1265$ N

Gaya Geser Kolom Gempa Arah 1- $V_{col,1-} = \frac{\left(M_{pr}^{+}{}_{b1} + M_{pr}^{-}{}_{b2}\right) + \left(V_{e,b1} + V_{e,b2}\right) \times c_2 / 2}{L_{n,k}}$

$= 129254.1265$ N

Gaya Geser Kolom Gempa Arah 2+ $V_{col,2+} = \frac{\left(M_{pr}^{-}{}_{b3} + M_{pr}^{+}{}_{b4}\right) + \left(V_{e,b3} + V_{e,b4}\right) \times c_1 / 2}{L_{n,k}}$

$= 129254.1265$ N

Gaya Geser Kolom Gempa Arah 2- $V_{col,2-} = \frac{\left(M_{pr}^{+}{}_{b3} + M_{pr}^{-}{}_{b4}\right) + \left(V_{e,b3} + V_{e,b4}\right) \times c1 / 2}{L_{n,k}}$

$= 129254.1265$ N

4.3 Pengecekan Kapasitas Geser Joint

Gaya Geser Joint Gempa Arah 1+ $V_{u,1+} = \left(F_{st,b1} + F_{sb,b2}\right) - V_{col,1+}$

$= 527787.5658 + 316672.5395 - 129254.1265$

$= 715205.9788 < 860625$ OK

Gaya Geser Joint Gempa Arah 1- $V_{u,1-} = \left(F_{sb,b1} + F_{st,b2}\right) - V_{col,1-}$

$= 316672.5395 + 527787.5658 - 129254.1265$

$= 715205.9788 < 860625$ OK

Gaya Geser Joint Gempa Arah 2+ $V_{u,2+} = \left(F_{st,b3} + F_{sb,b4}\right) - V_{col,2+}$

$= 527787.5658 + 316672.5395 - 129254.1265$

$= 715205.9788 < 860625$ OK

Gaya Geser Joint Gempa Arah 2- $V_{u,2-} = \left(F_{sb,b3} + F_{st,b4}\right) - V_{col,2-}$

$= 316672.5395 + 527787.5658 - 129254.1265$

$= 715205.9788 < 860625$ OK

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5 Tulangan Transversal Joint

Luas per Spasi Sengkang X Terpasang

$$\frac{A_{sh,x}}{s} = \frac{A_{v,x}}{s} = \frac{392.6991}{100} = 3.927 \text{ mm}^2/\text{mm}$$

Luas per Spasi Sengkang Y Terpasang

$$\frac{A_{sh,y}}{s} = \frac{A_{v,y}}{s} = \frac{392.6991}{100} = 3.927 \text{ mm}^2/\text{mm}$$

Lebar Inti Beton $b_c = c_1 - 2\,c_c - d_s = 360$ mm

Panjang Inti Beton $h_c = c_2 - 2\,c_c - d_s = 360$ mm

Luas Inti Beton $A_{ch} = b_c \times h_c = 129600$ mm^2

Tulangan Transversal Pengekang Perlu

(SNI 2847:2019 tabel 18.8.3.2)

(SNI 2847:2019 tabel 18.7.5.4)

$$= \begin{Bmatrix} 0.09 \times \frac{f_c'}{f_{yv}} \\ 0.3 \times \left(\frac{A_g}{A_{ch}} - 1\right) \times \frac{f_c'}{f_{yv}} \end{Bmatrix}$$

$$= \begin{Bmatrix} 0.09 \times \frac{25}{420} \\ 0.3 \times \left(\frac{202500}{129600} - 1\right) \times \frac{25}{420} \end{Bmatrix}$$

$$= \begin{Bmatrix} 0.005357 \\ 0.010045 \end{Bmatrix}$$

$$= 0.010045$$

Faktor Pengali Kebutuhan Tulangan Transversal $= 1$

(SNI 2847:2019 pasal 18.8.3.2)

Tulangan Transversal Pengekang X

$$= \frac{A_{sh,x}}{s\,h_c}$$

(SNI 2847:2019 tabel 18.7.5.4)

$= 0.010908 > 0.010045$ OK

Tulangan Transversal Pengekang Y

$$= \frac{A_{sh,y}}{s\,b_c}$$

(SNI 2847:2019 tabel 18.7.5.4)

$= 0.010908 > 0.010045$ OK

Jarak Antar Kaki Terbesar $x_x = 131.2$ mm < 350 mm OK

(SNI 2847:2019 pasal 18.7.5.2) $x_y = 131.2$ mm < 350 mm OK

Spasi Sengkang Maksimum s_{max}

(SNI 2847:2019 pasal 18.7.5.3)

$$= \begin{Bmatrix} \frac{b}{4} \\ 6\,d_b \\ 100 \le 100 + \frac{350 - x_{i,max}}{3} \le 150 \end{Bmatrix}$$

$$= \begin{Bmatrix} \frac{450}{4} \\ 6 \times 22 \\ 100 \le 100 + \frac{350 - 131.2}{3} \le 150 \end{Bmatrix}$$

$$= \begin{Bmatrix} 112.5 \\ 132 \\ 150 \end{Bmatrix}$$

*jika joint terkekang 4 balok, s_{max} = 150 mm

(SNI 2847:2019 pasal 18.8.3.2)

$= 112.5$ mm > 100 mm OK

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6 Kesimpulan

No	Parameter	Cek
1	Tinggi Joint Minimum	OK
2	Kapasitas Geser Joint	OK
3	Confinement/Kekangan Joint	OK
4	Jarak Antar Kaki Tulangan Transversal	OK
5	Spasi Tulangan Transversal	OK