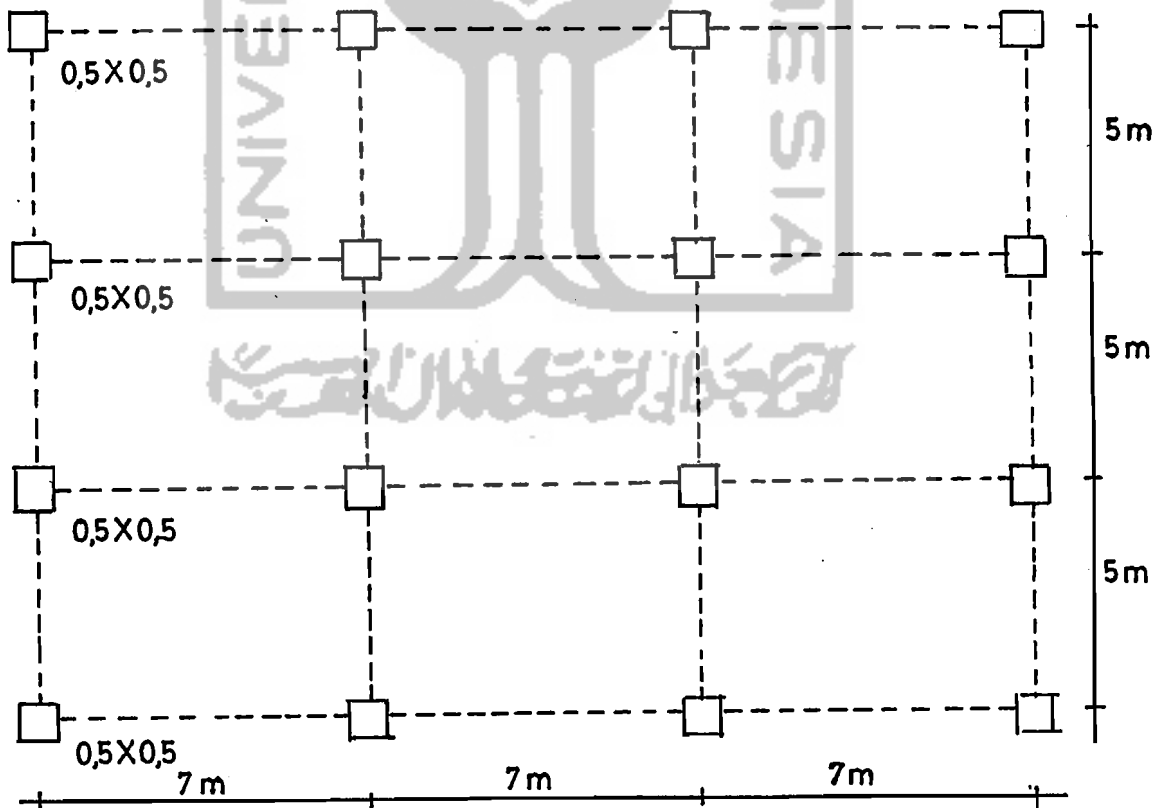


BAB IV
STUDI KASUS

4.1. Perhitungan

Diketahui salah satu denah lantai bangunan tanpa balok pemikul seperti terlihat pada gambar 4.1. Adapun beban hidup yang diterima 3,00 kPa, beban mati 0,5 kPa, tinggi lantai 3,75 m, $f_y = 400$ MPa, $f'_c = 30$ MPa, ukuran kolom 50x50 cm², bentang terdiri dari 3x3 bentang. Hitung gaya-gaya yang terjadi dengan menggunakan dua cara :

1. Cara Perencanaan Langsung (Koefisien Momen) dan
2. Cara Portal Ekuivalen.



Gambar 4.1. Denah Lantai Bangunan

4.2 Cara Perencanaan Langsung (Koefisien Momen)

Penyelesaian :

a. Menentukan tebal pelat

$$h \geq \frac{\left[0,8 + \frac{f_y}{1500} \right] l_n}{36 + 5\beta \{ \alpha_m - 0,12 (1 + 1/\beta) \}}$$

$$\beta = \frac{l_{n1}}{l_{n2}} = \frac{7000 - 1/2 \cdot 500 - 1/2 \cdot 5000}{5000 - 1/2 \cdot 500 - 1/2 \cdot 5000} = \frac{6500}{4500} = 1,444$$

$\alpha_m = 0$, karena tidak ada balok tepi,
dipilih salah satu dari dua persamaan di bawah ini:

$$h \geq \frac{\left[0,8 + \frac{f_y}{1500} \right] l_n}{36 + 9\beta} \quad \text{atau} \quad h \leq \frac{\left[0,8 + \frac{f_y}{1500} \right] l_n}{36}$$

dengan memperhatikan panjang bentang, maka dipilih persamaan

$$h \leq \frac{\left[0,8 + \frac{f_y}{1500} \right] l_n}{36}$$

$$h \leq \frac{\left[0,8 + \frac{400}{1500} \right] 6500}{36} = 192,5 \text{ mm}$$

Karena tidak menggunakan balok tepi, maka harus di tambah 10%, sehingga $h = 211,75$ diambil $h = 210 \text{ mm}$.

b. Periksa batasan penggunaan cara koefisien momen

Nilai banding bentang panjang terhadap pendek,

$$\frac{l_1}{l_2} = \frac{7}{5} = 1,4 < 2 \quad \dots\dots\dots \text{OK}$$

Bentang dari masing - masing arah 3 OK

Perbandingan beban hidup terhadap beban mati < 3

$$\text{beban hidup} = 3 \text{ kPa}$$

$$\text{beban mati} = 0,21.23 \text{ kPa}$$

$$\frac{\text{beban hidup}}{\text{beban mati}} = \frac{3 + \frac{0,5}{3} \text{ kPa}}{5,33} = 0,563 < 3 \dots\dots \text{OK}$$

Selisih panjang bentang panjang terhadap bentang pendek tidak boleh lebih dari sepertiga pajang bentang panjang,

$$l_1 - l_2 < 1/3 l_1$$

$$7000 - 5000 < 1/3 7000$$

$$2000 < 2333 \dots\dots\dots \text{Ok}$$

c. Beban rencana terhadap syarat kekuatan dan laik lakai

$$\begin{aligned} W_u &= 1,2W_D + 1,6W_L \\ &= 1,2 \cdot 5,33 + 1,6 \cdot 3 \\ &= 11,196 \text{ kPa} \end{aligned}$$

d. Perhitungan momen statis total

$$l_{n1} \text{ (arah memanjang)} = 7000 - 1/2 \cdot 500 - 1/2 \cdot 500 = 6500 \text{ mm}$$

$$l_{n2} \text{ (arah memendek)} = 5000 - 1/2 \cdot 500 - 1/2 \cdot 500 = 4500 \text{ mm}$$

Arah memanjang

$$\begin{aligned} M_o &= 1/8 W_u l_2 (l_{n1})^2 \\ &= 1/8 \cdot 11,196 \cdot 5 \cdot (6,5)^2 \\ &= 295,644 \text{ kNm} \end{aligned}$$

Pembagian momen pada bentang akhir

momen rencana negatif interior

$$\begin{aligned} M_u &= 0,7 M_o \\ &= 0,7 \cdot 295,644 = 206,95 \text{ kNm} \end{aligned}$$

momen rencana positif

$$\begin{aligned} M_u &= 0,52 M_o \\ &= 0,52 \cdot 295,644 = 153,735 \text{ kNm} \end{aligned}$$

momen rencana negatif eksterior

$$\begin{aligned} M_u &= 0,26 M_o \\ &= 0,26 \cdot 295,644 = 76,867 \text{ kNm} \end{aligned}$$

Pembagian momen rencana pada bentang dalam

momen rencana negatif

$$\begin{aligned} M_u &= 0,65 M_o \\ &= 0,65 \cdot 295,644 = 192,169 \text{ kNm} \end{aligned}$$

momen rencana positif

$$\begin{aligned} M_u &= 0,35 M_o \\ &= 0,35 \cdot 295,644 = 103,475 \text{ kNm} \end{aligned}$$

Pembagian momen rencana pada jalur kolom

Karena tidak ada balok sehingga $\beta_c=0$ dan $\alpha_1=0$, sehingga momen-momennya,

momen rencana negatif interior (dari tabel 3.2)

$$\begin{aligned} M_u &= 75 \% \cdot 206,95 \\ &= 155,213 \text{ kNm} \end{aligned}$$

momen rencana negatif eksterior (dari tabel 3.3)

$$\begin{aligned} M_u &= 100 \% \cdot 76,867 \\ &= 76,867 \text{ kNm} \end{aligned}$$

momen rencana positif (dari tabel 3.4)

$$\begin{aligned} M_u &= 60 \% \cdot 153,735 \\ &= 92,241 \text{ kNm} \end{aligned}$$



Pembagian momen rencana pada jalur tengah

momen rencana negatif interior

$$\begin{aligned} M_u &= 206,95 - 155,213 \\ &= 51,737 \text{ kNm} \end{aligned}$$

momen rencana positif

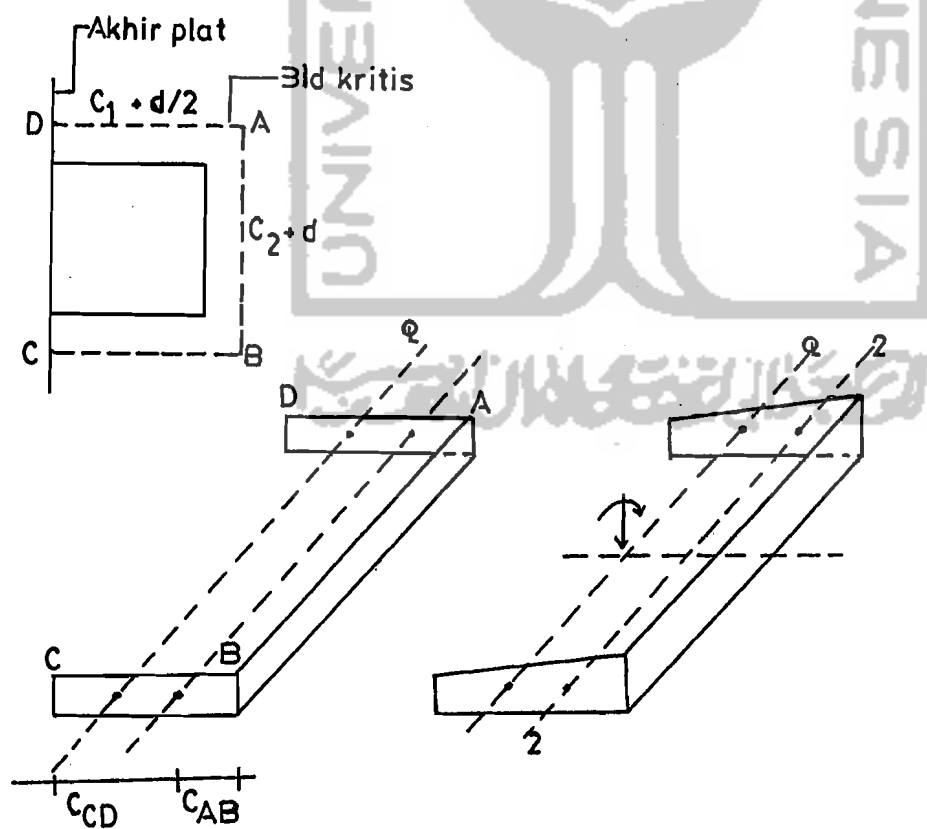
$$\begin{aligned} M_u &= 153,735 - 92,241 \\ &= 61,494 \text{ kNm} \end{aligned}$$

momen rencana negatif eksterior

$$\begin{aligned} M_u &= 76,867 - 76,867 \\ &= 0 \end{aligned}$$

e. Perhitungan Gaya Geser

Kolom Eksterior



Gambar 4.2. kolom eksterior yang mengalami geser

$$t = 210 \text{ mm} \qquad a = C_1 + d/2$$

$$d = 210 - 20 = 190 \text{ mm} \qquad b = C_2 + d$$

$$\begin{aligned} b_o &= 2 (C_1 + d/2) + (C_2 + d) \\ &= 2 (500 + 190/2) + (500 + 190) \\ &= 1880 \text{ mm} \end{aligned}$$

Luas permukaan bidang geser

$$\begin{aligned} A_c &= b_o d \\ &= 1880 \cdot 190 \\ &= 357200 \text{ mm}^2 \end{aligned}$$

Jarak titik berat penampang kritis

$$\begin{aligned} C_{AB} &= \frac{2 (C_1 + d/2) d \cdot 1/2 (C_1 + d/2)}{A_c} \\ C_{AB} &= \frac{d (C_1 + d/2)^2}{A_c} \\ &= \frac{190 (500 + 190)^2}{375200} = 188 \text{ mm} \end{aligned}$$

Jarak muka kolom ke titik berat penampang kritis

$$\begin{aligned} S &= C_{AB} - 1/2 d \\ &= 188 - 1/2 \cdot 190 = 93 \text{ mm} \end{aligned}$$

Momen Inersi

$$\begin{aligned} J_c &= d [2/3 a^3 - (2a + b) (C_{AB})^2] + 1/6 a d^3 \\ &= 190 [2/3 (595)^3 - (2 \cdot 595 + 690) (188)^2] + 1/6 \cdot 595 \\ &\quad (190)^3 \\ &= 190 [14042916,7 - 66446720] + 680184167 \\ &= 14736991600 \text{ mm}^4 \end{aligned}$$

Gaya geser netto terfaktor keliling

$$\begin{aligned} V &= 1/2 l_2 l_1 W_u \\ &= 0,5 \cdot 5,7 \cdot 11,196 \\ &= 195,93 \text{ kN} \end{aligned}$$

Gaya geser yang terjadi pada muka kolom

$$\begin{aligned} V_{mk} &= 195,93 - \frac{(M_{ex} - M_{in})}{l_n} \\ &= 195,93 - \frac{(206,95 - 76,867)}{6,5} \\ &= 175,917 \text{ kN} \end{aligned}$$

Gaya geser yang terjadi sumbu kolom

$$\begin{aligned} V_u &= 175,917 + 5 \cdot 0,5 \cdot 11,196 \\ &= 203,907 \text{ kN} \end{aligned}$$

Momen pada sumbu kolom

$$\begin{aligned} M &= -76,867 - \left[\frac{175,917 - 189,912}{2} \right] \cdot 0,25 \\ &= -122,296 \text{ kNm} \end{aligned}$$

Momen pada titik berat geser

$$\begin{aligned} M_u &= -0,093 \left[\frac{(11,196 (0,500 - 0,188) + 2 \cdot 175,917)}{2} \right] - \\ &\quad 76,867 \\ &= -17,406 - 76,867 \\ &= -94,273 \text{ kNm} \end{aligned}$$

Kuat momen tak seimbang minimum yang diperlukan

$$M_n = \frac{M_u}{\phi} = \frac{94,273}{0,85} = 110,909 \text{ kNm}$$

Kuat momen nominal M_n yang dilimpahkan oleh geser

$$\tau_v = 1 - \frac{1}{1 + 2/3 \sqrt{b_1/b_2}} \quad \text{di mana } \begin{matrix} b_1 = C_1 + 1/2 d \\ b_2 = C_2 + d \end{matrix}$$

$$= 1 - \frac{1}{1 + 2/3 \sqrt{595/690}} = 0,382$$

$$M_{nv} = 0,382 \cdot 110,909 = 42,367 \text{ kNm}$$

Kombinasi geser akibat beban vertikal dan transfer momen

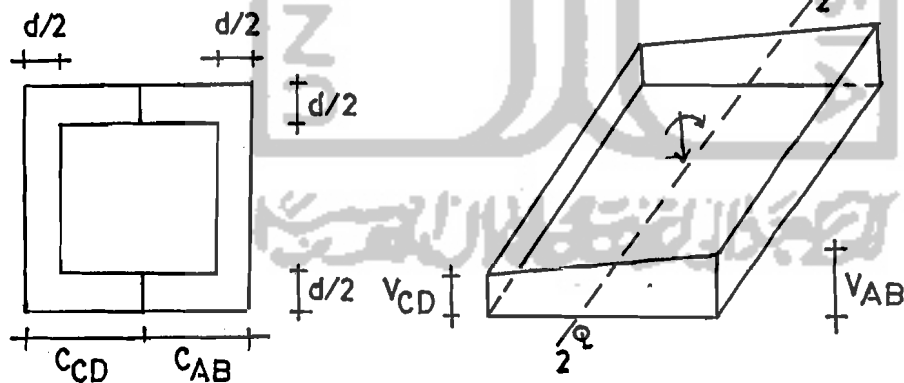
$$v_n = \frac{V_u}{\phi A_c} \pm \frac{\tau_v M_n C_{AB}}{J_c}$$

$$= \frac{181,425 \cdot 10^3}{0,85 \cdot 357200} \pm \frac{0,382 \cdot 110,909 \cdot 188 \cdot 10^6}{14736991600}$$

$$v_{n1} = 1,138 \text{ MPa}$$

$$v_{n2} = 0,057 \text{ MPa}$$

Kolom interior



Gambar 4.3. Kolom interior yang mengalami geser

$$t = 210 \text{ mm}$$

$$a = C_1 + d$$

$$C_1 = C_2$$

$$d = 210 - 20 = 190 \text{ mm}$$

$$b = C_2 + d$$

$$a = b$$

$$b_o = 2 (C_1 + d) + (C_2 + d)$$

$$\begin{aligned}
 A_c &= [2 (C_1 + d) + (C_2 + d)] d ; \text{ di mana } C_1 = C_2 \\
 &= 2 d (2C_1 + 2d) \\
 &= 2 \cdot 190 (2 \cdot 500 + 2 \cdot 190) \\
 &= 524400 \text{ mm}^2
 \end{aligned}$$

Jarak titik berat penampang kritis

Karena simetris maka jatuh di tengah-tengah

$$\begin{aligned}
 C_{AB} &= 1/2 (C_1 + d) \\
 &= 1/2 (500 + 190) = 345 \text{ mm}
 \end{aligned}$$

Momen Inersi

$$\begin{aligned}
 J_o &= d (1/6 a^3 + 1/2 a^3) + 1/6 a d^3 \\
 &= 190 [1/6 (690)^3 + 1/2 (690)^3] + 1/6 \cdot 690 (190)^3 \\
 &= 190 [41611140000 + 788785000] \\
 &= 42399925000 \text{ mm}^4
 \end{aligned}$$

Gaya geser netto terfaktor keliling

$$\begin{aligned}
 V_u &= l_1 l_2 W_u \\
 &= 5 \cdot 7 \cdot 11,196 \\
 &= 391,86 \text{ kN}
 \end{aligned}$$

Geser yang terjadi pada sumbu kolom

$$\begin{aligned}
 V &= 391,86 + \frac{(M_{\text{max}} - M_{\text{min}})}{l_n} \\
 &= 391,86 + \frac{(206,95 - 76,867)}{6,5} \\
 &= 411,873 \text{ kN}
 \end{aligned}$$

Momen akibat pembebanan plat

$$\begin{aligned}
 M &= 0,07 [(W_d + 0,5 W_1) l_2 (l_n)^2 - W_d' l_2' (l_n')^2] \\
 \text{di mana } - W_d &= W_d' = 1,2 \cdot 5,33 \\
 &= 6,393 \text{ kPa}
 \end{aligned}$$

$$W_1 = 1,63$$

$$= 4,8 \text{ kPa}$$

$$l_2 = 7 \text{ m} ; l_n = 6,5 \text{ m}$$

$$l_2' = 5 \text{ m} ; l_n' = 4,5 \text{ m}$$

$$M = 0,07 [(6,393 + 0,5 \cdot 4,8) \cdot 7 \cdot (6,5)^2 - 6,393 \cdot 5 \cdot (4,5)^2]$$

$$= 0,07 [2601,417 - 647,595]$$

$$= 136,768 \text{ kNm}$$

Kuat momen nominal M_n yang dilimpahkan oleh geser

$$\tau_v = 1 - \frac{1}{1 + 2/3 \sqrt{b_1/b_2}} \quad \text{di mana } \begin{matrix} b_1 = C_1 + d \\ b_2 = C_2 + d \end{matrix}$$

$$= 1 - \frac{1}{1 + 2/3 \sqrt{690/690}} = 0,4$$

$$M_{nv} = 0,4 \cdot 136,768$$

$$= 54,707 \text{ kNm}$$

Kombinasi geser dan akibat transfer momen

$$v_n = \frac{V}{\theta A_c} + \frac{\tau_v M_n x}{\theta J_c}$$

$$= \frac{411,873 \cdot 10^3}{0,85 \cdot 524400} \pm \frac{0,4 \cdot 136,768 \cdot 395 \cdot 10^6}{0,85 \cdot 42399925000}$$

$$v_{n1} = 1,524 \text{ MPa}$$

$$v_{n2} = 0,324 \text{ MPa}$$

Pelat sepanjang 7m, luas bidang geser sejarak d dari muka kolom

$$A_d = 7 \cdot 0,19 = 1,33 \text{ m}^2$$

$$V_d = (0,5 \cdot 11,196 \cdot 5 \cdot 6,5 + 20,013 - (11,196 \cdot 5 \cdot 0,19))$$

$$= 201,945 - 10,636 = 191,312 \text{ kN}$$



Momen pada sumbu kolom

$$M = -206,95 - \left[\frac{201,945 + 201,945 + 5 \cdot 0,25 \cdot 11,196}{2} \right] \cdot 0,25$$

$$= 215,945 \text{ kNm}$$

Gaya geser pada sumbu kolom (akibat bentang akhir)

$$= 201,945 + 5 \cdot 0,25 \cdot 11,196$$

$$V = 215,945 \text{ kN}$$

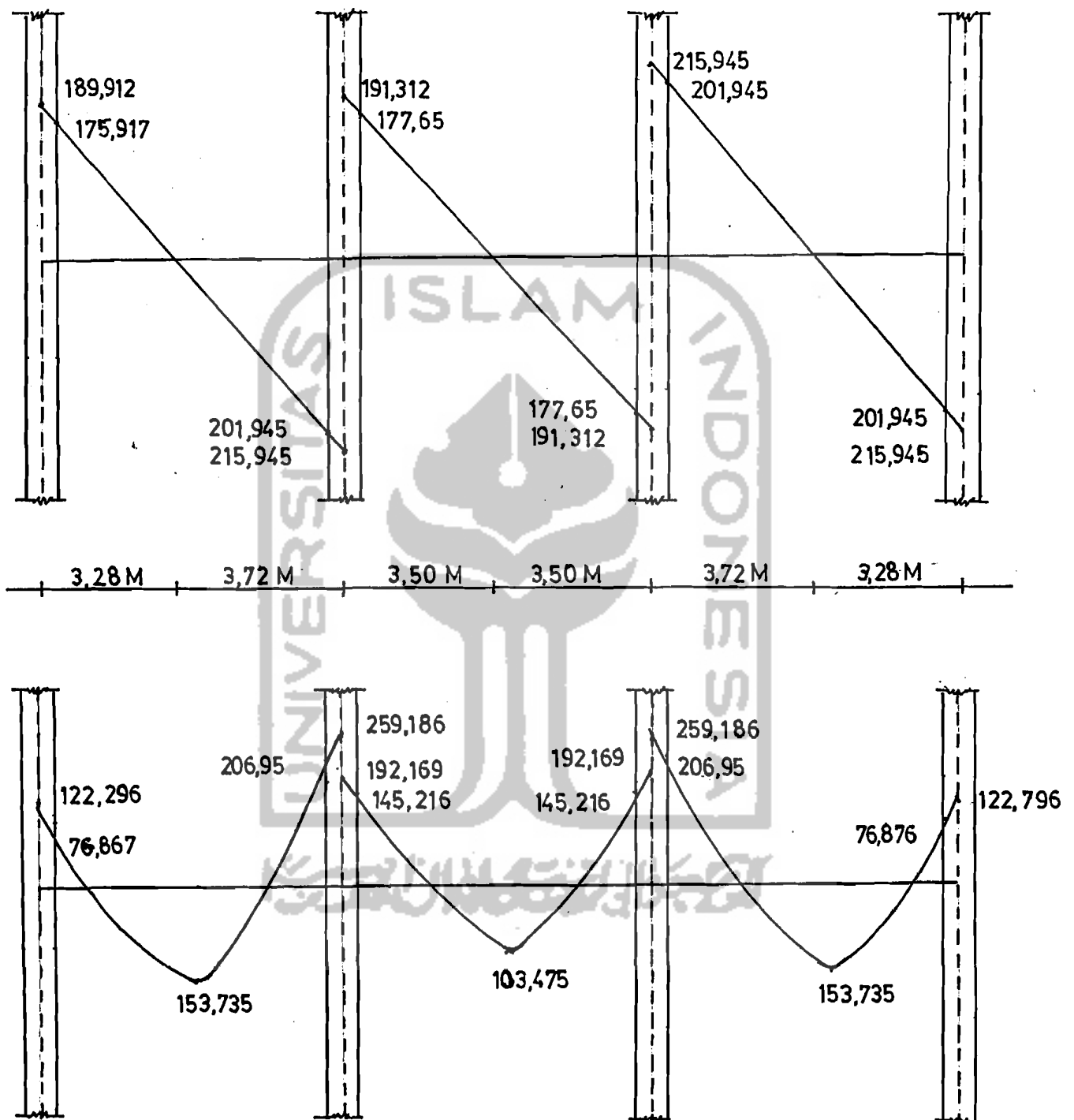
Gaya geser total pada sumbu kolom

$$V = 215,945 + 11,196 \cdot 0,5 \cdot 7,5$$

$$= 411,875 \text{ kN}$$

Daftar 4.1 Distribusi Momen

Lokasi	Momen arah memanjang kNm		
	momen negatif interior	momen positif lapangan	momen negatif eksterior
bentang akhir	206,95	153,735	76,867
jalur kolom	75% 206,95 155,213	60% 153,735 92,241	100% 76,867 76,867
jalur tengah	25% 206,95 51,738	40% 153,735 61,494	-



Gambar 4.4. Gaya lintang dan momen bentang panjang

Arah memendek Bangunan

$$M_o = 1/8 W_u l_1 (l_{n2})^2$$

$$= 1/8 11,196 7 (4,5)^2 = 198,379 \text{ kNm}$$

Pembagian momen pada bentang akhir

momen rencana negatif interior

$$M_u = 0,7 M_o$$

$$= 0,7 198,379 = 138,865 \text{ kNm}$$

momen rencana positif

$$M_u = 0,52 M_o$$

$$= 0,52 198,379 = 103,157 \text{ kNm}$$

momen rencana negatif eksterior

$$M_u = 0,26 M_o$$

$$= 0,26 198,379 = 51,579 \text{ kNm}$$

Pembagian momen rencana pada bentang dalam

momen rencana negatif

$$M_u = 0,65 M_o$$

$$= 0,65 198,379 = 128,946 \text{ kNm}$$

momen rencana positif

$$M_u = 0,35 M_o$$

$$= 0,35 198,379 = 69,433 \text{ kNm}$$

Pembagian momen rencana pada jalur kolom

Karena tidak ada balok sehingga $\beta_c=0$ dan $\alpha_1=0$,

momen rencana negatif interior (dari tabel 3.2)

$$M_u = 75 \% 138,865$$

$$= 104,149 \text{ kNm}$$

momen rencana negatif eksterior (dari tabel 3.3)

$$\begin{aligned} M_u &= 100 \% 51,579 \\ &= 51,579 \text{ kNm} \end{aligned}$$

momen rencana positif (dari tabel 3.4)

$$\begin{aligned} M_u &= 60 \% 103,157 \\ &= 61,894 \text{ kNm} \end{aligned}$$

Pembagian momen rencana pada jalur tengah

momen rencana negatif interior

$$\begin{aligned} M_u &= 138,865 - 104,149 \\ &= 34,716 \text{ kNm} \end{aligned}$$

momen rencana positif

$$\begin{aligned} M_u &= 103,157 - 61,894 \\ &= 41,263 \text{ kNm} \end{aligned}$$

momen rencana negatif eksterior

$$M_u = 51,579 - 51,579 = 0$$

Perhitungan gaya geser

Kolom Eksterior

$$t = 210 \text{ mm} \quad a = C_1 + d/2$$

$$d = 210 - 20 = 190 \text{ mm} \quad b = C_2 + d$$

$$\begin{aligned} b_o &= 2 (C_1 + d/2) + (C_2 + d) \\ &= 2 (500 + 190/2) + (500 + 190) \\ &= 1880 \text{ mm} \end{aligned}$$

Luas permukaan bidang geser

$$\begin{aligned} A_c &= b_o d \\ &= 1880 \cdot 190 \\ &= 357200 \text{ mm}^2 \end{aligned}$$



Jarak titik berat penampang kritis

$$C_{AB} = \frac{2 (C_1 + d/2) d 1/2 (C_1 + d/2)}{Ac}$$

$$C_{AB} = \frac{d (C_1 + d/2)^2}{Ac}$$

$$= \frac{190 (500 + 190)^2}{357200} = 188 \text{ mm}$$

Jarak muka kolom ke titik berat penampang kritis

$$S = C_{AB} - 1/2 d$$

$$= 188 - 1/2 190 = 93 \text{ mm}$$

Momen Inersi

$$J_c = d [2/3 a^3 - (2a + b) (C_{AB})^2] + 1/6 a d^3$$

$$= 190 [2/3 (595)^3 - (2 \cdot 595 + 690) (188)^2] + 1/6 \cdot 190 \cdot (190)^3$$

$$= 190 [14042916,7 - 66446720] + 680184167$$

$$= 14736991600 \text{ mm}^4$$

Gaya geser netto terfaktor keliling

$$V = 1/2 l_2 l_1 W_u$$

$$= 0,5 \cdot 5,7 \cdot 11,196$$

$$= 195,93 \text{ kN}$$

Gaya geser yang terjadi pada muka kolom

$$V_{mk} = 195,93 - \frac{(M_{ex} - M_{in})}{l_n}$$

$$= 195,93 - \frac{(138,865 - 51,579)}{4,5}$$

$$= 176,533 \text{ kN}$$

Gaya geser yang terjadi pada sumbu kolom

$$\begin{aligned} V_u &= 176,533 + 7 \cdot 0,5 \cdot 11,196 \\ &= 215,719 \text{ kN} \end{aligned}$$

Momen pada sumbu kolom

$$\begin{aligned} M &= -51,579 - \left[\frac{176,533 - 196,126}{2} \right] \cdot 0,25 \\ &= -98,161 \text{ kNm} \end{aligned}$$

Momen pada titik berat geser

$$\begin{aligned} M_u &= -51,579 - \left[\frac{(11,196 (0,500 - 0,188) + 2 \cdot 176,533)}{2} \right] \\ &\quad \cdot 0,093 \\ &= -51,579 - 17,825 \\ &= -69,404 \text{ kNm} \end{aligned}$$

Kuat momen tak seimbang minimum yang diperlukan

$$M_n = \frac{M_u}{\phi} = \frac{69,404}{0,85} = 81,652 \text{ kNm}$$

Kuat momen nominal M_n yang dilimpahkan oleh geser

$$\begin{aligned} \tau_v &= 1 - \frac{1}{1 + 2/3 \sqrt{b_1/b_2}} \quad \text{di mana } \begin{aligned} b_1 &= C_1 + 1/2 d \\ b_2 &= C_2 + d \end{aligned} \\ &= 1 - \frac{1}{1 + 2/3 \sqrt{595/690}} = 0,382 \end{aligned}$$

$$M_{nv} = 0,382 \cdot 81,652 = 31,191 \text{ kNm}$$

Kombinasi geser akibat beban vertikal dan transfer momen

$$v_n = \frac{V_u}{\phi A_c} \pm \frac{\tau_v M_n C_{AB}}{J_c}$$

$$= \frac{215,719 \cdot 10^3}{0,85 \cdot 357200} \pm \frac{0,382 \cdot 69,404 \cdot 188 \cdot 10^6}{0,85 \cdot 14736991600}$$

$$v_{n1} = 1,108 \text{ MPa}$$

$$v_{n2} = 0,313 \text{ MPa}$$

Kolom interior

$$t = 210 \text{ mm} \quad ; \quad a = C_1 + d \quad C_1 = C_2$$

$$d = 210 - 20 = 190 \text{ mm} \quad b = C_2 + d \quad a = b$$

$$b_o = 2 (C_1 + d) + (C_2 + d)$$

$$A_c = [2 (C_1 + d) + (C_2 + d)] d \quad \text{di mana } C_1 = C_2$$

$$= 2 d (2C_1 + 2d)$$

$$= 2 \cdot 190 (2 \cdot 500 + 2 \cdot 190)$$

$$= 524400 \text{ mm}^2$$

Jarak titik berat penampang kritis

Karena simetris maka jatuh di tengah-tengah

$$C_{AB} = 1/2 (C_1 + d)$$

$$= 1/2 (500 + 190)$$

$$= 345 \text{ mm}$$

Momen Inersi

$$J_c = d (1/6 a^3 + 1/2 a^3) + 1/6 a d^3$$

$$= 190 [1/6 (690)^3 + 1/2 (690)^3] + 1/6 \cdot 690 (190)^3$$

$$= 190 [41611140000 + 788785000]$$

$$= 42399925000 \text{ mm}^4$$

Gaya geser netto terfaktor keliling

$$V_u = l_1 l_2 W_u$$

$$= 5 \cdot 7 \cdot 11,196 = 391,86 \text{ kN}$$



Geser yang terjadi pada sumbu kolom

$$\begin{aligned}
 V &= 391,86 + \frac{(M_{\text{ex}} - M_{\text{in}})}{l_n} \\
 &= 391,86 + \frac{(51,579 - 138,865)}{4,5} \\
 &= 411,257 \text{ kN}
 \end{aligned}$$

Momen akibat pembebanan plat

$$M = 0,07 [(W_d + 0,5 W_1) l_2 (l_n)^2 - W_d' l_2' (l_n')^2]$$

$$\begin{aligned}
 \text{di mana } - W_d &= W_d' = 1,2 \cdot 5,33 \\
 &= 6,393 \text{ kPa}
 \end{aligned}$$

$$\begin{aligned}
 W_1 &= 1,6 \cdot 3 \\
 &= 4,8 \text{ kPa}
 \end{aligned}$$

$$l_2 = 5 \text{ m} ; l_n = 4,5 \text{ m}$$

$$l_2' = 7 \text{ m} ; l_n' = 6,5 \text{ m}$$

$$\begin{aligned}
 M &= 0,07 [(6,393 + 0,5 \cdot 4,8) 5 (4,5)^2 - 6,393 \cdot 7 (6,5)^2] \\
 &= 0,07 [890,595 - 1891,617] \\
 &= 70,071 \text{ kNm}
 \end{aligned}$$

Kuat momen nominal M_n yang dilimpahkan oleh geser

$$\begin{aligned}
 \tau_v &= 1 - \frac{1}{1 + 2/3 \sqrt{b_1/b_2}} \quad \text{di mana } \begin{matrix} b_1 = C_1 + d \\ b_2 = C_2 + d \end{matrix} \\
 &= 1 - \frac{1}{1 + 2/3 \sqrt{690/690}} = 0,4
 \end{aligned}$$

$$\begin{aligned}
 M_{nv} &= 0,4 \cdot 70,071 \\
 &= 28,029 \text{ kNm}
 \end{aligned}$$

Kombinasi geser dan akibat transfer momen

$$v_n = \frac{V}{\theta A_c} + \frac{\tau_v M_n x}{\theta J_c}$$

$$= \frac{411,257 \cdot 10^3}{0,85 \cdot 524400} \pm \frac{0,4 \cdot 70,071 \cdot 395 \cdot 10^6}{0,85 \cdot 42399925000}$$

$$v_{n1} = 1,23 \text{ MPa}$$

$$v_{n2} = 0,615 \text{ MPa}$$

Pelat sepanjang 5 m, luas bidang geser sejajar d dari muka kolom

$$A_d = 5 \cdot 0,19 = 0,95 \text{ m}^2$$

$$V_d = (0,5 \cdot 11,196 \cdot 4,5 \cdot 7 + 19,397 - (11,196 \cdot 7 \cdot 0,19))$$

$$= 195,734 - 14,891 = 180,843 \text{ kN}$$

Momen pada sumbu kolom

$$M = -138,95 - \left[\frac{195,734 + 195,734 + 7 \cdot 0,25 \cdot 11,196}{2} \right] \cdot 0,25$$

$$= -190,248 \text{ kNm}$$

Gaya geser pada sumbu kolom (akibat bentang akhir)

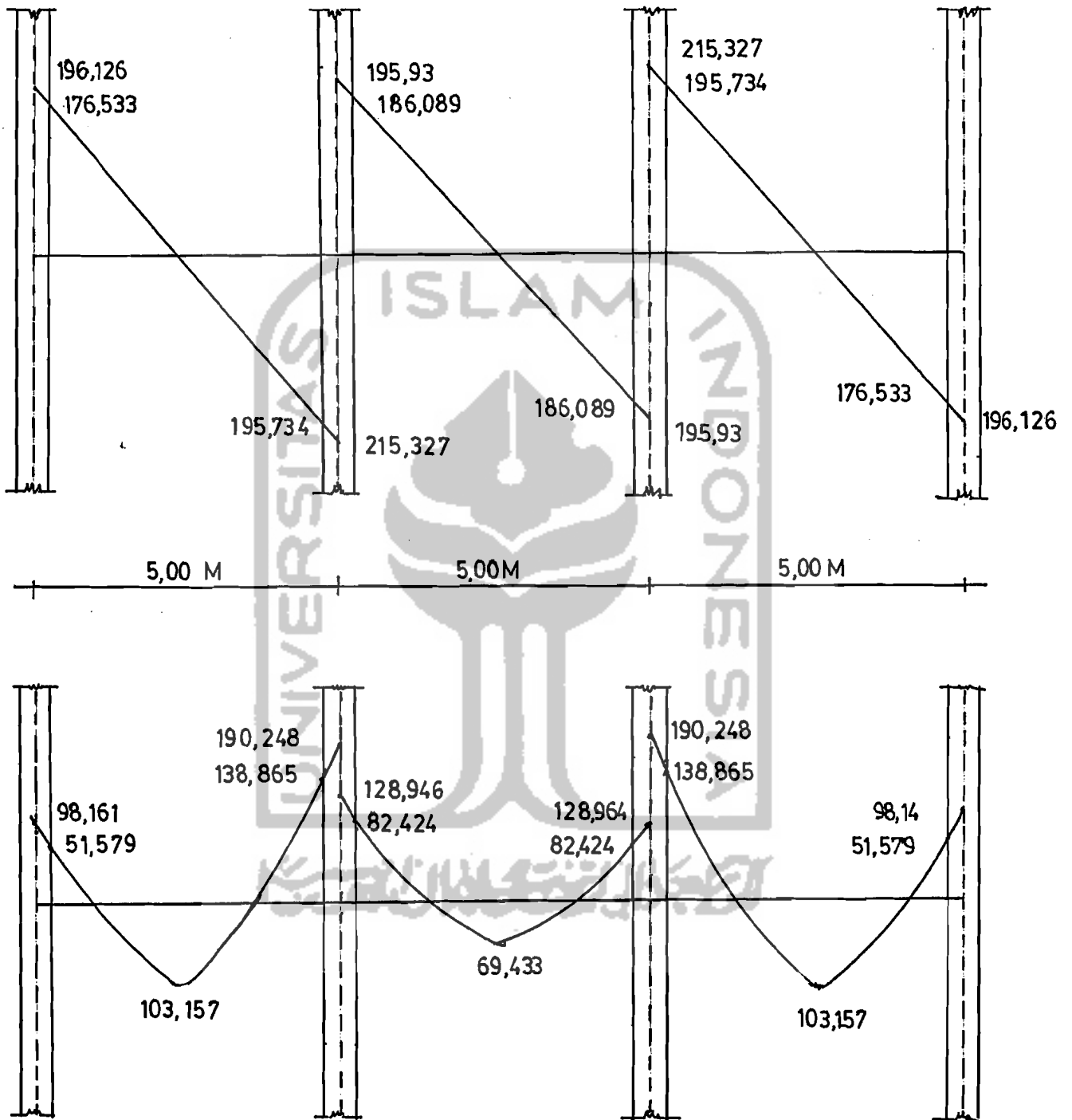
$$V = 195,734 + 7 \cdot 0,25 \cdot 11,196 \text{ N}$$

$$V = 215,327 \text{ kN}$$

Daftar 4.2. Distribusi Momen

Lokasi	Momen arah memendek kNm		
	momen negatif interior	momen positif lapangan	momen negatif eksterior
bentang akhir	138,865	103,157	51,867
jalur kolom	75% 138,865 155,213	60% 103,157 92,241	100% 51,867 51,867
jalur tengah	25% 138,865 34,716	40% 103,157 41,263	-





Gambar 4.5 Gaya lintang dan momen bentang pendek.

4.3. Perhitungan Cara Portal Ekuivalen

Penyelesaian

a. Penentuan tebal pelat (sama dengan cara di atas)

b. Perhitungan kekakuan (bentang memanjang)

Kekakuan kolom (cara kolom analog)

$$\begin{aligned} \frac{K_c}{E} &= \frac{I_c}{(h-t)} \left[1 + \frac{3h^2}{(h-t)} \right] \\ &= \frac{1/12 \cdot 500 \cdot 500^3}{(3750 - 210)} \left[1 + \frac{3 \cdot 3750^2}{(3750 - 210)} \right] \\ &= 6424331 \end{aligned}$$

Kekakuan pelat (cara kolom analog)

$$\frac{K_s}{E} = \frac{1}{A_{ca}} + \frac{(1) (l_1/2)(l_1/2)}{I_{ca}}$$

$$\begin{aligned} I_s &= 1/12 \cdot l_2 \cdot t^3 \\ &= 1/12 \cdot 5000 \cdot 210^3 \\ &= 3,85875 \cdot 10^9 \text{ mm}^4 \end{aligned}$$

$$\begin{aligned} I_{sc} &= \frac{I_s}{(1 - C_2/l_2)^2} \\ &= \frac{3,85875 \cdot 10^9}{(1 - 500/5000)^2} \\ &= 4,763888889 \cdot 10^9 \text{ mm}^4 \end{aligned}$$

$$\begin{aligned} A_{ca} &= \frac{l_{n1}}{I_s} + 2 \left[\frac{C_1/2}{I_{sc}} \right] \\ &= \frac{6500}{3,85875 \cdot 10^9} + 2 \left[\frac{250}{4,763888889 \cdot 10^9} \right] \\ &= 1,789 \cdot 10^{-6} \text{ mm}^2 \end{aligned}$$

$$I_{ca} = \frac{l_1^3}{12I_{sc}} + \frac{l_{n1}^3}{12} \left[\frac{1}{I_s} - \frac{1}{I_{sc}} \right]$$

$$= \left[\frac{1}{3,85875 \cdot 10^9} - \frac{1}{4,763888889 \cdot 10^9} \right] \frac{6500^3}{12} + \frac{7000^3}{12 \cdot 4,763888889 \cdot 10^9}$$

$$= 7,127 \text{ mm}^4$$

$$\frac{K_s}{E} = \frac{1}{A_{ca}} + \frac{(l_1/2)^2}{I_{ca}}$$

$$= \frac{1}{1,789 \cdot 10^{-6}} + \frac{(7000/2)^2}{7,127}$$

$$= 2277787$$

Menentukan kekakuan kolom ekuivalen

$$\frac{E}{K_{ce}} = \frac{E}{\sum K_c} + \frac{E}{K_t}$$

$$K_t = \frac{\sum 9 E_{bs} C}{l_2 (1 - C_2/l_2)^3}$$

$$\text{di mana } C = \sum (1 - 0,63 X/Y) X^3 Y/3$$

$$= \sum (1 - 0,63 \cdot 210/500) \cdot 210^3 \cdot 500/3$$

$$= 1135089900$$

$$\frac{K_t}{E} = \frac{2,9 \cdot 1135089900}{5000 (1 - 500/5000)^3}$$

$$= 5605382$$

$$\frac{K_{ce}}{E} = \frac{2K_c}{1 + 2K_c/K_t}$$

$$= \frac{2 \ 6424331}{1 + 2 \ 6424331/5605382} = 3902758$$

c. Menentukan koefisien distribusi

$$\text{Kolom akhir} = \frac{K_s}{K_s + K_{ce}} = \frac{2277787}{2277787 + 3902758} = 0,369$$

$$\text{Kolom tengah} = \frac{K_s}{2K_s + K_{ce}} = \frac{2277787}{2 \cdot 2277787 + 3902758} = 0,269$$

d. Menentukan koefisien induksi (Carry-over faktor)

$$\text{COF} = \frac{\frac{1}{A_{ca}} \frac{(l_1/2)(l_1/2)}{I_{ca}}}{\frac{1}{A_{ca}} \frac{(l_1/2)(l_1/2)}{I_{ca}} + \frac{1}{A_{ca}} \frac{(l_2/2)(l_2/2)}{I_{ca}}} = \frac{\frac{1}{1,789 \cdot 10^{-6}} \frac{(3500)^2}{7,127}}{\frac{1}{1,789 \cdot 10^{-6}} \frac{(3500)^2}{7,127} + \frac{1}{1,789 \cdot 10^{-6}} \frac{(3500)^2}{7,127}} = \frac{-1159844,274}{2277787,263} = -0,509$$

e. Menentukan momen-momen (cara kolom analog)

$$\text{beban hidup} = 3 \cdot 1,6 = 4,8 \text{ kPa}$$

$$\text{beban mati} = 5,33 \cdot 1,2 = 6,396 \text{ kPa}$$

$$\underline{11,196 \text{ kPa}}$$

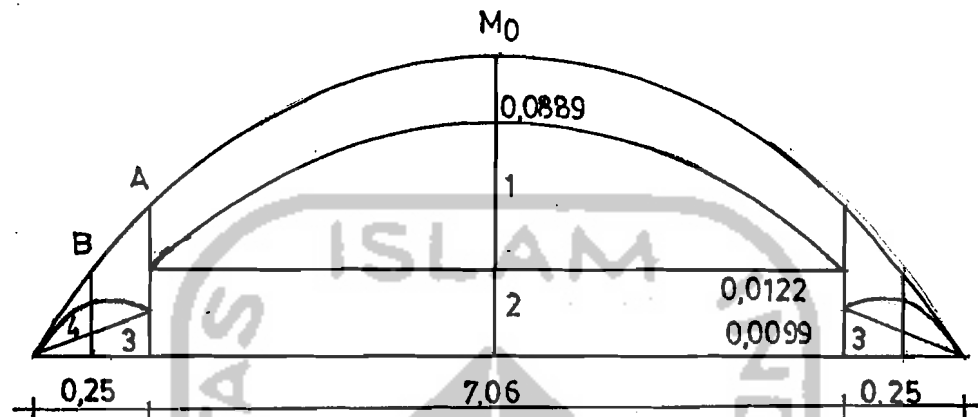
Untuk bentang sepanjang 5 m

$$q = 11,196 \cdot 5 = 55,98 \text{ kN/m}$$

$$M_{ou} = 1/8 \cdot q \cdot l^2$$

$$= 1/8 \cdot 55,98 \cdot 7^2 = 342,8775 \text{ kNm}$$

$$= 342877500 \text{ Nmm}$$



Gambar 4.5 Pembagian momen

$$\text{Didapat : } \frac{M_{uo}}{I_s} = \frac{342877500}{3,85875 \cdot 10^9} = 0,0889$$

$$\begin{aligned} \text{Titik A : } M_A &= 0,5 q x (1 - x) \\ &= 0,5 \cdot 55,96 \cdot 0,25 (7 - 0,25) \\ &= 47,233125 \text{ kNm} = 47233125 \text{ Nmm} \end{aligned}$$

$$\frac{M_A}{I_s} = \frac{47233125}{3,85875 \cdot 10^9} = 0,0122$$

$$\frac{M_A}{I_{sc}} = \frac{47233125}{4763888889} = 0,0099$$

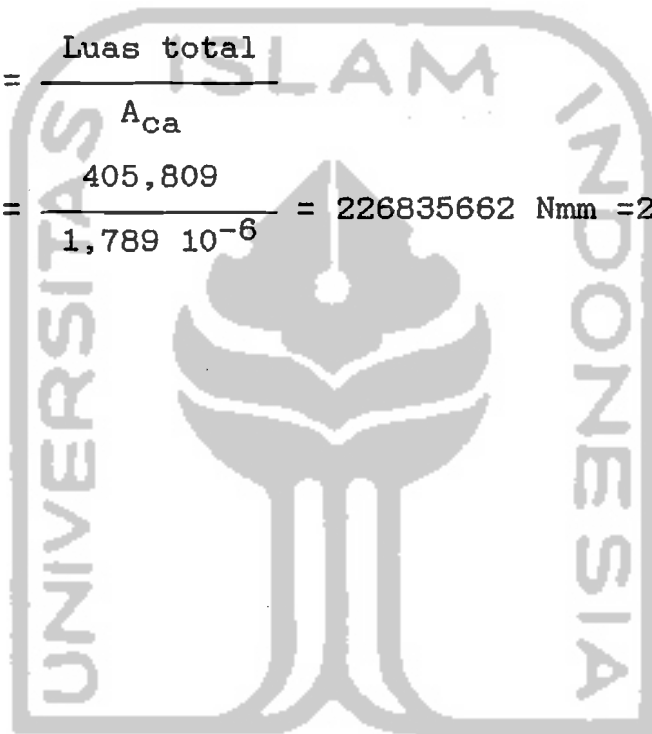
$$\begin{aligned} \text{Titik B : } M_B &= 0,5 q \cdot 0,5 x (1 - 0,5 x) \\ &= 0,5 \cdot 55,96 \cdot 0,5 \cdot 0,25 (7 - 0,5 \cdot 0,25) \\ &= 24,053906 \text{ kNm} = 24053906 \text{ Nmm} \end{aligned}$$

$$\frac{M_B}{I_{sc}} = \frac{24053906}{4763888889} = 0,005$$

Hitung luas diagram

$$\begin{aligned}
 \text{Luas 1} &: \frac{2}{3} 6500 (0,0889 - 0,0122) = 322,367 \text{ mm}^2 \\
 \text{2} &: 6500 0,0122 = 79,3 \text{ mm}^2 \\
 \text{3} &: 2 \cdot 0,5 \cdot 250 \cdot 0,0099 = 2,475 \text{ mm}^2 \\
 \text{4} &: 2 \cdot \frac{2}{3} \cdot 250 \cdot 0,005 = 1,667 \text{ mm}^2 \\
 & \hline
 & 405,809 \text{ mm}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Momen primer} &= \frac{\text{Luas total}}{A_{ca}} \\
 &= \frac{405,809}{1,789 \cdot 10^{-6}} = 226835662 \text{ Nmm} = 226,836 \text{ kNm}
 \end{aligned}$$



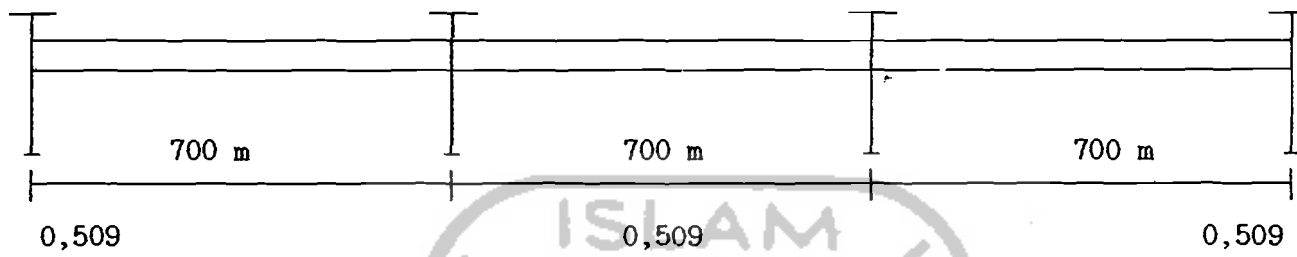
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$q : 55,98 \text{ KN/m}$

$q : 55,98 \text{ KN/m}$

$q : 55,98 \text{ KN/m}$



KOLOM	PELAT
0,631	0,369
-	226,836
-143,134	-83,702
-	-
-	-
-	5,833
-3,681	-2,152
-	0,799
-0,504	-0,295
-	0,259
-0,163	-0,096
-	0,056
-0,035	-0,021
-	0,014
-0,009	-0,005
147,519	147,519

PELAT	KOLOM	PELAT
0,269	0,462	0,269
-226,836	-	226,836
-	-	-
-42,604	-	-
11,460	19,684	11,460
-	-	-5,833
1,569	2,695	1,569
-1,095	-	-0,799
0,509	0,876	0,509
-0,150	-	-0,259
0,11	0,189	0,11
-0,049	-	-0,049
0,028	0,049	0,028
-0,011	-	-0,011
0,007	0,011	0,007
-257,061	23,496	233,565

PELAT	KOLOM	PELAT
0,269	0,462	0,269
-226,836	-	226,836
-	-	-
-	-	42,604
-11,460	-19,684	-11,460
5,833	-	-
-1,569	-2,695	-1,569
0,799	-	1,095
-0,509	-0,876	-0,509
0,259	-	0,150
-0,11	-0,189	-0,11
0,049	-	0,049
-0,028	-0,049	-0,028
0,011	-	0,011
-0,007	-0,011	-0,007
-233,565	23,496	257,061

PELAT	KOLOM
0,369	0,631
-226,836	-
83,702	143,134
-	-
-	-
-5,833	-
2,152	3,681
-0,799	-
0,295	0,504
-0,259	-
0,096	0,163
-0,056	-
0,021	0,035
-0,014	-
0,005	0,009
-147,519	147,519

$$\begin{array}{r}
 \begin{array}{cc}
 \left(\begin{array}{c} 55,98 \text{ kN/m} \\ \downarrow \quad \uparrow \end{array} \right) & \left(\begin{array}{c} 55,98 \text{ kN/m} \\ \downarrow \quad \uparrow \end{array} \right) \\
 \begin{array}{cc}
 147,519 & 257,061 \\
 \uparrow 195,93 & \uparrow 195,93 \\
 \downarrow 15,649 & \downarrow 15,649 \\
 \hline
 180,281 & 211,579
 \end{array} & \begin{array}{cc}
 233,565 & 233,565 \\
 \uparrow 195,93 & \uparrow 195,93 \\
 \hline
 195,93 & 195,93
 \end{array}
 \end{array} \\
 \frac{55,98 \cdot 7}{2} = 195,93 \quad ; \quad \frac{(257,061 - 147,519)}{7} = 15,649 \text{ kN}
 \end{array}$$

Menentukan momen-momen

Momen positif pada bentang akhir

$$\begin{aligned}
 \frac{x}{7-x} &= \frac{180,281}{211,579} \\
 211,579x &= 1261,967 - 180,281x \\
 391,86x &= 1261,967 \\
 x &= 3,22 \text{ m} \\
 M_x &= R_a x - 0,5 q x^2 \\
 &= 180,281 \cdot 3,22 - 0,5 \cdot 55,98 \cdot 3,22^2 \\
 &= 290,293 \text{ kNm} \\
 M_u &= M_x - 147,519 \\
 &= 290,293 - 147,519 \\
 &= 142,744 \text{ kNm}
 \end{aligned}$$

Momen negatif eksterior pada bentang akhir

$$\begin{aligned}
 x &= 0,25 \\
 M_x &= R_a x - 0,5 q x^2 \\
 &= 180,281 \cdot 0,25 - 0,5 \cdot 55,98 \cdot 0,25^2 \\
 &= 43,321 \text{ kNm} \\
 M_u &= M_x - 147,519 \\
 &= 43,321 - 147,519 \\
 &= -104,198 \text{ kNm}
 \end{aligned}$$

Momen negatif interior pada bentang akhir

$$x = 0,25$$

$$\begin{aligned} M_x &= R_a x - 0,5 q x^2 \\ &= 211,579 \cdot 0,25 - 0,5 \cdot 55,98 \cdot 0,25^2 \\ &= 51,145 \text{ kNm} \end{aligned}$$

$$\begin{aligned} M_u &= M_x - 257,061 \\ &= 205,916 \text{ kNm} \end{aligned}$$

Momen rencana pada bentang dalam

Momen rencana positif

$$x = 3,5$$

$$\begin{aligned} M_x &= R_a x - 0,5 q x^2 \\ &= 195,93 \cdot 3,5 - 0,5 \cdot 55,98 \cdot 3,5^2 \\ &= 342,878 \text{ kNm} \end{aligned}$$

$$\begin{aligned} M_u &= M_x - 233,565 \\ &= 109,313 \text{ kNm} \end{aligned}$$

Momen rencana Negatif

$$x = 0,25$$

$$\begin{aligned} M_x &= R_a x - 0,5 q x^2 \\ &= 195,93 \cdot 0,25 - 0,5 \cdot 55,98 \cdot 0,25^2 \\ &= 47,233 \text{ kNm} \end{aligned}$$

$$\begin{aligned} M_u &= M_x - 233,565 \\ &= 186,332 \text{ kNm} \end{aligned}$$

Pembagian momen rencana pada jalur kolom

Momen rencana negatif interior

$$\begin{aligned} M_u &= 75\% \cdot 205,916 \\ &= 154,437 \text{ kNm} \end{aligned}$$



Momen rencana positif

$$\begin{aligned} M_u &= 60\% 142,774 \\ &= 85,664 \text{ kNm} \end{aligned}$$

Momen rencana negatif eksterior

$$\begin{aligned} M_u &= 100\% 104,198 \\ &= 104,198 \text{ kNm} \end{aligned}$$

Pembagian momen rencana jalur tengah

Momen rencana negatif interior

$$\begin{aligned} M_u &= 205,916 - 154,437 \\ &= 51,479 \text{ kNm} \end{aligned}$$

Momen rencana positif

$$\begin{aligned} M_u &= 142,774 - 85,664 \\ &= 57,479 \text{ kNm} \end{aligned}$$

f. Perhitungan Gaya Geser

Kolom Eksterior

$$t = 210 \text{ mm} \quad ; \quad a = C_1 + d/2$$

$$d = 210 - 20 = 190 \text{ mm} \quad b = C_2 + d$$

$$\begin{aligned} b_o &= 2 (C_1 + d/2) + (C_2 + d) \\ &= 2 (500 + 190/2) + (500 + 190) \\ &= 1880 \text{ mm} \end{aligned}$$

Luas permukaan bidang geser

$$\begin{aligned} A_c &= b_o d \\ &= 1880 \cdot 190 = 357200 \text{ mm}^2 \end{aligned}$$

Jarak titik berat penampang kritis

$$C_{AB} = \frac{2 (C_1 + d/2) d \cdot 1/2 (C_1 + d/2)}{A_c}$$

$$C_{AB} = \frac{d (C_1 + d/2)^2}{A_c}$$

$$= \frac{190 (500 + 95)^2}{357200} = 188 \text{ mm}$$

Sehingga :

$$C_{CD} = 595 - C_{AB}$$

$$= 595 - 188 = 407 \text{ mm}$$

$$e = 407 - 210 = 197 \text{ mm}$$

Momen Inersi

$$J_c = d [2/3 a^3 - (2a + b) (C_{AB})^2] + 1/6 a d^3$$

$$= 190 [2/3 (595)^3 - (2 \cdot 595 + 690) (188)^2] + 1/6 \cdot 595$$

$$(190)^3$$

$$= 190 [140429917 - 66446720] + 680184167$$

$$= 14736991600 \text{ mm}^4$$

Gaya geser yang terjadi pada sumbu kolom

$$V_u = 180,281 + 5 \cdot 0,25 \cdot 11,196$$

$$= 194,276 \text{ kN}$$

Momen pada sumbu kolom

$$M_u = - (147,519 - 0,5 \cdot 5 \cdot 0,25 \cdot 11,196) + 194,276 \cdot 0,197$$

$$= - 102,249 \text{ kNm}$$

$$\tau_v = 1 - \frac{1}{1 + 2/3 \sqrt{b_1/b_2}}$$

$$= 1 - \frac{1}{1 + 2/3 \sqrt{595/690}} =$$

$$= 0,382$$

$$\text{di mana } b_1 = C_1 + 1/2 d$$

$$b_2 = C_2 + d$$

Kombinasi geser akibat beban vertikal dan transfer momen

$$v_n = \frac{V_u}{\theta A_c} \pm \frac{\tau_v M_u C_{AB}}{\theta J_c}$$

$$= \frac{194,276 \cdot 10^3}{0,85 \cdot 357200} \pm \frac{0,382 \cdot 102,249 \cdot 188 \cdot 10^6}{0,85 \cdot 14736991600}$$

$$v_{n1} = 0,698 \text{ MPa}$$

$$v_{n2} = 0,581 \text{ MPa}$$

Kolom interior

$$t = 210 \text{ mm} \quad ; \quad a = C_1 + d \quad C_1 = C_2$$

$$d = 210 - 20 = 190 \text{ mm} \quad b = C_2 + d \quad a = b$$

$$b_o = 2 (C_1 + d) + (C_2 + d)$$

$$A_c = [2 (C_1 + d) + (C_2 + d)] d \quad \text{di mana } C_1 = C_2$$

$$= 2 d (2C_1 + 2d)$$

$$= 2 \cdot 190 (2 \cdot 500 + 2 \cdot 190)$$

$$= 524400 \text{ mm}^2$$

Jarak titik berat penampang kritis

Karena simetris maka jatuh di tengah-tengah

$$C_{AB} = 1/2 (C_1 + d)$$

$$= 1/2 (500 + 190)$$

$$= 345 \text{ mm}$$

Momen Inersi

$$J_c = d (1/6 a^3 + 1/2 a^3) + 1/6 a d^3$$

$$= 190 [1/6 (690)^3 + 1/2 (690)^3] + 1/6 \cdot 690 (190)^3$$

$$= 190 [41611140000 + 788785000]$$

$$= 42399925000 \text{ mm}^4$$

Geser yang terjadi pada sumbu kolom

$$\begin{aligned} V_u &= 211,59 + 195,93 \\ &= 407,509 \text{ kN} \end{aligned}$$

Momen pada sumbu kolom

$$\begin{aligned} M_u &= 257,061 - 233,565 \\ &= 23,496 \text{ kNm} \end{aligned}$$

$$\begin{aligned} \tau_v &= 1 - \frac{1}{1 + \frac{2}{3} \sqrt{b_1/b_2}} \quad \text{di mana } \begin{matrix} b_1 = C_1 + d \\ b_2 = C_2 + d \end{matrix} \\ &= 1 - \frac{1}{1 + \frac{2}{3} \sqrt{690/690}} = 0,4 \end{aligned}$$

Kombinasi geser dan akibat transfer momen

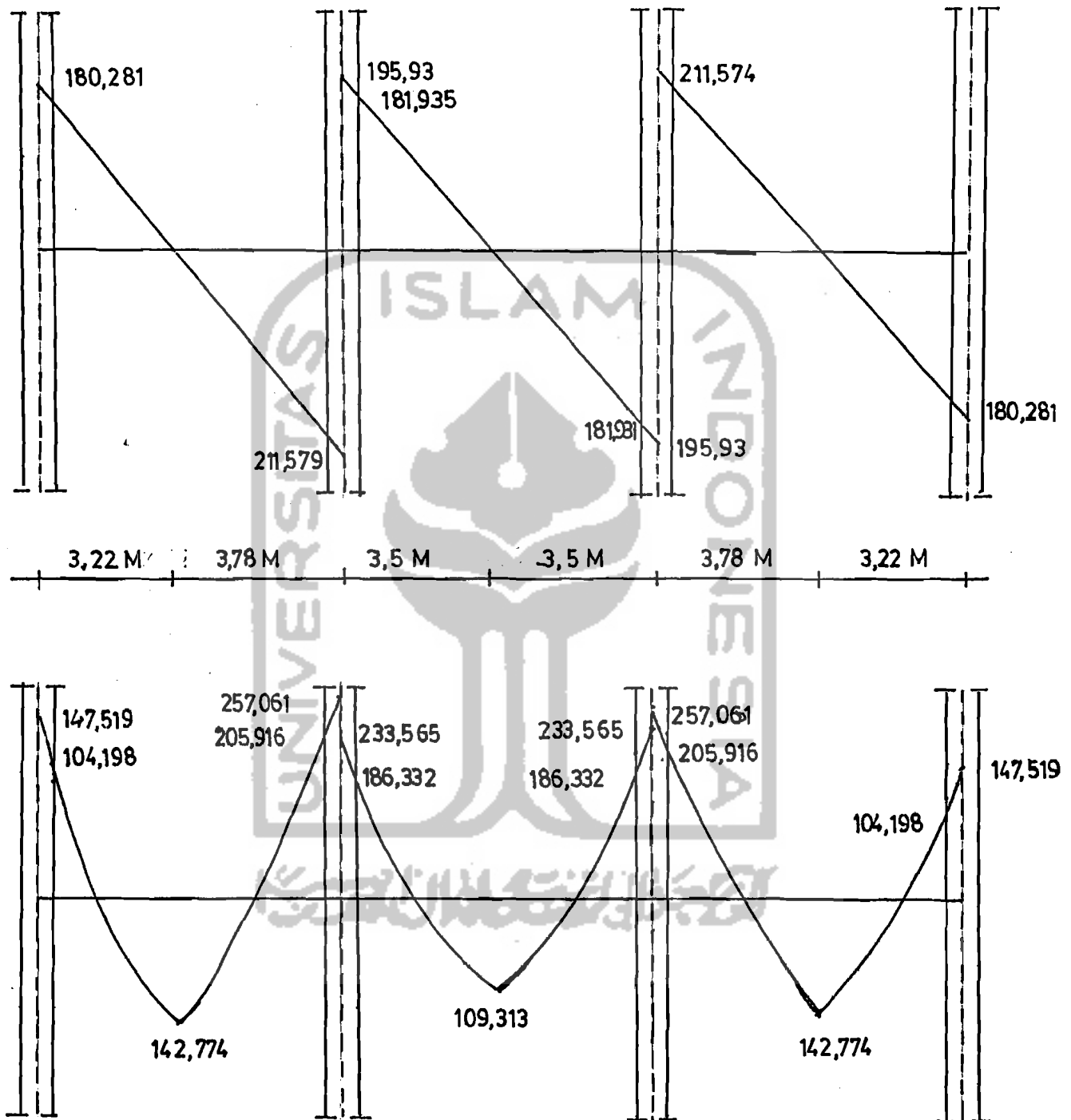
$$\begin{aligned} v_n &= \frac{V_u}{\theta A_c} + \frac{\tau_v M_u x}{\theta J_c} \\ &= \frac{407,509 \cdot 10^3}{0,85 \cdot 524400} \pm \frac{0,4 \cdot 23,496 \cdot 395 \cdot 10^6}{0,85 \cdot 42399925000} \end{aligned}$$

$$v_{n1} = 1,944 \text{ MPa}$$

$$v_{n2} = 0,116 \text{ MPa}$$

Daftar 4.3. Distribusi Momen

Lokasi	Momen arah memendek kNm		
	momen negatif interior	momen positif lapangan	momen negatif eksterior
bentang akhir	205,916	142,774	104,198
jalur kolom	75% 205,916 154,437	60% 142,774 85,664	100% 104,198 104,198
jalur tengah	25% 205,916 51,479	40% 142,774 57,11	-



Gambar 4.7 Gaya lintang dan momen bentang panjang

g. Perhitungan kekakuan (bentang memendek)

Kekakuan kolom (cara kolom analog)

$$\begin{aligned} \frac{K_c}{E} &= \frac{I_c}{(h-t)} \left[1 + \frac{3 \cdot h^2}{(h-t)} \right] \\ &= \frac{1/12 \cdot 500 \cdot 500^3}{(3750 - 210)} \left[1 + \frac{3 \cdot 3750^2}{(3750 - 210)} \right] \\ &= 6424331 \end{aligned}$$

Kekakuan pelat (cara kolom analog)

$$\begin{aligned} \frac{K_s}{E} &= \frac{1}{A_{ca}} + \frac{(1) \cdot (l_2/2) \cdot (l_2/2)}{I_{ca}} \\ I_s' &= 1/12 \cdot l_1 \cdot t^3 \\ &= 1/12 \cdot 7000 \cdot 210^3 = 5,40225 \cdot 10^9 \text{ mm}^4 \\ I_{sc} &= \frac{I_s}{(1 - C_1/l_1)^2} \\ &= \frac{5,40225 \cdot 10^9}{(1 - 500/7000)^2} = 6,26533136 \cdot 10^9 \text{ mm}^4 \\ A_{ca} &= \frac{l_n^2}{I_s} + 2 \left[\frac{C_2/2}{I_{sc}} \right] \\ &= \frac{4500}{5,40225 \cdot 10^9} + 2 \left[\frac{250}{6,26533136 \cdot 10^9} \right] \\ &= 9,12 \cdot 10^{-7} \text{ mm}^2 \\ I_{ca} &= \frac{l_2^3}{12 I_{sc}} + \frac{l_n^2}{12} \left[\frac{1}{I_s} - \frac{1}{I_{sc}} \right] \\ &= \frac{4500^3}{12} \left[\frac{1}{5,40225 \cdot 10^9} - \frac{1}{6,26533136 \cdot 10^9} \right] \end{aligned}$$

$$+ \frac{5000^3}{12 \cdot 6,26533136 \cdot 10^9} = 1,857 \text{ mm}^4$$

$$\begin{aligned} \frac{K_S}{E} &= \frac{1}{A_{ca}} + \frac{(l_2/2)^2}{I_{ca}} \\ &= \frac{1}{9,12 \cdot 10^{-7}} + \frac{(5000/2)^2}{1,857} \\ &= 4462135 \end{aligned}$$

Menentukan kekakuan kolom ekuivalen

$$\begin{aligned} \frac{E}{K_{ce}} &= \frac{E}{\Sigma K_C} + \frac{E}{K_t} \\ K_t &= \frac{\Sigma 9 E_{cs} C}{l_1 (1 - C_1/l_1)^3} \end{aligned}$$

$$\begin{aligned} \text{di mana } C &= \Sigma (1 - 0,63 X/Y) X^3 Y/3 \\ &= \Sigma (1 - 0,63 \cdot 210/500) \cdot 210^3 \cdot 500/3 \\ &= 1135089900 \end{aligned}$$

$$\begin{aligned} \frac{K_t}{E} &= \frac{2,9 \cdot 1135089900}{7000 (1 - 500/7000)^3} \\ &= 3645514 \end{aligned}$$

$$\begin{aligned} \frac{K_{ce}}{E} &= \frac{2K_C}{1 + 2K_C/K_t} \\ &= \frac{2 \cdot 6424331}{1 + 2 \cdot 6424331/3645514} = 2839789 \end{aligned}$$

h. Menentukan koefisien distribusi

$$\text{Kolom akhir} = \frac{K_S}{K_S + K_{ce}} = \frac{4462135}{4462135 + 2839789} = 0,611$$

$$\text{Kolom tengah} = \frac{K_S}{2K_S + K_{ce}} = \frac{4462135}{2 \cdot 4462135 + 2839789} = 0,379$$

i. Menentukan koefisien induksi (Carry-over factor)

$$\text{COF} = \frac{\frac{1}{A_{ca}} - \frac{(l_2/2)(l_2/2)}{I_{ca}}}{\frac{1}{A_{ca}} + \frac{(l_2/2)(l_2/2)}{I_{ca}}} = \frac{\frac{1}{9,12 \cdot 10^{-7}} - \frac{(2500)^2}{1,857}}{\frac{1}{9,12 \cdot 10^{-7}} + \frac{(2500)^2}{1,857}} = \frac{-2269152,274}{4462135,263} = -0,509$$

j. Menentukan momen-momen (cara kolom analog)

$$\text{beban hidup} = 3 \cdot 1,6 = 4,8 \text{ kPa}$$

$$\text{beban mati} = 5,33 \cdot 1,2 = 6,396 \text{ kPa}$$

$$\underline{\hspace{10em}} \\ 11,196 \text{ kPa}$$

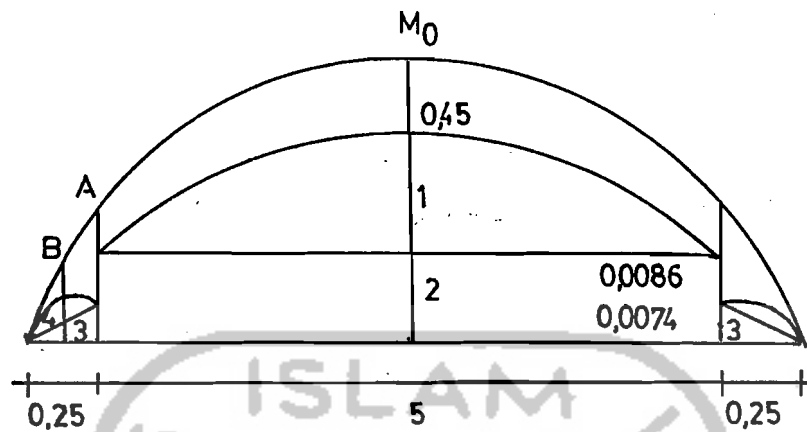
Untuk bentang sepanjang 7 m

$$q = 11,196 \cdot 7 = 78,372 \text{ kN/m}$$

$$M_{ou} = 1/8 \cdot q \cdot l^2$$

$$= 1/8 \cdot 78,372 \cdot 5^2 = 244,9125 \text{ kNm}$$

$$= 244912500 \text{ Nmm}$$



Gambar 4.8 Pembagian momen

$$\text{Didapat : } \frac{M_{uo}}{I_s} = \frac{244912500}{5,40225 \cdot 10^9} = 0,045$$

$$\begin{aligned} \text{Titik A : } M_A &= 0,5 q x (1 - x) \\ &= 0,5 \cdot 78,372 \cdot 0,25 (5 - 0,25) \\ &= 46,533375 \text{ kNm} = 46533375 \text{ Nmm} \end{aligned}$$

$$\frac{M_A}{I_s} = \frac{46533375}{5,40225 \cdot 10^9} = 0,0086$$

$$\frac{M_A}{I_{sc}} = \frac{46533375}{6265331360} = 0,0074$$

$$\begin{aligned} \text{Titik B : } M_B &= 0,5 q \cdot 0,5 x (1 - 0,5 x) \\ &= 0,5 \cdot 78,372 \cdot 0,5 \cdot 0,25 (5 - 0,5 \cdot 0,25) \\ &= 23,878969 \text{ kNm} = 23878969 \text{ Nmm} \end{aligned}$$

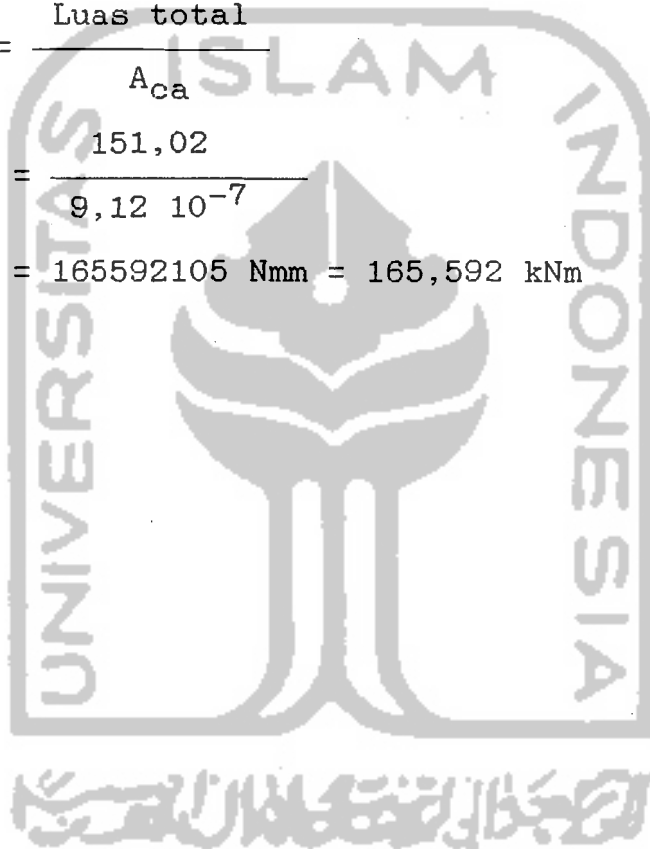
$$\frac{M_B}{I_{sc}} = \frac{23878969}{6265331360} = 0,0038$$

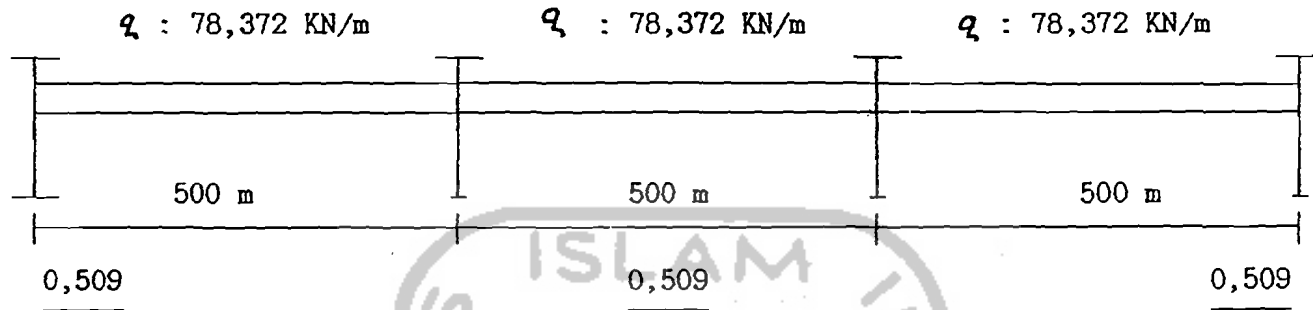


Hitung luas diagram

$$\begin{array}{rcl}
 \text{Luas 1} & : & 2/3 \cdot 4500 (0,045 - 0,0086) = 109,2 \text{ mm}^2 \\
 \text{2} & : & 4500 \cdot 0,0086 = 38,7 \text{ mm}^2 \\
 \text{3} & : & 2 \cdot 0,5 \cdot 250 \cdot 0,0074 = 1,85 \text{ mm}^2 \\
 \text{4} & : & 2 \cdot 2/3 \cdot 250 \cdot 0,0038 = 1,27 \text{ mm}^2 \\
 & & \hline
 & & 151,02 \text{ mm}^2
 \end{array}$$

$$\begin{aligned}
 \text{Momen primer} &= \frac{\text{Luas total}}{A_{ca}} \\
 &= \frac{151,02}{9,12 \cdot 10^{-7}} \\
 &= 165592105 \text{ Nmm} = 165,592 \text{ kNm}
 \end{aligned}$$





KOLOM	PELAT
0,389	0,611
-	165,592
-64,415	-101,177
-	-
-	-
-	9,935
-3,865	-6,070
-	1,916
-0,745	-1,171
-	0,966
-0,376	-0,590
-	0,301
-0,117	-0,184
-	0,116
-0,045	-0,071
-69,563	-69,563

PELAT	KOLOM	PELAT
0,379	0,242	0,379
-165,592	-	165,592
-	-	-
-15,499	-	-
19,518	12,463	19,518
-	-	-9,935
3,765	2,405	3,765
-3,090	-	-1,916
1,897	1,212	1,897
-0,596	-	-0,966
0,592	0,378	0,592
-0,300	-	-0,301
0,228	0,145	0,228
-0,094	-	-0,116
0,08	0,05	0,08
-195,091	16,653	178,438

PELAT	KOLOM	PELAT
0,379	0,242	0,379
-165,592	-	165,592
-	-	-
-	-	51,499
-19,518	-12,463	-19,518
9,935	-	-
-3,765	-2,405	-3,765
1,916	-	3,090
-1,897	-1,212	-1,897
0,966	-	0,596
-0,592	-0,378	-0,592
0,301	-	0,300
-0,228	-0,145	-0,228
0,116	-	0,094
-0,08	-0,05	-0,08
-178,438	-16,653	-195,091

PELAT	KOLOM
0,611	0,389
-165,592	-
101,177	64,415
-	-
-	-
-9,935	-
6,070	3,865
-1,916	-
1,171	0,745
-0,966	-
0,590	0,376
-0,301	-
0,184	0,117
-0,116	-
0,071	0,045
-69,563	69,563

$$\left(\frac{78,372 \text{ kN/m}}{68,563 \quad 195,091} \right) \quad \left(\frac{78,372 \text{ kN/m}}{178,438 \quad 178,438} \right)$$

$$\begin{array}{r} \uparrow 195,93 \\ \downarrow 25,106 \\ \hline 170,824 \end{array} \quad \begin{array}{r} 195,93 \uparrow \\ 25,106 \downarrow \\ \hline 221,036 \end{array} \quad \begin{array}{r} \uparrow 195,93 \\ \hline 195,93 \end{array} \quad \begin{array}{r} 195,93 \uparrow \\ \hline 195,93 \end{array}$$

$$\frac{78,372 \cdot 5}{2} = 195,93 \quad ; \quad \frac{(195,091 - 68,563)}{5} = 25,106 \text{ kN}$$

Menentukan momen-momen

Momen positif pada bentang akhir

$$\frac{x}{5 - x} = \frac{170,824}{221,036}$$

$$221,036x = 854,12 - 170,824x$$

$$391,86x = 854,12$$

$$x = 2,18 \text{ m}$$

$$M_x = R_a x - 0,5 q x^2$$

$$= 170,824 \cdot 2,18 - 0,5 \cdot 78,372 \cdot 2,18^2$$

$$= 186,169 \text{ kNm}$$

$$M_u = M_x - 69,563$$

$$= 116,606 \text{ kNm}$$

Momen negatif eksterior pada bentang akhir

$$x = 0,25$$

$$M_x = R_a x - 0,5 q x^2$$

$$= 170,824 \cdot 0,25 - 0,5 \cdot 78,372 \cdot 0,25^2$$

$$= 40,257 \text{ kNm}$$

$$M_u = M_x - 69,563$$

$$= -29,306 \text{ kNm}$$

Momen negatif interior pada bentang akhir

$$x = 0,25$$

$$\begin{aligned} M_x &= R_a x - 0,5 q x^2 \\ &= 221,036 \cdot 0,25 - 0,5 \cdot 78,372 \cdot 0,25^2 \\ &= 52,807 \text{ kNm} \end{aligned}$$

$$\begin{aligned} M_u &= M_x - 195,091 \\ &= 142,284 \text{ kNm} \end{aligned}$$

Momen rencana pada bentang dalam

Momen rencana positif

$$x = 2,5$$

$$\begin{aligned} M_x &= R_a x - 0,5 q x^2 \\ &= 195,93 \cdot 2,5 - 0,5 \cdot 78,372 \cdot 2,5^2 \\ &= 249,913 \text{ kNm} \end{aligned}$$

$$\begin{aligned} M_u &= M_x - 178,438 \\ &= 66,475 \text{ kNm} \end{aligned}$$

Momen rencana Negatif

$$x = 0,25$$

$$\begin{aligned} M_x &= R_a x - 0,5 q x^2 \\ &= 195,93 \cdot 0,25 - 0,5 \cdot 78,372 \cdot 0,25^2 \\ &= 46,533 \text{ kNm} \end{aligned}$$

$$\begin{aligned} M_u &= M_x - 178,438 \\ &= 131,905 \text{ kNm} \end{aligned}$$

Pembagian momen rencana pada jalur kolom

Momen rencana negatif interior

$$\begin{aligned} M_u &= 75\% \cdot 142,284 \\ &= 106,713 \text{ kNm} \end{aligned}$$



Momen rencana positif

$$\begin{aligned} M_u &= 60\% 116,606 \\ &= 69,964 \text{ kNm} \end{aligned}$$

Momen rencana negatif eksterior

$$\begin{aligned} M_u &= 100\% 29,306 \\ &= 29,306 \text{ kNm} \end{aligned}$$

Pembagian momen rencana jalur tengah

Momen rencana negatif interior

$$\begin{aligned} M_u &= 142,284 - 106,713 \\ &= 35,571 \text{ kNm} \end{aligned}$$

Momen rencana positif

$$\begin{aligned} M_u &= 116,606 - 69,964 \\ &= 46,642 \text{ kNm} \end{aligned}$$

k. Perhitungan Gaya Geser

Kolom Eksterior

$$\begin{aligned} t &= 210 \text{ mm} & ; a &= C_1 + d/2 \\ d &= 210 - 20 = 190 \text{ mm} & b &= C_2 + d \\ b_o &= 2 (C_1 + d/2) + (C_2 + d) \\ &= 2 (500 + 190/2) + (500 + 190) \\ &= 1880 \text{ mm} \end{aligned}$$

Luas permukaan bidang geser

$$\begin{aligned} A_c &= b_o d \\ &= 1880 \cdot 190 = 357200 \text{ mm}^2 \end{aligned}$$

Jarak titik berat penampang kritis

$$C_{AB} = \frac{2 (C_1 + d/2) d \cdot 1/2 (C_1 + d/2)}{A_c}$$

$$C_{AB} = \frac{d (C_1 + d/2)^2}{A_c}$$

$$= \frac{190 (500 + 95)^2}{357200} = 188 \text{ mm}$$

Sehingga :

$$C_{CD} = 595 - C_{AB}$$

$$= 595 - 188 = 407 \text{ mm}$$

$$e = 407 - 210 = 197 \text{ mm}$$

Momen Inersi

$$J_c = d [2/3 a^3 - (2a + b) (C_{AB})^2] + 1/6 a d^3$$

$$= 190 [2/3 (595)^3 - (2 \cdot 595 + 690) (188)^2] + 1/6 \cdot 595$$

$$(190)^3$$

$$= 190 [140429917 - 66446720] + 680184167$$

$$= 14736991600 \text{ mm}^4$$

Gaya geser yang terjadi pada sumbu kolom

$$V_u = 170,824 + 7 \cdot 0,25 \cdot 11,196$$

$$= 190,417 \text{ kN}$$

Momen pada sumbu kolom

$$M_u = - (69,563 - 0,5 \cdot 7 \cdot 0,25 \cdot 11,196) + 190,417 \cdot 0,197$$

$$= - 22,254 \text{ kNm}$$

$$\tau_v = 1 - \frac{1}{1 + 2/3 \sqrt{b_1/b_2}} \quad \text{di mana } \begin{matrix} b_1 = C_1 + 1/2 d \\ b_2 = C_2 + d \end{matrix}$$

$$= 1 - \frac{1}{1 + 2/3 \sqrt{595/690}} = 0,382$$

Kombinasi geser akibat beban vertikal dan transfer momen

$$v_n = \frac{V_u}{\theta A_c} \pm \frac{\tau_v M_u C_{AB}}{\theta J_c}$$

$$= \frac{190,417 \cdot 10^3}{0,85 \cdot 357200} \pm \frac{0,382 \cdot 22,254 \cdot 188 \cdot 10^6}{0,85 \cdot 14736991600}$$

$$v_{n1} = 0,755 \text{ MPa}$$

$$v_{n2} = 0,499 \text{ MPa}$$

Kolom interior

$$t = 210 \text{ mm} \quad ; \quad a = C_1 + d \quad C_1 = C_2$$

$$d = 210 - 20 = 190 \text{ mm} \quad b = C_2 + d \quad a = b$$

$$b_o = 2 (C_1 + d) + (C_2 + d)$$

$$A_c = [2 (C_1 + d) + (C_2 + d)] d \quad \text{di mana } C_1 = C_2$$

$$= 2 d (2C_1 + 2d)$$

$$= 2 \cdot 190 (2 \cdot 500 + 2 \cdot 190)$$

$$= 524400 \text{ mm}^2$$

Jarak titik berat penampang kritis

Karena simetris maka jatuh di tengah-tengah

$$C_{AB} = 1/2 (C_1 + d)$$

$$= 1/2 (500 + 190)$$

$$= 345 \text{ mm}$$

Momen Inersi

$$J_c = d (1/6 a^3 + 1/2 a^3) + 1/6 a d^3$$

$$= 190 [1/6 (690)^3 + 1/2 (690)^3] + 1/6 \cdot 690 \cdot (190)^3$$

$$= 190 [41611140000 + 788785000]$$

$$= 42399925000 \text{ mm}^4$$

Geser yang terjadi pada sumbu kolom

$$V_u = 221,036 + 195,93$$

$$= 416,966 \text{ kN}$$

Momen pada sumbu kolom

$$M_u = 195,091 - 178,438$$

$$= 16,653 \text{ kNm}$$

$$\tau_v = 1 - \frac{1}{1 + 2/3 \sqrt{b_1/b_2}} \quad \begin{array}{l} \text{di mana } b_1 = C_1 + d \\ b_2 = C_2 + d \end{array}$$

$$= 1 - \frac{1}{1 + 2/3 \sqrt{690/690}} = 0,4$$

Kombinasi geser dan akibat transfer momen

$$v_n = \frac{V_u}{\theta A_c} + \frac{\tau_v M_u x}{\theta J_c}$$

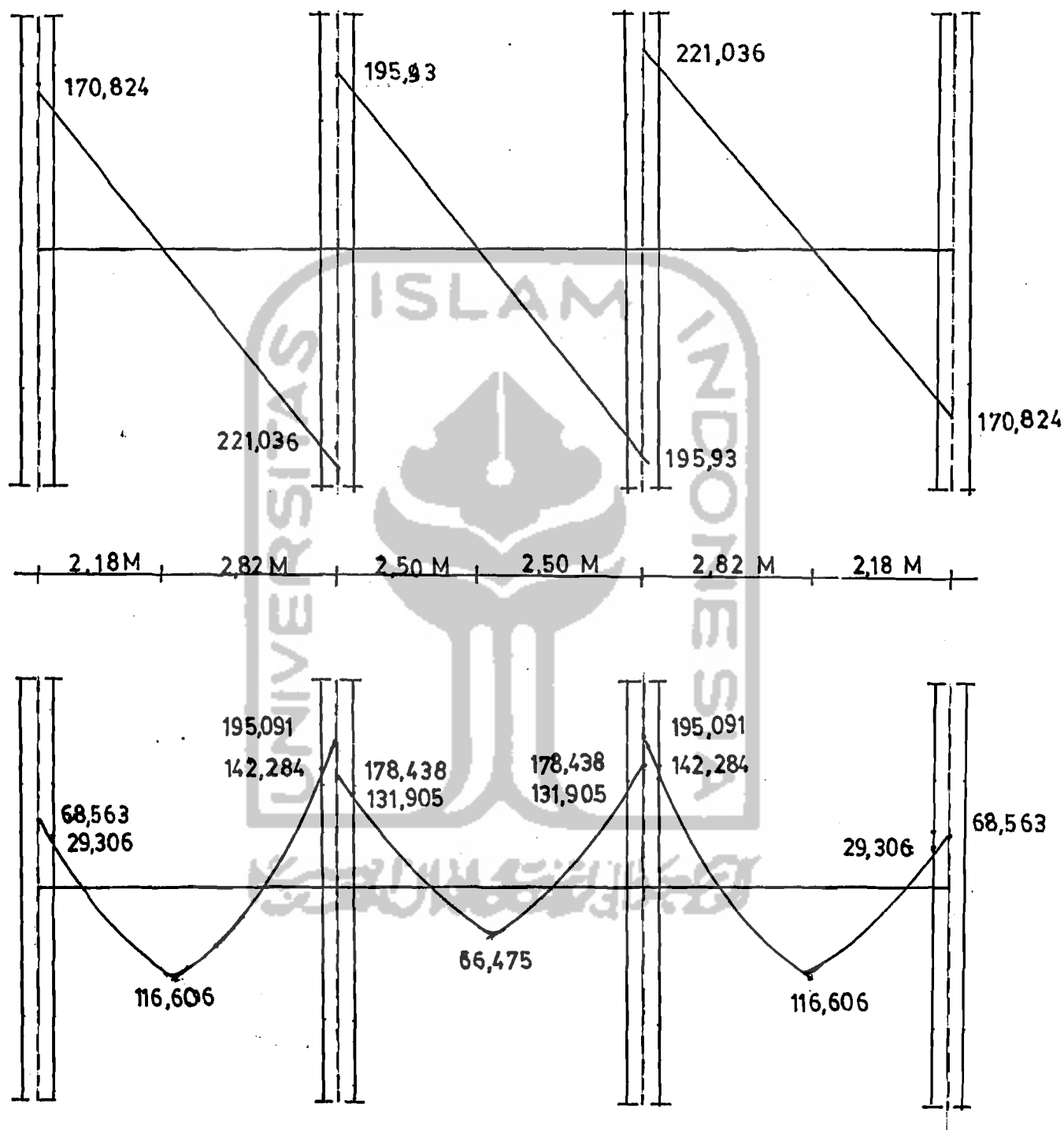
$$= \frac{416,966 \cdot 10^3}{0,85 \cdot 524400} \pm \frac{0,4 \cdot 16,653 \cdot 395 \cdot 10^6}{0,85 \cdot 42399925000}$$

$$v_{n1} = 1,666 \text{ MPa}$$

$$v_{n2} = 0,205 \text{ MPa}$$

Daftar 4.4 Distribusi Momen

Lokasi	Momen arah memendek kNm		
	momen negatif eksterior	momen positif lapangan	momen negatif interior
bentang akhir	205,916	142,774	104,198
jalur kolom	75% 205,916 154,437	60% 142,774 85,664	100% 104,198 104,198
jalur tengah	25% 205,916 51,479	40% 142,774 57,11	-



Gambar 4.9 Gaya lintang dan momen bentang panjang

Tabel 4.5 Hasil perbandingan pada bentang panjang

Lokasi	Cara perhitungan	
	Koefisien Momen	Portal Ekivalen
- Momen batas rencana total	295,644	342,878
- Momen bentang akhir		
momen negatif interior	206,950	205,916
momen positif	153,735	142,774
momen negatif eksterior	76,867	104,198
- Momen bentang dalam		
momen negatif	192,169	186,332
momen positif	103,475	109,313
- Momen jalur kolom		
momen negatif interior	155,213	154,437
momen positif	92,241	85,664
momen negatif eksterior	76,867	104,198
- Momen jalur tengah		
momen negatif interior	51,738	51,479
momen positif	61,494	57,110
- Reaksi kolom akhir	203,907	180,281
- Reaksi kolom tengah	411,873	407,509