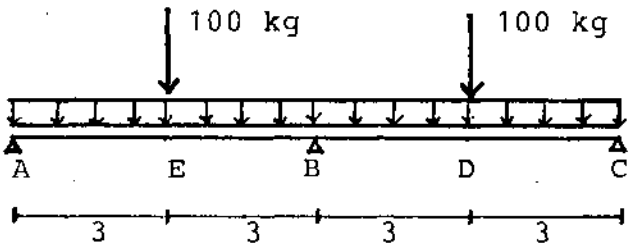
IV. CONTOH PERHITUNGAN

4.1. Balok terlentur

Rencanakanlah balok terlentur di bawah ini dengan pembebanan sebagai berikut :

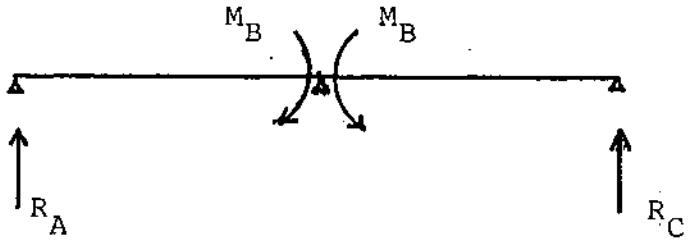


q_L = 250 kg/m'

q_D = 50 kg/m'

DI TITIK D dan E terdapat LATERAL BRACING

* Menghitung gaya-gaya dalam



$\theta_B$kiri = $\theta_B$kanan

$\Sigma\ \theta_B = 0$

$$\frac{2 \times M_B \times 6}{3EI} - \frac{2\{\ 250 \times 1 + 50 \times 1.4\ \} \times 6^3}{24EI} - \frac{2 \times 100 \times 6^2}{16EI} = 0$$

$$4xM_B - 5760 - 450 = 0$$

$$M_B = 1552.5 \text{ kgm}$$

$\Sigma M_B = 0$

$R_A x6 - 100x3 - 1/2x320x6^2 + M_B = 0$

$$R_A = 751.25 \text{ kg}$$

$R_B = 320x12 + 2x200 - 2x751.25$

$R_B = 2737.5$ kg

Momen di bawah beban terpusat ,

$M_D = 751.25x3 - 1/2x320x3^2$

$M_D = 831.75$ Kgm

Momen maksimum pada gaya lintang = 0

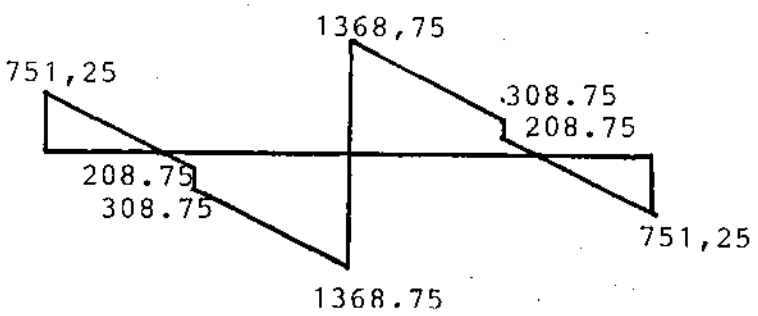
$751.25 - 320\ X = 0$

$X = 2.348$ m

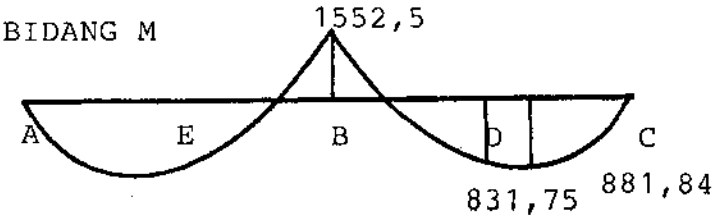
Momen maksimum $= 751.25x2.348 - 1/2x320x2.348^2$

$= 881.84$ kgm

BIDANG D



BIDANG M



Direncanakan dengan menggunakan profil double kanal stiffened][8" x 6" x 0.06" dengan Fy = 2809 kg/cm^2 , lihat tabel 1.1 pada lampiran 1.

D = 20.32 cm

B = 15.24 cm

t = 0.1524 cm

d = 1.524 cm

R = 0.2381 cm

A = 11.419 cm

Ix = 732.567 cm^4

Iy = 132.778 cm^4

<u>Pemeriksaan Kekuatan Nominal Penampang</u>

Mn = Se.Fy

Menghitung Se

$$\tau = \frac{1.052}{\sqrt{k}} \frac{w}{t} \sqrt{\frac{f}{E}}$$

w = B/2 - 2(R+t)

w = 15.24/2 - 2(0.2381 + 0.1524)

w = 6.839 cm

k = 4

f = Fy

$$\tau = \frac{1.052}{\sqrt{4}} \frac{6.839}{0.1524} \sqrt{\frac{2809}{2.1 \times 10^6}}$$

τ = 0.863 > 0.673 maka b = $\int$ w

$$\int = \frac{(1 - 0.22/\tau)}{\tau}$$

= 0.863

b = 0.863 x 6.839

b = 5.902 cm

Perhitungan momen inersia dan modulus penampang

ELEMEN	LUAS (cm2) A	JARAK (cm) y	Ay (cm3)	Ay^2 (cm4)
sayap atas	2x5.902x0.1524 = 1.7989	0.0762	0.137	0.010
sudut atas	4x0.0752 = 0.3008	0.1864	0.056	0.011
lip atas	2x1.1335x0.1524 = 0.3455	0.9573	0.331	0.317
badan	2x19.529x0.1524 = 5.9555	10.160	60.508	614.76
sudut bawah	0.3008	20.1336	6.056	121.974
lip bawah	0.3455	19.3627	6.688	129.496
sayap bawah	2x6.839x0.1524 = 2.0845	20.2438	42.198	854.252
Σ	11.1315		115.976	1720.820

tabel ini untuk medapatkan Ay^2

$$Y_{cg} = \frac{\Sigma (A.y)}{\Sigma A} = \frac{115.976}{11.1315} = 10.419 \text{ cm}$$

$$\Sigma (A.y^2) = 1720.824$$

$I_{lip} = 4/12 \ (0.1524) \ (1.1335)^3 = 0.074$

$I_{badan} = 2/12 \ (0.1524) \ (19.539)^3 = 189.470$

$-(\Sigma A) \ (Y^2_{cg}) = (11.1315) \ (10.419^2) = -1208.386$

$+$

$I_x = 701.979 \text{ cm}^4$

$$Se = \frac{Ix}{Ycg} = 67.37 \text{ cm}^3$$

Mn = 67.37 x 2809

= 189242 kgcm

ø Mn = 0.95 x 189242 = 179780 kgcm > M maks = 155250 kgcm

Pemeriksaan Kekuatan Lateral Buckling

a. Untuk bentang BD

$$Sf = \frac{732.567}{20.32/2} = 72.1\ cm^3$$

My =Sf x Fy = 72.1 x 2809 = 202528.9 kgcm

$$Me = \pi^2 \times E \times Cb \times d \times Iyc/L^2$$

$$Cb = 1.75 + 1.05 \frac{M1}{M2} + 0.3 \{\frac{M1}{M2}\}^2 \leq 2.3$$

$$= 1.75 + 1.05 \frac{83175}{155250} + 0.3 \{\frac{83175}{155250}\}^2 \leq 2.3$$

$$= 2.47 > 2.3$$

jadi Cb = 2.3

$$Me = \frac{\pi^2 \times 2.1x10^6 \times 20.32 \times 132.778/2}{300^2}$$

Me = 310667.9 kgcm

2.78 My > Me > 0.56 My

$$Mc = \frac{10}{9} My \left(1 - \frac{10\ My}{36\ Me} \right)$$

Mc = 184281.6 kgcm

Menghitung lebar efektif :

$$\tau = \frac{1.052}{\sqrt{k}} \frac{w}{t} \sqrt{\frac{f}{E}}$$

w = B/2 - 2(R+t)

w = 15.24/2 - 2(0.2381 + 0.1524)

$w = 6.839$ cm

$k = 4$

$$f = \frac{Mc}{Sf}$$

$f = 2555.92$ kg/cm²

$$\tau = \frac{1.052}{\sqrt{4}} \quad \frac{6.839}{0.1524} \sqrt{\frac{2555.92}{2.1 \times 10^6}}$$

$\tau = 0.823 > 0.673$ maka $b = \int w$

$$\int = \frac{1 - 0.22/\tau}{\tau}$$

$\int = 0.89$

$b = 0.89 \times 6.839$

$b = 6.088$ cm

ELEMEN	LUAS (cm2) A	JARAK (cm) y	Ay (cm3)	Ay^2 (cm4)
sayap atas	2x6.088x0.1524 = 1.8556	0.0762	0.141	0.011
sudut atas	4x0.0752 = 0.3008	0.1864	0.056	0.011
lip atas	2x1.1335x0.1524 = 0.3455	0.9573	0.331	0.317
badan	2x19.529x0.1524 = 5.9555	10.160	60.508	614.76
sudut bawah	0.3008	20.1336	6.058	121.974
lip bawah	0.3455	19.3627	6.688	129.496
sayap bawah	2x6.839x0.1524 = 2.0845	20.2438	42.198	854.252
$\sum$	11.1315		115.976	1720.820

tabel ini untuk mendapatkan Ay^2

$$Y_{cg} = \frac{\Sigma\ (\ A.y\ )}{\Sigma\ A} = \frac{115.976}{11.1315} = 10.366\ cm$$

$$\Sigma\ (\ A.y^2\ ) = 1720.821$$

$I_{lip} = 4/12\ (0.1524)\ (1.1335)^3 = 0.074$

$I_{badan} = 2/12\ (0.1524)\ (19.539)^3 = 189.470$

$-(\Sigma A)\ (Y_{cg}) = (11.1882^2)\ (10.366^2) = -1202.216$

$+$

$I_x = 708.149\ cm^4$

$$Se = \frac{Ix}{Ycg} = 68.316\ cm^3$$

Mn = 68.316 x 2555.92

Mn = 174610.2 kgcm

øMn = 157149.21 kgcm > M max = 155250 kgcm

<u>Pemeriksaan Kekuatan Geser</u>

Gaya Lintang maksimum D_B = 1368.75 kg

h = D - 2t

h = 20.32 - 2 x 0.1524

h = 20.015 cm

$$\frac{a}{h} = \frac{300}{20.015} = 14.99 > 1$$

$$\text{maka}\quad kv = 5.34 + \frac{4}{(a/h)^2}$$

$$kv = 5.3578$$

$$\frac{h}{t} = \frac{20.0152}{0.1524} = 131.33$$

$\frac{h}{t} > 1.415 \sqrt{(Ekv/Fy)}$

$131.33 > 1.415 \sqrt{(2.1x10^6x5.3578/2809)}$

$131.33 > 89.554$

$\phi v = 0.90$

$Vn = 0.905Ekvt^3 / h$

$= 0.905x2.1x10^6x5.3578x0.1524^3 / 20.0152$

$= 1800.73$ kg

$\phi Vn = 1620.66$ kg > gaya lintang maksimum

Pemeriksaan Kombinasi Geser dan Lentur

Periksa di titik B

$\frac{M_D}{\phi Mn} > 0.5$ dan $\frac{V_D}{\phi Vn} > 0.7$

$\frac{155250}{179780} > 0.5$ dan $\frac{1368.75}{1620.66} > 0.7$

$0.86 > 0.5$ dan $0.8 > 0.7$

persamaan interaksinya :

$0.6 \frac{M_D}{\phi Mn} + \frac{V_D}{\phi V_D} \leq 1.3$

$0.6 \times 0.86 + 0.8 \leq 1.3$

$1.32 \approx 1.3$

Pemeriksaan Pengaku di bawah Beban Terpusat

a. Panjang tumpuan di titik D , N = 6 cm

P terpusat = 100 kg

syarat - syarat digunakannya perumusan pada tabel

kekuatan lipat badan (Pn)

$$\frac{R}{t} \leq 7 \quad ; \quad \frac{N}{t} \leq 210 \quad ; \quad \frac{N}{h} \leq 3.5$$

$$\frac{0.2381}{0.1524} \leq 7 \quad ; \quad \frac{6}{0.1524} \leq 210 \quad ; \quad \frac{6}{20.32} \leq 3.5$$

$$1.56 \leq 7 \quad ; \quad 39 \leq 210 \quad ; \quad 0.3 \leq 3.5$$

$Pn = t^2 FyC5 \; (0.88 + 0.12m) \; (15 + 3.25\sqrt{(N/t)})$

$C5 = (1.49 - 0.53k) \geq 0.6$

$k = Fy / 2317 = 1.212$

$m = t / 0.191 = 0.798$

$C5 = 0.848 > 0.6$

$Pn = 0.1524^2 \; 2809 \; 0.848 \; (0.88 + 0.12x0.798)$

$...x \; (15 + 3.25\sqrt{\; 6/0.1524})$

$Pn = 1911.05$ kg

$\phi = 0.8$

$\phi Pn = 1529$ kg $> P$

digunakan pengaku praktis

b. Panjang tumpuan di titik B , N = 8 cm

$P = 2737.5$ kg

$Pn = t^2 FyC5 \; (0.88 + 0.12m) \; (15 + 3.25\sqrt{(N/t)})$

$Pn = 2081.41$ kg

$\phi Pn = 1665.13$ kg

$\phi Pn < P$

pengaku harus direncanakan

Perhitungan pengaku :

1. $Pn = Fwy \; Ac$

Fwy = Fy

Ac = 18 t^2 + As

As = 0.3 x 7 x 2 = 4.2 cm^2

Ac = 18 x 0.1524^2 + 4.2

Ac = 4.618 cm^2

Pn = 2819 x 4.618

Pn = 12972 kg

2. Pn = Ab Fn

Ab = b1t + As

$$b1 = 25t \left\{ 0.0024 \frac{Lst}{t} + 0.72 \right\} \leq 25t$$

$$b1 = 25x0.1524 \left\{0.0024 \frac{7}{0.1524} + 0.72\right\} \leq 25x0.1524$$

b1 = 3.16 ≤ 3.81

Ab = 3.81 x 0.1524 + 4.2

Ab = 4.78 cm^2

Fe = π^2 E / $(KL/r)^2$

KL = 20.32 - 2x 0.1524 = 20.05 cm

Pengaku ini dipandang sebagai kolom yang menerima beban sentris.

I min = 2/12 0.1524 3.16^3 + 2/12 7 0.3^3

I min = 0.833 cm^4

$$r \text{ min} = \sqrt{\frac{I \text{ min}}{Ab}}$$

$$= \sqrt{\frac{0.833}{4.78}}$$

= 0.417 cm

$$\frac{KL}{r} = \frac{20.05}{0.417} = 48.1 < 200$$

$Fe = \pi^2 \; 2.1x10^6 \; / \; 48.1^2$

$Fe = 8958 \; kg/cm^2$

$Fe > Fy/2$ maka

$Fn = Fy \{ 1 - Fy/(4Fe) \}$

$= 2809 \{ 1 - 2809/(4x8958) \}$

$= 2589 \; kg/cm^2$

$Pn = Ab \; Fn$

$= 4.78 \times 2589$

$= 12375 \; kg$

$\phi c \; Pn = 0.85 \times 12375 = 10518.75 \; kg$

$\phi c \; Pn > P$

c. **Panjang tumpuan di titik C , N = 8 cm**

$Pn = t^2 \; Fy \; C6 \; (10 + 1.25 \sqrt{} \; N/t \;)$

$h/t = 20.32/0.1524 = 132 < 150$, maka $C_6 = 1+h/750t$

$C6 = 1.2$

$Pn = 0.1524^2x2809x1.2x(10+1.25\sqrt{}(8/0.1524))$

$Pn = 1492 \; kg$

$\phi Pn = 1194 \; kg > P$

<u>Pemeriksaan Kombinasi Lentur dan Lipat</u>

a. Di titik B

$\phi = 0.95$

$\phi w = 0.80$

$P_D = 2737.5 \; kg$

$Pn = 1237.5 \; kg$

M_D = 155250 kgcm

Mn = 183204 kgcm

persamaan interaksinya :

$$0.82\ \frac{P_D}{\text{øw Pn}} + \frac{M_D}{\text{ø Mn}} \leq 1.32$$

$$0.82\ \frac{2737.5}{0.80 \times 12375} + \frac{155250}{0.95 \times 183204} \leq 1.32$$

$$0.227 + 0.892 \leq 1.32$$

$$1.119 \leq 1.32$$

b. Di titik D

P_D = 100 kg

Pn = 1911.05 kg

M_D = 83175 kgcm

Mn = 183204 kgcm

persamaan interaksinya :

$$0.82\ \frac{P_D}{\text{øw Pn}} + \frac{M_D}{\text{ø Mn}} \leq 1.32$$

$$0.82\ \frac{100}{0.80 \times 1911.05} + \frac{83175}{0.95 \times 183204} \leq 1.32$$

$$0.054 + 0.478 \leq 1.32$$

$$0.53 \leq 1.32$$

<u>Pemeriksaan Penurunan</u>

$$EI\ y = \frac{P}{48}(3L^2x - 4x^3) + \frac{w}{24}(L^3x - 2Lx^3 + x^4) - \frac{M_B}{6}\left(Lx - \frac{x^3}{L}\right)$$

$$EI\ \frac{dy}{dx} = \frac{P}{48}(3L^2 - 12x^2) + \frac{w}{24}(L^3 - 6Lx^2 + 4x^3) - \frac{M_B}{6}\left(L - \frac{3x^2}{L}\right)$$

Penurunan maksimum terjadi pada $EI \frac{dy}{dx} = 0$

$$EI \frac{dy}{dx} = \frac{100}{48}(3\,600^2 - 12x^2) + \frac{3}{24}(600^3 - 6\,600\,x^2 + 4x^3)$$

$$-\frac{155250}{6}\left(600 - \frac{3x^2}{600}\right) = 0$$

$0.5x^3 - 345.625x^2 + 13725000 = 0$

$x = 249.19$ cm

sehingga pada penurunan maksimum EI $y = 1.452 \times 10^9$ kgcm^3

Momen pada penurunan maksimum = 751.25×249.19 - ……$0.5 \times 3.2 \times 249.19^2 = 87851$ kgcm

Perhitungan lebar efektif untuk menentukan momen inersia penurunan :

$\tau = 1.052/\sqrt{k} \times w/t \times \sqrt{(f/E)}$

$w = 6.839$ cm

$k = 4$

f perkiraan = 1220 kg/cm^2

$\tau = 0.569 < 0.673$

$b = w = 6.839$

$$Y_{cg} = \frac{\Sigma (A.y)}{\Sigma A} = \frac{115.976}{11.1315} = 10.366 \text{ cm}$$

$$\Sigma (A.y^2) = 1720.821$$

$I_{lip} = 4/12\ (0.1524)\ (1.1335)^3 = 0.074$

$I_{badan} = 2/12\ (0.1524)\ (19.539)^3 = 189.470$

$-(\Sigma A)(Y_{cg}) = (11.1882^2)\ (10.366^2) = -1178.589$

$I_x = 731.77 \text{ cm}^4$ +

$S = Ix/Y_{cg} = 72.03 \text{ cm}^3$

ELEMEN	LUAS (cm2) A	JARAK (cm) y	Ay (cm3)	Ay^2 (cm4)
sayap atas	2x6.839x0.1524 = 2.085	0.0762	0.159	0.012
sudut atas	4x0.0752 = 0.3008	0.1864	0.056	0.011
lip atas	2x1.1335x0.1524 = 0.3455	0.9573	0.331	0.317
badan	2x19.529x0.1524 = 5.9555	10.160	60.508	614.76
sudut bawah	0.3008	20.1336	6.058	121.974
lip bawah	0.3455	19.3627	6.688	129.496
sayap bawah	2x6.839x0.1524 = 2.0845	20.2438	42.198	854.252
Σ	11.4176		115.998	1720.822

tabel ini untuk mendapatkan Ay^2

f terjadi = M/S

= 87851/72.03

= 1219.6 kg/cm² ≈ 1220 kg/cm²

Ix = 731.77 cm^4

E = 2.1×10^6 kg/cm²

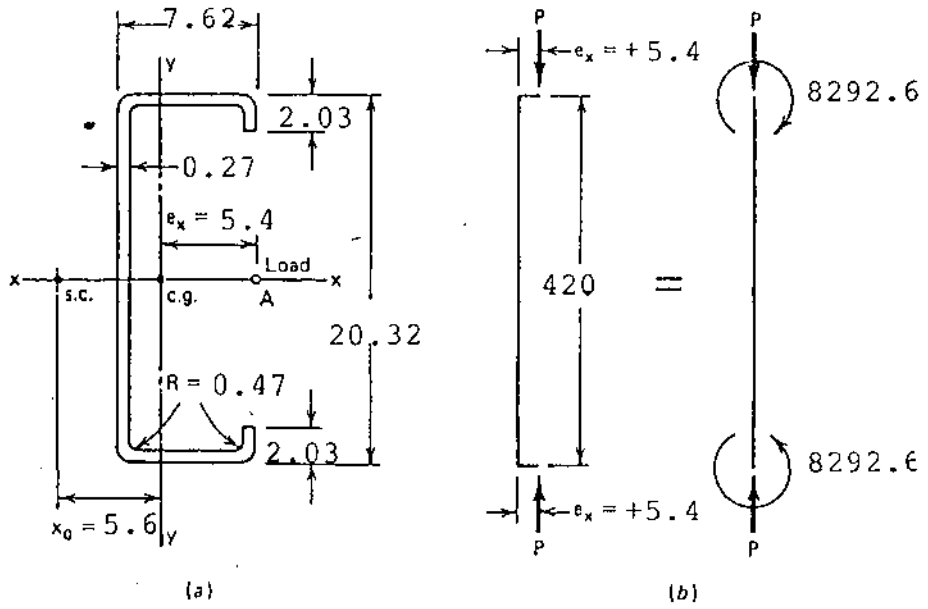
E I_x y = 1.452×10^9

didapat y = 0.94 cm

Penurunan ijin = L/250 = 2.4 cm

Jadi profil tersebut dapat dipakai.

4.2. BEAM-COLUMN



lihat tabel 1.1 pada lampiran 1.

A = 10 cm^2

Iy = 74.51 cm^4

Sy = 13.84 cm^4

ry = 2.72 cm

Fy = 3510.75 kg/cm^2

P = 1535.67 kg

Periksa penampang berdasarkan beban yang ada!

PD = 1535.67 kg

øc = 0.85 dan ø = 0.95

Pn = 21064.5 kg

$$Pn = \frac{A\pi^2 E}{(25.7(w/t)^2)} = \frac{10 \times 3.14^2 \times 2.1x10^6}{(25.7(6.13/0.27)^2} = 15629.75 \text{ kg}$$

PD/øcPn = 0.12 ≤ 0.15

M_{DY} = 5.4 x 1535.67

= 8292.62 Kgcm

Mny = SeFy

Perhitungan modulus penampang efektif

$$\tau = \frac{1.052}{\sqrt{k}} \quad \frac{w}{t} \sqrt{\frac{f}{E}}$$

w = 2.03 - 0.47 - 0.27 = 1.29 cm

k = 4

f = Fy = 3510.75 Kg/cm²

τ = 0.051 < 0.673 maka b = w

ELEMEN	LUAS (cm2) A	JARAK (cm) y	Ay (cm3)	Ay^2 (cm4)
sayap	2x6.14x0.27 = 3.316	3.81	12.634	48.135
sudut atas	2x0.256 = 0.178	0.348	0.062	0.022
lip	2x1.29x0.27 = 0.697	0.135	0.094	0.013
badan	19.84x0.27 = 5.807	7.485	38.076	285
sudut bawah	2x0.256 =0.178	7.002	1.246	8.727
Σ	9.456		52.112	341.897

tabel ini untuk mendapatkan Ay^2

$$X_{cg} = \frac{\Sigma\ (\ A.x\ )}{\Sigma\ A} = \frac{52.112}{9.456} = 5.511\ cm$$

$$\Sigma\ (\ A.x^2\ ) = 341.897$$

$$I_{sayap} = 2/12\ (0.27)(\ 6.14\ )^3 = 10.416$$

$$-(\Sigma A)(X^2_{cg}) = (\ 9.456\ )(\ 5.511^2\ ) = -\ 287.189$$

$$I_y = 65.124\ cm^4$$

$Se = Iy/X_{cg} = 11.82\ cm^3$

Mny = 11.82 x 3510.75

= 41497.07 Kgcm

Persamaan interaksi yang dipakai:

$PD/\phi cPn + MDx/\phi Mnx + MDy/\phi Mny \leq 1$

$0.12 + 0 + 0.21 = 0.33 \leq 1$

Jadi profil tersebut dapat dipakai.