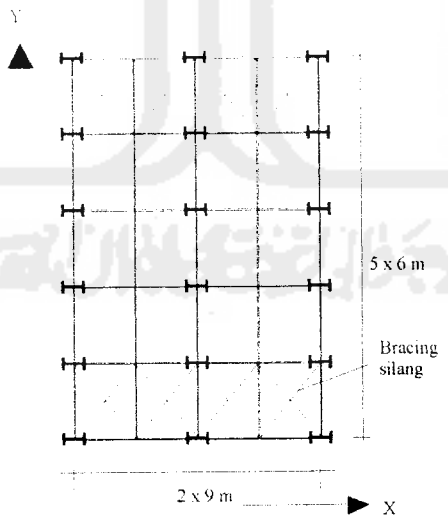
BAB V

PEMBEBANAN DAN PERHITUNGAN STRUKTUR BAJA

5.1 Pembebanan

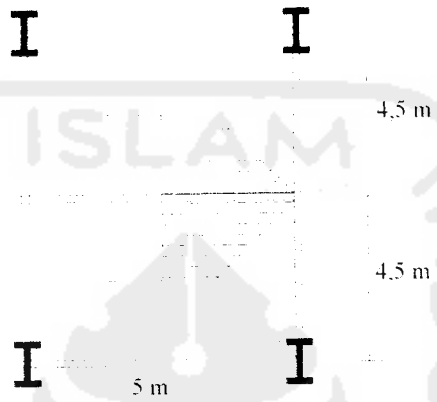
Pembebanan merupakan langkah paling awal dalam mengerjakan hitungan struktur. Dari beban-beban yang dihitung, kemudian ditransfer ke balok portal akan didapatkan gaya-gaya dalam yang dipergunakan untuk menghitung dimensi profil struktur. Beban yang bekerja dibagi menjadi tiga kelompok, yaitu beban mati, beban hidup, dan beban gempa. Untuk selanjutnya beban mati dan beban hidup disebut dengan beban gravitasi. Untuk menambah kekakuan dari elemen balok maka ditambahkan bracing silang.



Gambar 5.1 Denah Bangunan

5.1.1 Beban Gravitasi

Beban gravitasi merupakan beban yang terdiri dari beban mati dan beban hidup. Distribusi beban gravitasi dari pelat ke balok portal ditunjukkan pada gambar 5.2 dibawah ini.



Gambar 5.2 Distribusi Beban

Perkiraan ukuran balok portal arah-X $\rightarrow$ d = $\frac{1}{12}$ L = $\frac{1}{12}$. 9 = 0,75 m = 29,53 in

Pakai W 30x99 (d = 29,65 in ; bf = 10,45 in)

Berat = 99 lb/ft = 1,473 kN/m

Perkiraan ukuran balok portal arah-Y $\rightarrow$ d = $\frac{1}{12}$.5 = 0,416 m = 16,401 in

Pakai W 16x67 (d = 16,33 in ; bf = 10,235 in)

Berat = 67 lb/ft = 0,997 kN/m

Perkiraan ukuran balok anak $\rightarrow$ d = $\frac{1}{15}$. 5 = 0,3 m = 11,81 in

Pakai W 14x22 (d = 13,74 in ; bf = 5,0 in)

Berat = 22 lb/ft = 0,327 kN/m

Perkiraan ukuran kolom W 18x76 (d = 18,21 in ; bf = 11,035 in)

Berat = 76 lb/ft = 1,131 kN/m

Berat pelat lantai

Bahan		**Berat (kN/m^2)**
Pelat	0,12 x 24	2,88
Pasir	0,05 x 18	0,9
Spesi	0,03 x 24	0,72
Keramik	0,01 x 24	0,24

Q_D = (2,88 + 0,9 + 0,72 + 0,24) kN/m^2 = 4,74 kN/m^2

Q_L = 2,5 kN/m^2 (hotel)

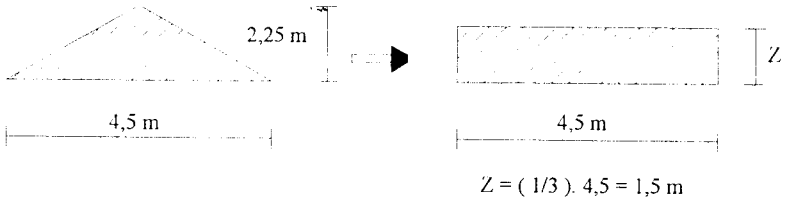
Berat pelat atap

Bahan		**Berat (kN/m^2)**
Pelat	0,1 x 24	2,4
Kedap air	0,03 x 24	0,72

Q_D = (2,4 + 0,72) kN/m^2 = 3,12 kN/m^2

Q_L = 1 kN/m^2 (atap)

Beban equivalen dihitung dengan asumsi equivalen momen.



Gambar 5.3 Beban Ekuivalen

Portal Tepi

Beban merata lantai → $Q_D = 4{,}74 \,.\, 1{,}5 +$ berat tembok

$= 7{,}11 + 2{,}5 \,.\, 4 = 17{,}11$ kN/m

$$Q_L = 2{,}5 \,.\, 1{,}5 = 3{,}75 \text{ kN/m}$$

Beban titik lantai → $P_D = 4{,}74. \left[\left(\frac{5+0{,}5}{2}\right).2{,}25\right] + 0{,}327. \,(\, 5/2 \,) = 30{,}146$ kN

$$P_L = 2{,}5. \left[\left(\frac{5+0{,}5}{2}\right).2{,}25\right] = 15{,}469 \text{ kN}$$

Beban merata atap → $Q_D = 3{,}12. \,1{,}5 = 4{,}68$ kN/m

$$Q_L = 1. \,1{,}5 = 1{,}5 \text{ kN/m}$$

Beban titik atap → $P_D = 3{,}12. \left[\left(\frac{5+0{,}5}{2}\right).2{,}25\right] + 0{,}327. \,(\, 5/2 \,) = 20{,}122$ kN

$$P_L = 1. \left[\left(\frac{5+0{,}5}{2}\right).2{,}25\right] = 6{,}187 \text{ kN}$$

Portal Tengah

Beban merata lantai → $Q_D = 4,74. 2. 1,5 + 2,5. 4 = 24,22$ kN/m

$Q_L = 2,5. 3 = 7,5$ kN/m

Beban titik lantai → $P_D = 30,146. 2 = 60,3$ kN

$P_L = 15,469. 2 = 30,94$ kN

Beban merata atap → $Q_D = 3,12. 3 = 9,36$ kN/m

$Q_L = 1. 3 = 3$ kN/m

Beban titik atap → $P_D = 20,122. 2 = 40,24$ kN

$P_L = 6,187. 2 = 12,37$ kN

5.1.2 Beban Gempa

Berat total beban mati lantai 1 (W_{D1})

Jenis		Berat (kN)
Pelat	4,74. 18. 30	2559,6
Balok Induk	(1,473. 18. 6) + (0,997. 30. 3)	248,814
Balok Anak	0,327. 30. 2	19,62
Kolom	1,131. 4. 18	81,432
Tembok	2,5. 4. (18. 6 + 30. 3)	1980
	Jumlah (W_{D1})	**4889,466**

Berat total beban hidup lantai 1 (W_{L1}) → $W_{L1} = 2,5. 30. 18 = 1350$ kN

W_{L1} tereduksi $= 0,3. 1350 = 405$ kN

W total lantai 1 = $W_D + W_L$ tereduksi = 4889,466 + 405 = 5294,466 kN

W total lantai 1 sampai dengan lantai 17 nilainya sama, yaitu sebesar 5294,466 kN

Berat total beban mati atap (W_{D2})

Jenis		Berat (kN)
Pelat	3,12. 18. 30	1684,8
Balok Induk	(1,473. 18. 6) + (0,997. 30. 3)	248,814
Balok Anak	0,327. 30. 2	19,62
Kolom	1,131. 4. 18	81,432
Tembok	2,5.(18.6 + 30. 3)	1980
	Jumlah (W_{D2})	**4014,67**

Berat total beban hidup atap (W_{L2}) → W_{L2} = 1. 18. 30 = 540 kN

W_{L2} tereduksi = 0,3. 540 = 162 kN

W total atap = 4014,67 + 162 = 4176,67 kN

Untuk portal 18 tingkat :

W total bangunan (Wt) = (5294,466. 17) + 4176,67 = 94182,592 kN

Untuk portal 6 tingkat :

W total bangunan (Wt) = (5294,466. 5) + 4176,67 = 30648,8 kN

Hitungan gaya geser dasar (V)

Untuk portal 18 tingkat:

$$\frac{H}{B} = \frac{18.4}{2.9} = 4 > 3$$

H = 18. 4 = 72 m

T = 0,085 (H)$^{3/4}$ = 0,085. (72)$^{3/4}$ = 2,1 dtDari grafik respon spektrum, daerah gempa 3, bangunan diatas tanah keras didapat nilai C = 0,025

V = C. I. K.Wt = 0,025. 1. 1. 94182,592 = 2354,56 kN.....(pers. 3.1)

0,9 V = 2119,1 kN

0,1 V = 235,456 kN

Tabel 5.1 Hitungan gaya geser tingkat

Lantai	hi(m)	Wi(kN)	Wi.hi	Fi tot (kN)	Fi,x (kN)
18	72	4176.67	300720	415.42444	69.237406
17	68	5294.47	360024	215.45906	35.909844
16	64	5294.47	338846	202.785	33.7975
15	60	5294.47	317668	190.11094	31.685156
14	56	5294.47	296490	177.43687	29.572812
13	52	5294.47	275312	164.76281	27.460469
12	48	5294.47	254134	152.08875	25.348125
11	44	5294.47	232957	139.41469	23.235781
10	40	5294.47	211779	126.74062	21.123437
9	36	5294.47	190601	114.06656	19.011094
8	32	5294.47	169423	101.3925	16.89875
7	28	5294.47	148245	88.718437	14.786406
6	24	5294.47	127067	76.044375	12.674062
5	20	5294.47	105889	63.370312	10.561719
4	16	5294.47	84711.5	50.69625	8.449375
3	12	5294.47	63533.6	38.022187	6.3370312
2	8	5294.47	42355.7	25.348125	4.2246875
1	4	5294.47	21177.9	12.674062	2.1123437
		∑Wi.hi	3540933		

Fi, total = $\frac{Wi.hi}{\sum Wi.hi}$.0 9V.....(pers. 3.2)

Nilai 0,1 V ditambahkan pada Fi total lantai 18.

Fi,x = $\frac{Ftotal}{6}$

Untuk portal 6 tingkat:

$\frac{H}{B} = \frac{24}{18} = 1{,}33 < 3$

T = 0,085 (24)$^{3/4}$ = 0,922 dt

Dari grafik respon spektrum, daerah gempa 3, bangunan diatas tanah keras didapat nilai C = 0,04

V = C. I. K. Wt = 0,04. 1. 1. 30648,8 = 12259,95 kN

Tabel 5.2 Hitungan Gaya Geser Tingkat

Lantai	hi (m)	Wi (kN)	Wi.hi	Fi,tot (kN)	Fi,x (kN)
6	24	4176.67	100240.08	294.058127	49.00968783
5	20	5294.47	105889.4	310.630624	51.77177072
4	16	5294.47	84711.52	248.504499	41.41741658
3	12	5294.47	63533.64	186.378375	31.06306243
2	8	5294.47	42355.76	124.25225	20.70870829
1	4	5294.47	21177.88	62.1261249	10.35435414
		ΣWi.hi	417908.28		

$$\text{Fi, total} = \frac{Wi.hi}{\sum Wi.hi} V \quad \text{.....(pers. 3.3)}$$

$$\text{Fi,x} = \frac{Fi,total}{6}$$

5.1.3 Kombinasi Pembebanan

Kombinasi beban terdiri dari beban gravitasi dan beban gempa. Karena bangunan simetris, maka beban gempa hanya dihitung dari satu sisi yaitu dari sisi kiri. Kombinasi pembebanan yang dipakai adalah seperti tabel 5.3.

Tabel 5.3 Kombinasi Beban

Combo	Kombinasi
Combo1	1.4D
Combo2	1.2D+1.6L
Combo3	1.2D+0.5L+E
Combo4	1.2D+0.5L-E
Combo5	0.9D+E
Combo6	0.9D-E
Combo7	D+L
Combo8	D+E
Combo9	D-E
Combo10	D+L+E
Combo11	D+L-E

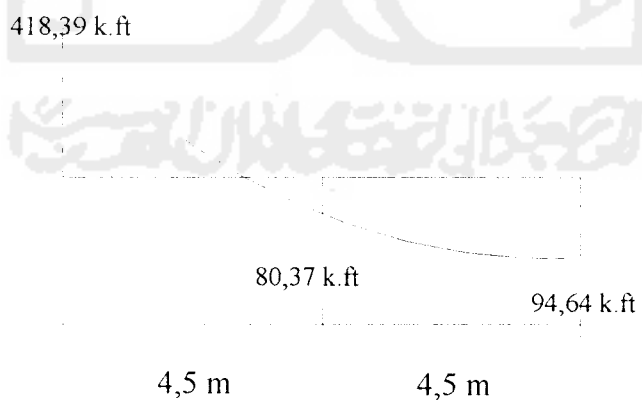
5.2 Perencanaan Balok

5.2.1 Perencanaan Balok Portal 18 Lantai

Portal Tepi

a. Metode ASD (balok lantai 1)

Kombinasi beban gempa dan gravitasi



Gambar 5.4 Bending Momen

Bentang yang terjadi lengkung ganda *(double curvature)*

Mu = 418,39 k.ft (lampiran 7, portal 18 lantai)

Mu tengah bentang = 80,37 k.ft (lampiran 7, portal 18 lantai)

$$Cb = 1{,}75 + 1{,}05.\left(\frac{80{,}37}{418{,}39}\right) + 0{,}3.\left(\frac{80{,}37}{418{,}39}\right)^2 = 1{,}96 \quad \text{(pers. 3.8)}$$

Coba W21x93 (r_T = 2,17; Sx = 2,76; bf = 8,42; $\frac{d}{Af}$ = 2,76; $\frac{bf}{2.tf}$ = 4,5; $\frac{d}{tw}$ = 37,3)

Lb = 4,5 m = 14,76 ft

$$Lc = \frac{76.bf}{12.\sqrt{fy}} = \frac{76.8{,}42}{12.\sqrt{36}} = 8{,}9 \text{ ft} \quad \text{(pers. 3.25)}$$

$$Lc = \frac{20000}{12.fy.\frac{d}{Af}} = \frac{20000}{12.36.2{,}76} = 16{,}77 \text{ ft} \quad \text{(pers. 3.26)}$$

Nilai Lc diambil yang terkecil = 8,9 ft

$$Lu = \frac{20000}{12.fy.\frac{d}{Af}} = 16{,}77 \text{ ft} \quad \text{(pers. 3.29)}$$

$$Lu = \frac{r_T}{12}\sqrt{\frac{102000.Cb}{fy}} = \frac{2{,}17}{12}\sqrt{\frac{102000.1{,}96}{36}} = 13{,}47 \text{ ft} \quad \text{(pers. 3.30)}$$

Nilai Lu diambil yang terbesar = 16,77 ft

Lb = 14,76 ft < Lu = 16,77 ft

> Lc = 8,9 ft

Fb = 0,6.fy = 0,6. 36 = 21,6 ksi (pers. 3.28)

Tegangan yang terjadi fb = $\frac{Mu}{Sx} = \frac{418{,}39.12}{192} = 26{,}14$ ksi

Karena terdapat beban gempa, maka nilai Fb boleh dinaikkan sebesar 1/3 kali nilai Fb semula.(AISC – ASD)

1,33 Fb = 1,33. 21,6 = 28,73 ksi > fb = 26,14 → **Aman**

$\frac{28,73}{26,14} = 1,1 < 1,25$ (sesuai dengan syarat yang kami tentukan)

M tersedia = 28,73. 192 = 5516,16 k.in = 459,7 k.ft

Bentang yang terjadi lengkung tunggal *(single curvature)*

Mu = 94,64 k.ft

Mu tengah bentang = 80,37 k.ft

$$Cb = 1,75 - 1,05\left(\frac{80,37}{94,64}\right) + 0,3.\left(\frac{80,37}{94,64}\right)^2 = 1,07$$

Dipakai profil W21x93 (sama dengan bentang yang terjadi *double curvature*)

Lc = 8,9 ft

$$Lu = \frac{20000}{12.fy.\frac{d}{Af}} = 16,77 \text{ ft}$$

$$Lu = \frac{r_T}{12}\sqrt{\frac{102000.Cb}{fy}} = \frac{2,17}{12}\sqrt{\frac{102000.1,07}{36}} = 9,96 \text{ ft}$$

Nilai Lu diambil yang terbesar = 16,77 ft

Lb = 14,76 ft < Lu = 16,77 ft

> Lc = 8,9 ft

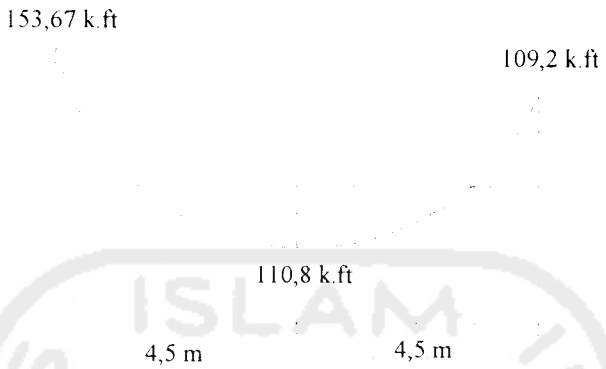
Fb = 0,6.fy = 21,6 ksi

1,33 Fb pakai = 1,33. 21,6 = 28,73 ksi

Tegangan yang terjadi $fb = \frac{Mu}{Sx} = \frac{94,64.12}{192} = 5,91$ ksi

1,33 Fb = 28,73 ksi > fb = 5,91 ksi → **Aman**

Beban Gravitasi



Gambar 5.5 Bending Momen

Mu = 153,67 k.ft (lampiran 7, portal 18 lantai)

Mu tengah bentang = 110,8 k.ft (lampiran 7, portal 18 lantai)

$$Cb = 1{,}75 + 1{,}05.\left(\frac{110{,}8}{153{,}67}\right) + 0{,}3.\left(\frac{110{,}8}{153{,}67}\right)^2 = 2{,}66 > 2{,}3$$

Cb pakai = 2,3

Dipakai profil W21x93

Lc = 8,9 ft

$$Lu = \frac{20000}{12.fy.\frac{d}{Af}} = 16{,}77 \text{ ft}$$

$$Lu = \frac{r_T}{12}\sqrt{\frac{102000.Cb}{fy}} = 14{,}6 \text{ ft}$$

Nilai Lu diambil yang terbesar = 16,77 ft

Lc = 8,9 ft < Lb = 14,76 ft < Lu = 16,77 ft

Fb = 0,6.fy = 21,6 ksi

Tegangan yang terjadi fb = $\frac{Mu}{Sx} = \frac{153{,}67.12}{192}$ = 9,6 ksi

Fb = 21,6 ksi > fb = 9,6 ksi → **Aman**

Kuat tarik yang tersedia

P aksial balok = 6,64 kip (batang tarik)

L = 9 m = 354,33 in

Profil balok W21x93 (Ag = 27,2 in^2 , rx = 8,7 in; ry = 1,84 in)

Kuat tarik yang tersedia T = 0,6. fy. Ag

T = 0,6. fy. Ag = 0,6. 36. 27,2 = 587,52 kip > P = 6,64 kip → **Aman**

Kontrol defleksi

Dari program SAP 2000, didapatkan defleksi untuk profil balok W21x93 pada bagian tengah bentang adalah 1,5 cm.

Maksimum defleksi yang diijinkan = $\frac{L}{360} = \frac{9}{360}$ = 0,025 m = 2,5 cm > 1,5 cm

Jadi profil balok W21x93 dapat digunakan.

b. Metode LRFD

424,19 k.ft

84,45 k.ft

86,81 k.ft

4,5 m 4,5 m

Gambar 5.6 Bending Momen

Bentang yang terjadi lengkung ganda *(double curvature)*

Mu = 424,19 k.ft (lampiran 7, portal 18 lantai)

Mu tengah bentang = 84,45 k.ft (lampiran 7, portal 18 lantai)

$$Cb = 1,75 + 1,05.\left(\frac{84,45}{424,19}\right) + 0,3.\left(\frac{84,45}{424,19}\right)^2 = 1,97$$

Dipakai profil W21x68 (ry = 1,8; Zx = 160; X_1 = 2000; X_2 = 10900; Sx = 140)

$$Lp = \frac{300.r_y}{\sqrt{fy}} = \frac{300.1,8}{\sqrt{36}} = 90 \text{ in}$$

$$Lr = \frac{r_y.X_1}{(fy - fr)}\sqrt{1+\sqrt{1+X_2.(fy-fr)^2}} = \frac{1,8.2000}{(36-10)}\sqrt{1+\sqrt{1+10900.10^{-6}.(36-10)^2}}$$

= 273,18 in.....(pers. 3.7)

Lb = 4,5 m = 177,165 in

Lp = 90 in < Lb = 177,165 in < Lr = 273,18 in

Mp = Zx. Fy = 160. 36 = 5760 k.in.....(pers. 3.5)

Mr = (fy – fr). Sx = (36 – 10). 140 = 3640 k.in

$$Mn = Cb.\left\{Mp - (Mp - Mr).\left[\frac{Lb - Lp}{Lr - Lp}\right]\right\} \leq Mp \quad \text{.....(pers. 3.6)}$$

$$= 1{,}97.\left\{5760 - (5760 - 3640).\left[\frac{177{,}165 - 90}{273{,}18 - 90}\right]\right\} = 9360 \text{ k.in} > Mp = 5760 \text{ k.in}$$

Mn pakai = 5760 k.in = 480 k.ft

0,9.Mn = 0,9. 5760 = 5184 k.in = 432 k.ft > 424,19 k.ft → **Aman**

$\frac{432}{424{,}19} = 1{,}02 < 1{,}25$ (sesuai dengan batasan yang kami tentukan)

Bentang yang terjadi lengkung tunggal

Mu = 86,81 k.ft

Mu tengah bentang = 84,45 k.ft

$$Cb = 1{,}75 - 1{,}05.\left(\frac{84{,}45}{86{,}81}\right) + 0{,}3.\left(\frac{84{,}45}{86{,}81}\right)^2 = 1{,}01$$

Dipakai profil W21x68

Lp = 90 in

Lr = 273,18 in

Lb = 177,165 in

Mp = 5760 k.in

Mr = 3640 k.in

Lp = 90 in < Lb = 177,165 in < Lr = 273,18 in

$$Mn = Cb.\left\{Mp - (Mp - Mr).\left[\frac{Lb - Lp}{Lr - Lp}\right]\right\} = 4798{,}7 \text{ k.in} < Mp = 5760 \text{ k.in}$$

Mn pakai = 4798,7 k.in

0,9.Mn = 4318,85 k.in = 359,9 k.ft > Mu = 86,81 k.ft → **Aman**

Kontrol Defleksi

Dari program SAP 2000 didapatkan defleksi profil balok W21x68 di tengah bentang adalah 2 cm.

Maksimum defleksi yang diijinkan adalah = $\frac{9}{360}$ = 0,025 m = 2,5 cm > 2 cm

Profil balok W21x68 dapat digunakan.

Kuat tarik yang tersedia

P aksial balok = 7,9 kip (batang tarik)

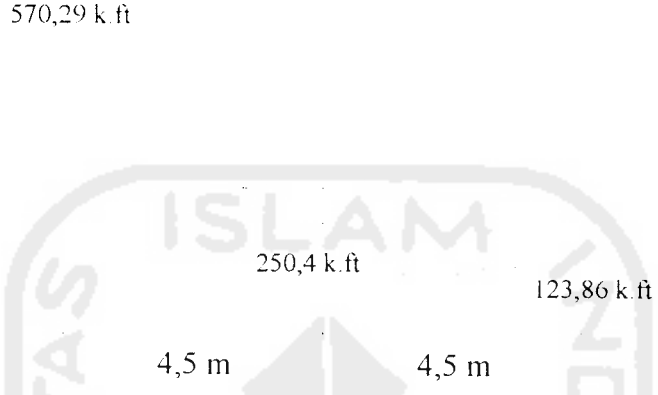
Profil balok W21x68 (Ag = 20 in^2)

Kuat tarik yang tersedia = 0,9. fy. Ag = 0,9. 36. 20 = 648 kip > P = 7,9 kip

Portal Tengah

a. Metode ASD (lantai 1)

Kombinasi beban gravitasi dan gempa



Gambar 5.7 Bending Momen

$$Cb = 1{,}75 + 1{,}05.\left(\frac{250{,}4}{570{,}29}\right) + 0{,}3.\left(\frac{250{,}4}{570{,}29}\right)^2 = 2{,}26$$

Coba profil W 27x94 (bf = 9,99; Sx = 243; $\frac{d}{Af} = 3{,}62; \frac{bf}{2.tf} = 6{,}7; \frac{d}{tw} = 54{,}9$;

$r_T = 2{,}53$)

$$Lc = \frac{76.bf}{12.\sqrt{fy}} = 10{,}54 \text{ ft}$$

$$Lc = \frac{20000}{12.fy.\frac{d}{Af}} = 12{,}79 \text{ ft}$$

Dipakai Lc = 10,54 ft

$$Lu = \frac{20000}{12.fy.\frac{d}{Af}} = 12{,}79 \text{ ft}$$

$$Lu = \frac{r_T}{12}\sqrt{\frac{102000.Cb}{fy}} = 16{,}87 \text{ ft}$$

Dipakai Lu = 16,87 ft

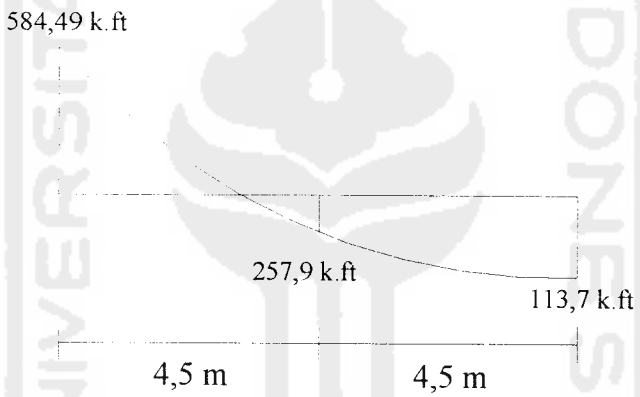
Lc = 10,54 ft < Lb = 14,76 ft < Lu = 16,87 ft

Fb = 0,6. fy = 0,6. 36 = 21,6 ksi

1,33. Fb = 28,73 ksi

Tegangan yang terjadi $fb = \frac{M}{Sx} = \frac{570{,}29.12}{243} = 28{,}1$ ksi < 28,73 → **Aman**

b. Metode LRFD



Gambar 5.8 Bending Momen

$$Cb = 1{,}75 + 1{,}05.\left(\frac{257{,}9}{584{,}49}\right) + 0{,}3.\left(\frac{257{,}9}{584{,}49}\right)^2 = 2{,}27$$

Coba profil W27x84 (Zx = 244; X1 = 1570; X2 = 31100; ry = 2,07;

$$\frac{bf}{2tf} = 7{,}8; \frac{d}{tw} = 52{,}7 \text{ ; Sx} = 213 \text{)}$$

$$Lp = \frac{300.ry}{\sqrt{fy}} = 8{,}62 \text{ ft}$$

Lr = 24,85 ft

Lp = 8,62 ft < Lb = 14,76 ft < Lr = 24,85 ft

Mp = Zx. fy = 244. 36 = 732 k.ft

Mr = (fy – fr). Sx = 461,5 k.ft

Mn = Cb. $\left\{Mp-(Mp-Mr).\left[\frac{Lb-Lp}{Lr-Lp}\right]\right\}$ = 1429,3 k.ft > Mp = 732 k.ft

Mn pakai = 732 k.ft

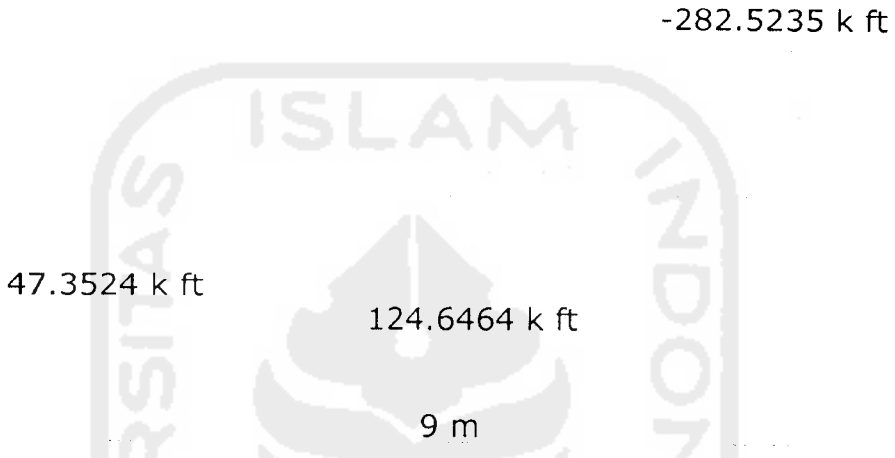
0,9.Mn = 0,9. 732 = 658,8 k.ft > 584,49 k.ft → **Aman**

5.2.2 Perencanaan Balok Portal 6 Lantai

Portal Tepi

a. Metode ASD (balok lantai 1)

Kombinasi beban gempa dan gravitasi



Gambar 5.9 Bending Momen

Bentang yang terjadi lengkung ganda *(double curvature)*

Mu = 282,5235 k.ft (lampiran 3, portal 6 lantai)

Mu tengah bentang = 124,6464 k.ft (lampiran 3, portal 6 lantai)

$$Cb = 1{,}75 + 1{,}05.\left(\frac{124{,}6464}{282{,}5235}\right) + 0{,}3.\left(\frac{124{,}6464}{282{,}5235}\right)^2 = 2{,}27 \quad \text{.....(pers. 3.8)}$$

Coba W14X82 (r_T =2,74; Sx=123; bf = 10,13; $\frac{d}{Af} = 1{,}65$; $\frac{bf}{2.tf} = 5{,}9$; $\frac{d}{tw} = 28{,}1$)

Lb = 4,5 m = 14,76 ft

$$Lc = \frac{76.bf}{12.\sqrt{fy}} = \frac{76.10,13}{12.\sqrt{36}} = 9,1 \text{ ft} \quad \text{.....(pers. 3.25)}$$

$$Lc = \frac{20000}{12.fy.\frac{d}{Af}} = \frac{20000}{12.36.1,65} = 28,1 \text{ ft} \quad \text{.....(pers. 3.26)}$$

Nilai Lc diambil yang terkecil = 9,1 ft

$$Lu = \frac{20000}{12.fy.\frac{d}{Af}} = 28,1 \text{ ft} \quad \text{.....(pers. 3.29)}$$

$$Lu = \frac{r_T}{12}\sqrt{\frac{102000.C_b}{fy}} = \frac{2,74}{12}\sqrt{\frac{102000.2,27}{36}} = 18,31 \text{ ft} \quad \text{.....(pers. 3.30)}$$

Nilai Lu diambil yang terbesar = 28,1 ft

Lb = 14,764 ft > Lc = 9,18 ft

< Lu = 28,1 ft

Fb = 0,6 fy = 21,6 ksi .....(pers. 3.28)

Tegangan yang terjadi, $fb = \frac{Mu}{Sx} = \frac{282,5235 \cdot 12}{123} = 27,56$ ksi

Karena terdapat beban gempa, maka nilai Fb pakai boleh dinaikkan sebesar 1/3 kali nilai Fb semula. .(AISC – ASD)

1,33 Fb = 1,33. 21,6 = 28,73 ksi > fb = 27,56 ksi → **Aman**

$\frac{28,73}{27,56} = 1,04 < 1,25$ (sesuai dengan syarat yang telah ditentukan)

M tersedia = 28,73. 123 = 3533,79 k.in = 294,48 k.ft

Bentang yang terjadi lengkung tunggal *(single curvature)*

Mu = 47,3524 k.ft (lampiran 3, portal 6 lantai)

Mu tengah bentang = 124,6464 k.ft (lampiran 3, portal 6 lantai)

$$Cb = 1{,}75 - 1{,}05\left(\frac{47{,}3524}{124{,}6464}\right) + 0{,}3\left(\frac{47{,}3524}{124{,}6464}\right)^2 = 1.39$$

Dipakai profil W14X82 (sama dengan bentang yang terjadi *double curvature*)

Lc = 9,1 ft

$$Lu = \frac{20000}{12.fy.\frac{d}{Af}} = 28{,}1 \text{ ft}$$

$$Lu = \frac{r_T}{12}\sqrt{\frac{102000.Cb}{fy}} = \frac{2{,}74}{12}\sqrt{\frac{102000.1{,}39}{36}} = 14{,}33 \text{ ft}$$

Nilai Lu diambil yang terbesar = 28,1 ft

Lb = 14,764 ft > Lc = 9,1 ft

< Lu = 28,1 ft

Fb = 0,6 fy = 21,6 ksi

Tegangan yang terjadi $fb = \frac{Mu}{Sx} = \frac{47.3524.12}{123} = 4{,}62$ ksi

Karena terdapat beban gempa, maka nilai Fb pakai boleh dinaikkan sebesar 1/3 kali nilai Fb semula.

1,33 Fb pakai = 1,33. 21, 6 = 28,73 ksi > fb = 4,62 → **Aman**

Beban Gravitasi

-162.07 k ft

-102.7973 k ft

109.8096 k ft

9 m

Gambar 5.10 Bending Momen

Mu = 162,07 k.ft (lampiran 3, portal 6 lantai)

Mu tengah bentang = 109,8096 k.ft (lampiran 3, portal 6 lantai)

$$Cb = 1{,}75 + 1{,}05.\left(\frac{109{,}8096}{162{,}07}\right) + 0{,}3.\left(\frac{109{,}8096}{162{,}07}\right)^2 = 2.6 > 2{,}3$$

Cb pakai = 2,3

Dipakai profil W14X82

Lc = 9,1 ft

$$Lu = \frac{20000}{12.fy.\frac{d}{Af}} = 28{,}1 \text{ ft}$$

$$Lu = \frac{r_T}{12}\sqrt{\frac{102000.Cb}{fy}} = 18{,}43 \text{ ft}$$

Nilai Lu diambil yang terbesar = 28,1 ft

Lb = 14,764 ft > Lc = 9,1 ft

< Lu = 28,1 ft

Fb = 0,6 fy = 21,6 ksi

Tegangan yang terjadi, $fb = \frac{Mu}{Sx} = \frac{162{,}07 \cdot 12}{123} = 15{,}81$ ksi

Fb = 21,6 ksi > fb = 15,81 ksi → **Aman**

Kuat tarik yang tersedia

P aksial balok = 7,41 kip (batang tarik)

L = 9 m = 354,33 in

Profil balok W14X82 (Ag = 24,1 in^2 , rx = 6,05 in; ry = 2,48 in)

Kuat tarik yang tersedia T = 0,6. fy. Ag

T = 0,6. fy. Ag = 0,6. 36. 24,1 = 520,56 kip > P = 7,41 kip → **Aman**

Kontrol defleksi

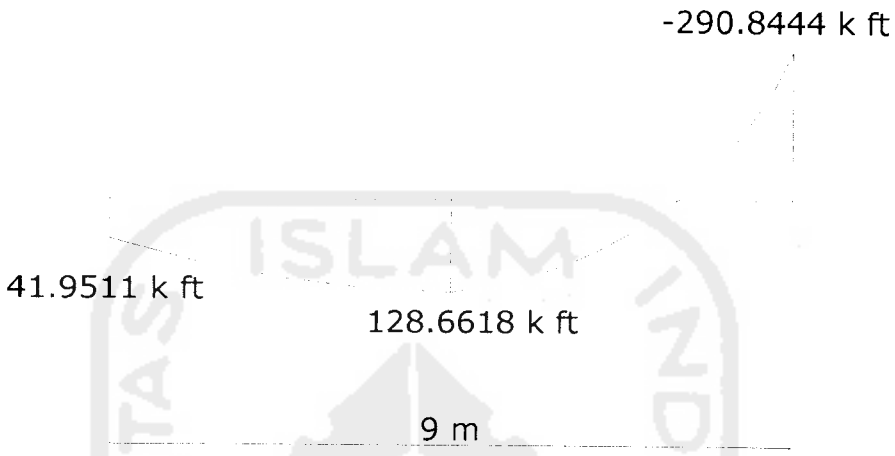
Dari progran SAP 2000, didapatkan defleksi untuk profil balok W14X82 pada bagian tengah bentang adalah 0,5 cm.

Maksimum defleksi yang diijinkan = $\frac{L}{360} = \frac{9}{360} = 0{,}025$ m = 2,5 cm > 0,5 cm

Jadi profil balok W14X82 dapat digunakan.

b. Metode LRFD

Kombinasi beban gempa dan gravitasi



Gambar 5.11 Bending Momen

Bentang yang terjadi lengkung ganda *(double curvature)*

Mu = 290,8444 k.ft (lampiran 3, portal 6 lantai)

Mu tengah bentang = 128,6618 k.ft (lampiran 3, portal 6 lantai)

$$Cb = 1{,}75 + 1{,}05.\left(\frac{128{,}6618}{290{,}8444}\right) + 0{,}3.\left(\frac{128{,}6618}{290{,}8444}\right)^2 = 2{,}27$$

Coba profil W 14 X 68 (rx = 6,01 ; Sx = 103 ; Zx = 115 ; X_1 = 3020 ; X_2 = 1650 ; ry = 2,46 ; $\frac{bf}{2tf}$ = 7,0 ; $\frac{h}{tw}$ = 27,5).

$$Lp = \frac{300 \cdot r_y}{\sqrt{fy}} = \frac{300 \cdot 2{,}46}{\sqrt{36}} = 123 \text{ in}$$

$$Lr = \frac{r_y . X_1}{(fy - fr)} \sqrt{1 + \sqrt{1 + X_2 (fy - fr)^2}} \quad \text{.....(pers. 3.7)}$$

$$= \frac{2,46 \cdot 3020}{(36 - 10)} \sqrt{1 + \sqrt{1 + 1650.10^{-6} \cdot (36 - 10)^2}}$$

= 447,66 in

Lb = 4,5 m = 177,165 in > Lp = 123 in

< Lr = 447,66 in

Mp = Zx. Fy = 115. 36 = 4140 k.in .....(pers. 3.5)

Mr = (fy – fr). Sx = (36 – 10). 103 = 2678 k.in

$$Mn = Cb. \left[Mp - (Mp - Mr) \left\{ \frac{Lb - Lp}{Lr - Lp} \right\} \right] \leq Mp \quad \text{.....(pers. 3.6)}$$

$$= 2,27. \left[4140 - (4140 - 2678) \left\{ \frac{177,165 - 123}{447,66 - 123} \right\} \right]$$

= 8844,11 k.in > Mp = 4140 k.in

$$\text{Mn pakai} = Mp = 4140 \text{ kip in} = \frac{4140}{12} = 345 \text{ k ft}$$

$0,9\ Mn = 0,9 \cdot 345 = 310,5$ k ft > Mu = 290,8444 k ft → **Aman**

$\frac{310,5}{290,8444} = 1,07 < 1,25$ (sesuai dengan syarat yang telah ditentukan)

Batang yang terjadi lengkung tunggal

Mu = 41,9511 k.ft

Mu tengah bentang = 128,6618 k.ft

$$Cb = 1{,}75 - 1{,}05.\left(\frac{41{,}9511}{128{,}6618}\right) + 0{,}3.\left(\frac{41{,}9511}{128{,}6618}\right)^2 = 1{,}44$$

Dipakai profil W 14 X 68

Lb = 4,5 m = 177,165 in > Lp = 123 in

< Lr = 447,66 in

Mp = 4140 k.in

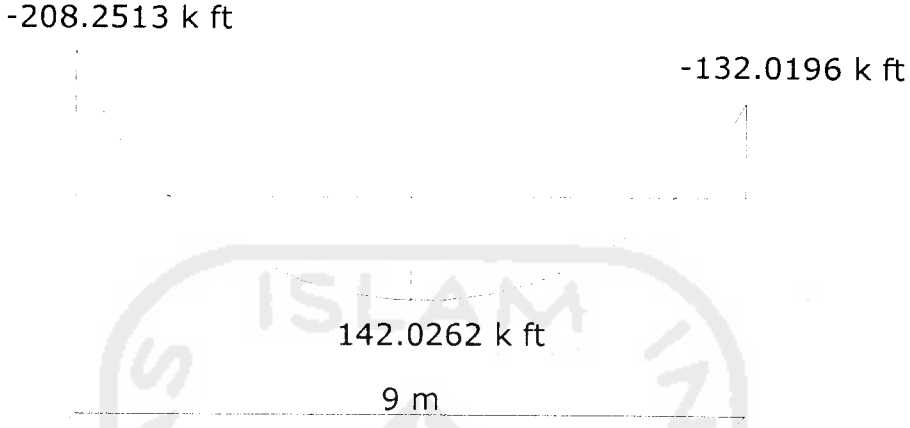
Mr = 2678 k.in

$$Mn = 1{,}44.\left\{4140 - (4140 - 2678).\left[\frac{177{,}165 - 123}{447{,}66 - 123}\right]\right\} = 5610{,}36 \text{ k.in} > 4140 \text{ k.in}$$

$$\text{Mn pakai} = Mp = 4140 \text{ kip in} = \frac{4140}{12} = 345 \text{ k ft}$$

$0{,}9\ Mn = 0{,}9 \cdot 345 = 310{,}5$ k ft > Mu = 41,9511 k ft → **Aman**

Beban Gravitasi



Gambar 5.12 Bending Momen

Mu = 208,2513 k.ft (lampiran 3, portal 6 lantai)

Mu tengah bentang = 142,0262 k.ft (lampiran 3, portal 6 lantai)

$$Cb = 1{,}75 + 1{,}05.\left(\frac{142{,}0262}{208{,}2513}\right) + 0{,}3.\left(\frac{142{,}0262}{208{,}2513}\right)^2 = 2{,}6 > 2{,}3$$

Cb pakai = 2,3

Dipakai profil W 14 X 68

Lb = 4,5 m = 177,165 in > Lp = 123 in

< Lr = 447,66 in

Mp = 4140 k.in

Mr = 2678 k.in

$$Mn = 2{,}3.\left\{4140 - (4140 - 2678)\left[\frac{177{,}165 - 123}{447{,}66 - 123}\right]\right\} = 8960{,}99 \text{ k.in} > 4140 \text{ k.in}$$

Mn pakai = Mp = 4140 kip in = $\frac{4140}{12}$ = 345 k ft

0,9 Mn = 0,9 · 345 = 310,5 k ft > Mu = 208,2513 k ft → **Aman**

Kuat tarik yang tersedia

P aksial balok = 4,37 kip (batang tarik)

Profil balok W14x68 (Ag = 20 in^2)

Kuat tarik yang tersedia = 0,9. fy. Ag = 0,9. 36. 20 = 648 kip > P = 4,37 kip

Kontrol defleksi

Dari program SAP 2000 untuk profil balok W14X68 didapatkan defleksi pada tengah bentang adalah 0,5 cm.

Maksimum defleksi yang boleh terjadi = $\frac{L}{360}$ = 0,025 m = 2,5 cm > 0,5 cm

Jadi profil balok W14X68 dapat dipakai.

Portal Tengah

a. Metode ASD (balok lantai 1)

Kombinasi beban gempa dan gravitasi

Kombinasi beban gempa dan gravitasi

-384.2684 k ft

-13.9597 k ft

199.8977 k ft

9 m

Gambar 5.13 Bending Momen

Mu = 384,2684 k.ft (lampiran 4, portal 6 lantai)

Mu tengah bentang = 199,8977 k.ft (lampiran 4, portal 6 lantai)

$$Cb = 1{,}75 + 1{,}05.\left(\frac{199{,}8977}{384{,}2684}\right) + 0{,}3.\left(\frac{199{,}8977}{384{,}2684}\right)^2 = 2{,}38 > 2.3 \quad \text{.....(pers. 3.8)}$$

Cb pakai = 2,3

Coba W14X109 (r_T =4,02; Sx=173; bf = 14,605; $\frac{d}{Af}$ = 1.14; $\frac{bf}{2.tf}$ = 8,5; $\frac{d}{tw}$ = 27,3)

Lb = 4,5 m = 14,76 ft

$$Lc = \frac{76.bf}{12.\sqrt{fy}} = \frac{76.14{,}605}{12.\sqrt{36}} = 15{,}42 \text{ ft} \quad \text{.....(pers. 3.25)}$$

$$Lc = \frac{20000}{12.fy.\frac{d}{Af}} = \frac{20000}{12.36.1,14} = 40,61 \text{ ft} \quad \text{.....(pers. 3.26)}$$

Nilai Lc diambil yang terkecil = 15,42 ft

$$Lu = \frac{20000}{12.fy.\frac{d}{Af}} = 40,61 \text{ ft} \quad \text{.....(pers. 3.29)}$$

$$Lu = \frac{r_T}{12}\sqrt{\frac{102000.Cb}{fy}} = \frac{2,74}{12}\sqrt{\frac{102000.2,27}{36}} = 27,04 \text{ ft} \quad \text{.....(pers. 3.30)}$$

Nilai Lu diambil yang terbesar = 40,61 ft

Lb = 14,764 ft < Lc = 15,42 ft

$$\frac{bf}{2tf} = 8,5 \leq \frac{65}{\sqrt{fy}} = \frac{65}{\sqrt{36}} = 10,83$$

$$\frac{d}{tw} = 27,3 \leq \frac{640}{\sqrt{fy}} = \frac{640}{\sqrt{36}} = 106,67$$

Jadi penampang adalah kompak.

Fb = 0,66 fy = 23,76 ksi .....(pers. 3.28)

Tegangan yang terjadi, $fb = \frac{Mu}{Sx} = \frac{384,2684 \cdot 12}{173} = 26,68$ ksi

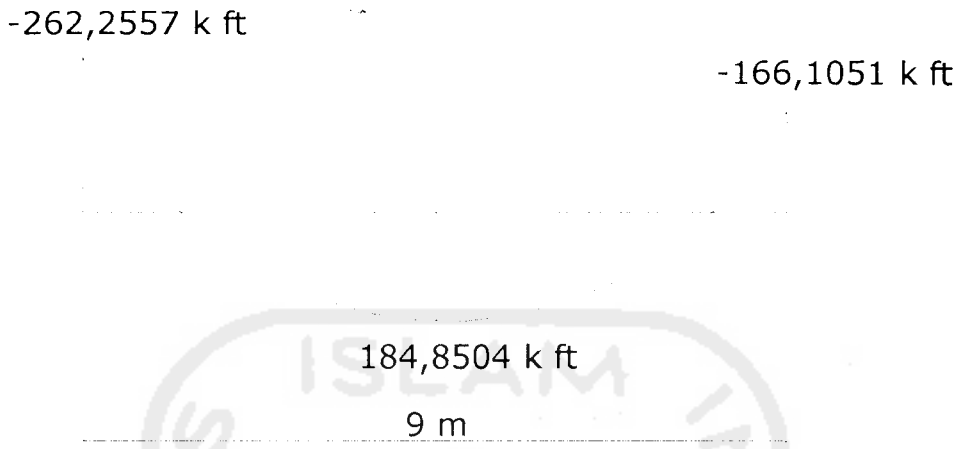
Karena terdapat beban gempa, maka nilai Fb pakai boleh dinaikkan sebesar 1/3 kali nilai Fb semula. .(AISC – ASD)

1,33 Fb = 1,33. 23,76 = 31,6 ksi > fb = 26,68 ksi → **Aman**

$\frac{31,6}{26,68} = 1,18 < 1,25$ (sesuai dengan syarat yang telah ditentukan)

M tersedia = 31,6. 173 = 5466,8 k.in = 455,57 k.ft

Beban Gravitasi



Gambar 5.14 Bending Momen

Mu = 262,2557 k.ft (lampiran 4, portal 6 lantai)

Mu tengah bentang = 184,8504 k.ft (lampiran 4, portal 6 lantai)

$$Cb = 1{,}75 + 1{,}05.\left(\frac{184{,}8504}{262{,}2557}\right) + 0{,}3.\left(\frac{184{,}8504}{262{,}2557}\right)^2 = 2.64 > 2{,}3$$

Cb pakai = 2,3

Dipakai profil W14X109

Lc = 15,42 ft

$$Lu = \frac{20000}{12.fy.\frac{d}{Af}} = 40{,}61 \text{ ft}$$

$$Lu = \frac{r_T}{12}\sqrt{\frac{102000.Cb}{fy}} = 27{,}04 \text{ ft}$$

Nilai Lu diambil yang terbesar = 40,61 ft

Lb = 14,764 ft < Lc = 15,42 ft

$$\frac{bf}{2tf} = 8,5 \leq \frac{65}{\sqrt{fy}} = \frac{65}{\sqrt{36}} = 10,83$$

$$\frac{d}{tw} = 27,3 \leq \frac{640}{\sqrt{fy}} = \frac{640}{\sqrt{36}} = 106,67$$

Jadi penampang adalah kompak.

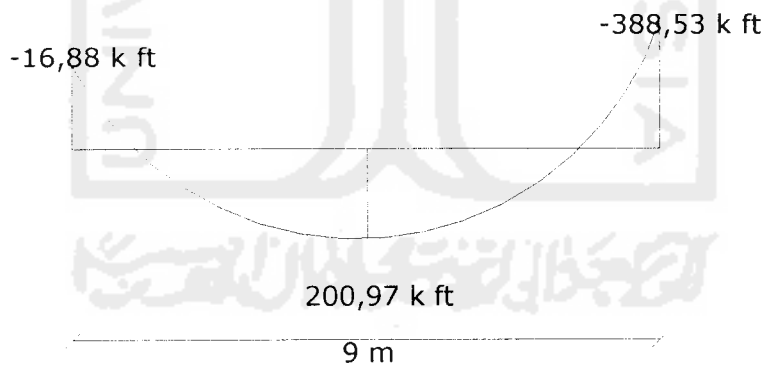
Fb = 0,66 fy = 23,76 ksi .....(pers. 3.28)

Tegangan yang terjadi, $fb = \frac{Mu}{Sx} = \frac{262,2557 \cdot 12}{173} = 18,19$ ksi

Fb = 23,76 ksi > fb = 18,19 ksi → **Aman**

b. Metode LRFD

Kombinasi beban gempa dan gravitasi



Gambar 5.15 Bending Momen

Mu = 388,53 k.ft (lampiran 4, portal 6 lantai)

Mu tengah bentang = 200,97 k.ft (lampiran 4, portal 6 lantai)

$$Cb = 1{,}75 + 1{,}05.\left(\frac{200{,}97}{388{,}53}\right) + 0{,}3.\left(\frac{200{,}97}{388{,}53}\right)^2 = 2{,}37 > 2{,}3$$

Coba profil W 14 X 90 (rx = 6,14 ; Sx = 143 ; Zx = 157 ; X_1 = 2900 ; X_2 = 1750

; ry = 3,7 ; $\frac{bf}{2tf} = 10{,}2$; $\frac{h}{tw} = 25{,}9$).

$$Lp = \frac{300 \cdot r_y}{\sqrt{fy}} = \frac{300 \cdot 3{,}7}{\sqrt{36}} = 185 \text{ in}$$

$$Lr = \frac{r_y . X_1}{(fy - fr)}\sqrt{1 + \sqrt{1 + X_2 (fy - fr)^2}} \quad \text{.....(pers. 3.7)}$$

$$= \frac{3{,}7 \cdot 2900}{(36 - 10)}\sqrt{1 + \sqrt{1 + 1750.10^{-6} \cdot (36 - 10)^2}}$$

= 649,58 in

Lb = 4,5 m = 177,165 in < Lp = 185 in

< Lr = 649,58 in

$$\frac{bf}{2tf} = 10{,}2 \le \frac{65}{\sqrt{fy}} = \frac{65}{\sqrt{36}} = 10{,}83$$

$$\frac{h}{tw} = 25{,}9 \le \frac{640}{\sqrt{fy}} = \frac{640}{\sqrt{36}} = 106{,}67$$

Jadi penampang adalah kompak

Mn = Mp = Zx. Fy = 157. 36 = 5652 k.in = 471 k.ft .....(pers. 3.5)

0,9 Mn = 0,9 · 471 = 423,9 k ft > Mu = 388,53 k ft → **Aman**

$\frac{423{,}9}{388{,}53} = 1{,}09 < 1{,}25$ (sesuai dengan syarat yang telah ditentukan)

Beban Gravitasi

Gambar 5.16 Bending Momen

Mu = 342,2446 k.ft (lampiran 4, portal 6 lantai)

Mu tengah bentang = 242,3317 k.ft (lampiran 4, portal 6 lantai)

$$Cb = 1{,}75 + 1{,}05.\left(\frac{142{,}0262}{208{,}2513}\right) + 0{,}3.\left(\frac{142{,}0262}{208{,}2513}\right)^2 = 2{,}64 > 2{,}3$$

Cb pakai = 2,3

Dipakai profil W 14 X 90

Lb = 4,5 m = 177,165 in < Lp = 185 in

< Lr = 649,58 in

$$\frac{bf}{2tf} = 10{,}2 \leq \frac{65}{\sqrt{fy}} = \frac{65}{\sqrt{36}} = 10{,}83$$

$$\frac{h}{tw} = 25{,}9 \leq \frac{640}{\sqrt{fy}} = \frac{640}{\sqrt{36}} = 106{,}67$$

Jadi penampang adalah kompak

Mn = Mp = 471 k.ft

0,9 Mn = 0,9 · 471 = 423,9 k ft > Mu = 342,2446 k ft → **Aman**

$$\frac{423,9}{342,2446} = 1,24 < 1,25$$ (sesuai dengan syarat yang telah ditentukan)

5.3 Perencanaan Kolom

5.3.1 Perencanaan Kolom Portal 18 Lantai

a. Metode ASD (Portal Tepi, kolom lantai 1)

Kolom Eksterior

Akibat beban gravitasi dan gempa

Mu = 255,6 k.ft (lampiran 18, Portal 18 lantai)

Pu = 820,26 kip (lampiran 21, Portal 18 lantai)

Profil balok W21x93 (I = 2070 in^4 , L = 354,33 in)

Asumsi profil kolom W18x76 (I = 1330 in^4 , L = 157,48 in)

$$G_A = \frac{\Sigma\left(\frac{I}{L}\right)_{kolom}}{\Sigma\left(\frac{I}{L}\right)_{balok}} = \frac{2.\left(\frac{1330}{157,48}\right)}{\left(\frac{2070}{354,33}\right)} = 2,9 \quad \text{(pers. 3.39)}$$

G_B = 1,0 (jepit)

Dari grafik Johnson dan Moreland , untuk portal bergoyang didapatkan nilai k = 1,6

Dicoba profil W14x211 (bf = 15,8; r_T = 4,37; $\frac{d}{Af}$ = 0,64; Sx = 338; ry = 4,07;

rx = 6,55; A = 62; $\frac{bf}{2.tf}$ = 5,1; $\frac{d}{tw}$ = 16)

Lb = 4 m = 157,48 in

Tegangan yang terjadi :

$$fa = \frac{Pu}{A} = \frac{820,26}{62} = 13,23 \text{ ksi} \quad \text{(pers. 3.38)}$$

$$fbx = \frac{Mu}{Sx} = \frac{255,6.12}{338} = 9,07 \text{ ksi} \quad \text{(pers. 3.39)}$$

Tegangan desak ijin (Fa):

$$\frac{(k.L)_x}{rx} = \frac{1,6.157,48}{6,55} = 38,5$$

$$\frac{(k.L)_y}{ry} = \frac{1,6.157,48}{4,07} = 70 \rightarrow \text{dipakai}$$

Dari tabel AISC-ASD hal 3.16, dengan nilai $\frac{k.l}{r} = 70$ dan fy = 36 ksi didapatkan nilai Fa = 16,43 ksi

Tegangan ijin lentur (Fb):

$$Lc = \frac{76.bf}{12.\sqrt{fy}} = 16,7 \text{ ft} \quad \text{(pers. 3.25)}$$

$$Lc = \frac{20000}{12.fy.\frac{d}{Af}} = 72,33 \text{ ft} \quad \text{(pers. 3.26)}$$

Nilai Lc diambil yang terkecil = 16,7 ft

Lb = 157,48 in = 13,123 ft < Lc = 16,7 ft

$$\frac{bf}{2.tf} = 5,1 < \frac{65}{\sqrt{fy}} = 10,8$$

$$\frac{d}{tw} = 16 < \frac{640}{\sqrt{fy}} = 106,6$$

Penampang adalah kompak

Fbx = 0,66.fy = 0,66.36 = 23,76 ksi (pers. 3.24)

$$\frac{fa}{Fa} = \frac{13,23}{16,43} = 0,8 > 0,15$$

$$Fe'x = \frac{12.\pi^2.E}{23.\left(\frac{kx.Lx}{rx}\right)^2} = \frac{12.\pi^2.29000}{23.(38,5)^2} = 100,6 \text{ ksi}$$

Karena portal bergoyang maka Cmx = 0,85

$$\frac{Cmx}{1-\frac{fa}{Fe'x}} = \frac{0,85}{1-\frac{13,23}{100,6}} = 0,98 < 1,0 \rightarrow \text{dipakai } 1,0$$

Karena beban termasuk beban gempa maka Fa dan Fb boleh dinaikkan sebesar 1/3 kali nilai semula.(tabel AISC-ASD)

1,33.Fa = 1,33.16,43 = 21,85 ksi

1,33.Fbx = 1,33.23,76 = 31,6 ksi

Rumus AISC-ASD untuk $\frac{fa}{Fa} > 0,15$

$$\frac{fa}{Fa} + \frac{Cmx.fbx}{\left(1-\frac{fa}{Fe'x}\right).Fbx} < 1,0 \quad \text{.....(pers. 3.35)}$$

$$\frac{13,23}{21,85} + \frac{1.9,07}{31,6} = 0,9 < 1,0 \rightarrow \textbf{Aman}$$

$$\frac{fa}{0,6.fy} + \frac{fbx}{Fbx} < 1,0 \quad \text{.....(pers. 3.36)}$$

$$\frac{13,23}{0,6.36} + \frac{9,07}{31,6} = 0,9 < 1,0 \rightarrow \textbf{Aman}$$

Akibat beban gravitasi

Pu = 574,9 kip (lampiran 21, Portal 18 lantai)

Mu = 46 k.ft (lampiran 18, Portal 18 lantai)

Dipakai profil W14x211 (A = 62; Sx = 338)

Fa = 16,43 ksi

Fbx = 23,76 ksi

Fe'x = 100,6 ksi

Tegangan yang terjadi:

$$fa = \frac{574,9}{62} = 9,3 \text{ ksi}$$

$$fbx = \frac{46.12}{338} = 1,63 \text{ ksi}$$

$$\frac{Cmx}{1-\frac{fa}{Fe'x}} = \frac{0,85}{1-\frac{9,3}{100,6}} = 0,93 < 1,0 \rightarrow \text{dipakai } 1,0$$

$$\frac{fa}{Fa} = \frac{9,3}{16,43} = 0,6 > 0,15$$

Rumus AISC-ASD :

$$\frac{fa}{Fa} + \frac{Cmx.fbx}{\left(1-\frac{fa}{Fe'x}\right).Fbx} < 1,0$$

$$\frac{9,3}{16,43} + \frac{1.1,63}{23,76} = 0,63 < 1,0 \rightarrow \textbf{Aman}$$

$$\frac{fa}{0{,}6.fy} + \frac{fbx}{Fbx} < 1{,}0$$

$$\frac{9{,}3}{0{,}6.36} + \frac{1{,}63}{23{,}76} = 0{,}5 < 1{,}0 \rightarrow \textbf{Aman}$$

Jadi profil W14x211 dapat digunakan

Kolom Interior

Akibat beban gravitasi dan gempa

Pu = 829,64 kip (lampiran 23, Portal 18 lantai)

Mu = 267,4 k.ft (lampiran 19, Portal 18 lantai)

$$G_A = \frac{2.\left(\frac{1330}{157{,}48}\right)}{2.\left(\frac{2070}{354{,}33}\right)} = 1{,}5$$

G_B = 1,0 (jepit)

Dari grafik Johnson dan Moreland didapatkan nilai k = 1,4

Dicoba profil W14x233 (A= 68,5; bf = 15,89; ry= 4,1; rx = 6,63; Sx = 375;

r_T = 4,4; $\frac{d}{Af} = 0{,}59$; $\frac{bf}{2.tf} = 4{,}6$; $\frac{d}{tw} = 15$)

Tegangan yang terjadi:

$$fa = \frac{829{,}64}{68{,}5} = 12{,}11 \text{ ksi}$$

$$fbx = \frac{267{,}4.12}{375} = 8{,}55 \text{ ksi}$$

Tegangan desak ijin (Fa):

$$\frac{(k.L)_y}{ry} = \frac{1{,}4.157{,}48}{4{,}1} = 53{,}8$$

Dari tabel AISC-ASD didapatkan nilai Fa = 17,99 ksi

Teganagan lentur ijin (Fb):

$$Lc = \frac{76.bf}{12.\sqrt{fy}} = 16{,}8 \text{ ft}$$

$$Lc = \frac{20000}{12.fy.\frac{d}{Af}} = 78{,}47 \text{ ft}$$

Nilai Lc dipakai = 16,8 ft

Lb = 13,123 ft < Lc = 16,8 ft

$$\frac{bf}{2.tf} = 4{,}6 < \frac{65}{\sqrt{fy}} = 10{,}8$$

$$\frac{d}{tw} = 15 < \frac{640}{\sqrt{fy}} = 106{,}6$$

Penampang adalah kompak

Fb = 0,66.fy = 23,76 ksi

1,33.Fb = 31,6 ksi

Karena kolom interior dan bentang antar kolom sama, maka gaya aksial akibat gempa tidak berpengaruh. Yang berpengaruh hanya gaya aksial akibat beban gravitasi. Jadi Fa *tidak dikalikan* dengan 1,33.

$$\frac{kx.Lx}{rx} = \frac{1{,}4.157{,}48}{6{,}63} = 333{,}25$$

$$\text{Fe'x} = \frac{12.\pi^2.29000}{23.(33{,}25)^2} = 135 \text{ ksi}$$

$$\frac{Cmx}{\left(1-\frac{fa}{Fe'x}\right)} = \frac{0{,}85}{\left(1-\frac{12{,}11}{135}\right)} = 0{,}93 < 1{,}0 \rightarrow \text{dipakai } 1{,}0$$

$$\frac{fa}{Fa} = \frac{12{,}11}{17{,}99} = 0{,}67 > 0{,}15$$

$$\frac{fa}{Fa} + \frac{Cmx.fbx}{\left(1-\frac{fa}{Fe'x}\right).Fbx} = \frac{12{,}11}{17{,}99} + \frac{1.8{,}55}{31{,}6} = 0{,}94 < 1{,}0 \rightarrow \textbf{Aman}$$

$$\frac{fa}{0{,}6.fy} + \frac{fbx}{Fbx} = \frac{12{,}11}{0{,}6.36} + \frac{8{,}55}{31{,}6} = 0{,}83 < 1{,}0 \rightarrow \textbf{Aman}$$

Akibat beban gravitasi

Pu = 829,52 kip

Mu = 0

Dipakai profil W14x233 (Fa = 17,99 ksi)

$$\text{fa} = \frac{829{,}52}{68{,}5} = 12{,}1 \text{ ksi}$$

fbx = 0

$$\frac{fa}{Fa} = \frac{12{,}1}{17{,}99} = 0{,}67 > 0{,}15$$

Rumus AISC-ASD untuk kolom:

$$\frac{fa}{Fa} + \frac{Cmx.fbx}{\left(1-\frac{fa}{Fe'x}\right).Fbx} = \frac{12{,}1}{17{,}99} + 0 = 0{,}67 < 1{,}0 \rightarrow \textbf{Aman}$$

$$\frac{fa}{0{,}6.Fa} + \frac{fbx}{Fbx} = \frac{12{,}1}{0{,}6.36} + 0 = 0{,}56 < 1{,}0 \rightarrow \textbf{Aman}$$

Jadi profil W14x233 dapat digunakan.

b. Metode LRFD (Portal Tepi)

Momen dan gaya aksial rencana kolom

Momen rencana dan gaya aksial rencana aksial kolom eksterior

Contoh untuk kolom lantai 18.

Profil balok lantai 18 adalah W16x36 (d = 15,86 in; Zx = 64 in^3)

Mp = Zx. Fy = 64. 36 = 2304 k.in

Profil balok lantai 17 adalah W21x62 (d = 20,99 in; Zx = 144 in^3)

Asumsi profil kolom W18x76 (d = 18,21 in)

L balok = 9 m = 354,33 in

h kolom = 4 m = 157,48 in

Gaya aksial rencana (Pu):

$$Pu = 1{,}2\ P_D + 0{,}5\ P_L + \left(\frac{2.Mp}{L}\right)_{lantai.18} \quad \text{.....(pers. 3.14)}$$

lamp 2A

$$= 1{,}2.14 + 0{,}5.\ 3{,}36 + \frac{2.2304}{354{,}33} = 31{,}5 \text{ kip}$$

Momen rencana (Mu):

Lc = 354,33 – 18,21 = 336,12 in

$$hc = 157{,}48 - \frac{15{,}86}{2} - \frac{20{,}99}{2} = 139{,}051 \text{ in}$$

$$Mu = Mp.\left(\frac{L}{Lc}\right).\left(\frac{hc}{2.h}\right) \quad \text{.....(pers. 3.16)}$$

$$= 2304.\left(\frac{354,33}{336,12}\right).\left(\frac{139,051}{2.157,48}\right) = 1072,8 \text{ k.in} = 89,36 \text{ k.ft}$$

Untuk kolom lantai 17.

Profil balok lantai 17 adalah W21x62 (Mp = 5184 k.in)

Profil balok lantai 16 adalah W21x62 (d = 20,99 in)

Gaya aksial rencana (Pu):

$$Pu = 1,2\ P_D + 0,5\ P_L + \left(\frac{2.Mp}{L}\right)_{lantai\ 18} + \left(\frac{2.Mp}{L}\right)_{lantai\ 17} \quad \text{.....(pers. 3.14)}$$

$$= 1,2.\ 42,32 + 0,5.\ 10,17 + \frac{2.2304}{354,33} + \frac{2.5184}{354,33} = 98,15 \text{ kip}$$

Momen rencana (Mu):

Lc = 336,12 in

$$hc = 157,48 - \frac{2.20,99}{2} = 136,486 \text{ in}$$

$$Mu = 5184.\left(\frac{354,33}{336,12}\right).\left(\frac{157,48}{2.136,486}\right) = 1368,2 \text{ k.in} = 197,35 \text{ k.ft}$$

Momen dan gaya aksial rencana kolom interior

Kolom lantai 18

Gaya aksial rencana (Pu):

$Pu = 1,2\ P_D + 0,5\ P_L = 1,2.\ 8,78 + 0,5.\ 2,13 = 11,6$ kip.....(pers. 3.15)

Momen rencana (Mu):

$$Mu = 2.\ Mp.\left(\frac{L}{Lc}\right)\left(\frac{hc}{2.h}\right) \quad \text{.....(pers. 3.17)}$$

$$= 2.\ 2304.\left(\frac{354{,}33}{336{,}12}\right)\left(\frac{139{,}051}{2.157{,}48}\right) = 2144{,}64 \text{ k.in} = 178{,}72 \text{ k.ft}$$

Kolom lantai 17

$Pu = 1{,}2\ P_D + 0{,}5\ P_L = 57{,}86$ kip.....(pers. 3.15)

$$Mu = 2.\ Mp\left(\frac{L}{Lc}\right)\left(\frac{hc}{2.h}\right) = 394{,}7 \text{ k.ft} \text{.....(pers. 3.17)}$$

Untuk selanjutnya momen dan gaya aksial kolom rencana akan ditabelkan.

Tabel 5.4 Kolom Eksterior, Mu dan Pu rencana

Lantai	Portal Tepi		Portal Tengah	
	Mu (k.ft)	Pu (kip)	Mu (k.ft)	Pu (kip)
1	236.02	1211.05	353.11	2091.12
2	268.05	1149.56	320.39	1986.47
3	267.75	1079.14	320.39	1878.65
4	267.75	1007.65	364.74	1768.75
5	267.75	935.19	364.44	1650.02
6	267.75	861.89	364.44	1529.65
7	267.75	787.87	364.44	1407.85
8	267.75	713.19	364.44	1284.8
9	235.13	637.99	364.44	1160.67
10	235.29	567.2	364.44	1035.62
11	197.07	496.01	319.87	909.78
12	197.15	417.18	320.13	767.83
13	197.15	364.09	320.13	670.04
14	197.25	297.79	320.13	549.45
15	197.35	231.33	320.13	428.51
16	197.35	164.77	320.13	307.33
17	197.35	98.16	320.13	185.97
18	89.36	31.5	162.44	64.37

Tabel 5.5 Kolom Interior, Mu dan Pu rencana

Lantai	Portal Tepi		Portal Tengah	
	Mu (k.ft)	Pu (kip)	Mu (k.ft)	Pu (kip)
1	472.06	881.52	706.21	1703.6
2	536.09	818.47	640.77	1582.32
3	536.5	758.65	640.77	1467.37
4	536.5	700.98	729.48	1356.64
5	536.5	645.25	728.89	1249.7
6	536.5	591.2	728.89	1146.03
7	536.5	538.61	728.89	1045.25
8	536.5	487.3	728.89	946.95
9	470.29	437.05	728.89	850.81
10	470.59	387.74	728.89	756.53
11	394.14	339.22	639.74	663.81
12	394.3	291.35	640.26	572.43
13	394.3	244.02	640.26	482.14
14	394.5	197.1	640.26	392.74
15	394.7	150.5	640.26	304.03
16	394.7	104.12	640.26	215.83
17	394.7	57.86	640.26	127.96
18	178.72	11.6	324.87	40.57

Perencanaan Kolom (lantai 1)

Kolom Eksterior

Mu = 236,02 k.ft (lampiran 39, Portal 18 lantai)

Pu = 1211,05 kip (lampiran 39, Portal 18 lantai)

Profil balok lantai 1 adalah W21x68 (Ix = 1480 in^4)

$$G_A = \frac{2.\left(\frac{3840}{157,48}\right)}{\left(\frac{1480}{354,33}\right)} = 4,0$$

G_B = 1,0 (jepit)

Dari grafik Johnson dan Moreland didapatkan nilai k = 1,75

Dicoba profil W14x233 (rx = 6,63; ry = 4,1; Zx = 436; Sx = 375; X_1 = 6820;

X_2 = 64,9; A = 68,5)

Lb = 4 m = 157,48 in

$$\frac{(k.L)_x}{rx} = \frac{1,75.157,48}{6,63} = 41,6$$

$$\frac{(k.L)_y}{ry} = 67,2 \rightarrow \text{yang dipakai}$$

Dari tabel AISC-LRFD hal 6-147 didapatkan nilai ϕc.Pcr = 24,14 ksi

ϕ.Pn = ϕc.Pcr. A = 24,14. 68,5 = 1653,59 kip

$$Lp = \frac{300.ry}{\sqrt{fy}} = \frac{300.4,1}{\sqrt{36}} = 205 \text{ in} > Lb = 157,48 \text{ in}$$

$$\frac{bf}{2.tf} = 4,6 < \frac{65}{\sqrt{fy}} = 10,8$$

$$\frac{d}{tw} = 10,7 < \frac{640}{\sqrt{fy}} = 106,6$$

Jadi penampang adalah kompak

Mn = Mp = Zx. fy = 436. 36 = 15696 k.in = 1308 k.ft

ϕ.Mn = 0,9. 1308 = 1177,2 k.ft

$$\frac{Pu}{\phi.Pn} = \frac{1211,05}{1653,59} = 0,73 > 0,2$$

Rumus AISC-LRFD:

$$\frac{Pu}{\phi.Pn}+\frac{8}{9}.\left(\frac{Mu}{\phi Mn}\right) \quad \text{.....(pers. 3.12)}$$

$$\frac{1211,05}{1653,59}+\frac{8}{9}\left(\frac{236,03}{1177,2}\right)=0,91<1,0 \rightarrow \textbf{Aman}$$

Kolom Interior

Mu = 472,06 k.ft (lampiran 39, Portal 18 lantai)

Pu = 881,52 kip(lampiran 39, Portal 18 lantai)

$$G_A=\frac{2.\left(\frac{1330}{157,48}\right)}{2.\left(\frac{1480}{354,33}\right)}=2$$

W18x76

W21x68

G_B = 1,0 (jepit)

Dari grafik Johnson dan Moreland didapatkan nilai k = 1,5

Dicoba profil W14x233 (ry = 4,1; rx = 6,63; Sx = 375; Zx = 436; A = 68,5;

X_1 = 6820; X_2 = 64,9; $\frac{bf}{2.tf}$ = 4,6; $\frac{d}{tw}$ = 10,7)

$$\frac{(k.L)_x}{rx}=\frac{1,5.157,48}{6,63}=35,63$$

$$\frac{(k.L)_y}{ry}=57,6 \rightarrow \text{yang dipakai}$$

Dari tabel AISC-LRFD hal 6-147 didapatkan nilai $\phi c.Pcr$ = 25,7 ksi

$\phi.Pn = \phi c.Pcr.\ A = 25,7.\ 68,5 = 1760,45$ kip

$$Lp = \frac{300.ry}{\sqrt{fy}} = 205 \text{ in} > Lb = 157{,}48 \text{ in}$$

$$\frac{bf}{2.tf} = 4{,}6 < \frac{65}{\sqrt{fy}} = 10{,}8$$

$$\frac{d}{tw} = 10{,}7 < \frac{640}{\sqrt{fy}} = 106{,}6$$

Jadi penampang adalah kompak.

Mn = Mp = Zx. fy = 436. 36 = 15696 k.in = 1308 k.ft

ϕ.Mn = 0,9. 1308 = 1177,2 k.ft

$$\frac{Pu}{\phi.Pn} = \frac{881{,}52}{1760{,}45} = 0{,}5 > 0{,}2$$

Rumus AISC-LRFD :

$$\frac{Pu}{\phi.Pn} + \frac{8}{9}\left(\frac{Mu}{\phi.Mn}\right) \quad \text{(pers. 3.12)}$$

$$\frac{881{,}52}{1760{,}45} + \frac{8}{9}\left(\frac{472{,}06}{1177{,}2}\right) = 0{,}86 < 1{,}0 \rightarrow \textbf{Aman}$$

Untuk perencanaan kolom portal tengah rumusnya sama dengan perencanaan kolom portal tepi, yang berbeda hanya gaya – gaya dalam yang terjadi.

5.3.2 Perencanaan Kolom Portal 6 Lantai

a. Metode ASD (Portal Tepi, kolom lantai 1)

Kolom Eksterior

Akibat beban gravitasi dan gempa

Mu = 136,7846 k.ft (lampiran 8, Portal 6 lantai)

Pu = 189,624 kip (lampiran 19, Portal 6 lantai)

Profil balok W14 x 82 (I = 882 in^4 , L = 354,33 in)

Asumsi profil kolom W18x76 (I = 1330 in^4 , L = 157,48 in)

$$G_A = \frac{\Sigma\left(\frac{I}{L}\right)_{kolom}}{\Sigma\left(\frac{I}{L}\right)_{balok}} = \frac{2\cdot\left(\frac{1330}{157,48}\right)}{0,67\cdot\left(\frac{882}{354,33}\right)} = 10,13 \qquad \text{(pers. 3.39)}$$

G_B = 1,0 (jepit)

Dari grafik Johnson dan Moreland , untuk portal bergoyang didapatkan nilai k = 1,9

Lb = 4 m = 157,48 in = 13,123 ft

$k \cdot l$ = 1,9 · 13,123 = 24,93 ft ; untuk portal bergoyang cm = 0,85.

Penentuan profil :

1) Untuk kl = 24,94 ft dan fy = 36 ksi, untuk asumsi pertama dari table AISC-ASD halaman 3.10 diambil m = 1,9 dan U = 3,0.
2) P_{eff} = Po + $Mx \cdot m + My \cdot m \cdot U$ = 189,624 + 136,7846 · 1,9 + 0 = 449,5147 kips.
3) Dari tabel AISC-ASD halaman 3.19 – 3.34 untuk kl = 24,94 ft, P_{eff} = 449,5147 kips, dan fy = 36 ksi pilih profil W 14 X 99 dengan P_{kap} = 475 kips.

4) Dari table AISC-ASD untuk kl = 24,94 ft dan profil W 14 didapat m = 1,7 dan U = 2,5.

5) P_{eff} = 189,624 + 136,7846 · 1,7 + 0 = 422,158 kips.

6) Dipilih profil W 14 X 99 dengan P_{kap} = 475 kips.

7) Didapat m = 1,7 dan U = 2,5.

8) P_{eff} = 189,624 + 136,7846 · 1,7 + 0 = 422,158 kips.

Dipakai profil W 14 X 99 (bf = 14,565; r_T = 4,0; $\frac{d}{Af}$ = 1,25; Sx = 157; ry = 3,71; rx = 6,17; A = 29,1; $\frac{bf}{2.tf}$ = 9,3; $\frac{d}{tw}$ = 29,2; I = 1110 in^4 ; L = 157,48 in).

Tegangan yang terjadi :

$$fa = \frac{Pu}{A} = \frac{189,624}{29,1} = 6,52 \text{ ksi} \quad \text{.....(pers. 3.38)}$$

$$fbx = \frac{Mu}{Sx} = \frac{136,7846.12}{157} = 10,45 \text{ ksi} \quad \text{.....(pers. 3.39)}$$

Tegangan desak ijin (Fa):

$$\frac{(k.L)_x}{rx} = \frac{1,9.157,48}{6,17} = 48,49$$

$$\frac{(k.L)_y}{ry} = \frac{1,9.157,48}{3,71} = 80,65 \rightarrow \text{dipakai}$$

Dari tabel AISC-ASD hal 3.16, dengan nilai $\frac{k.l}{r}$ = 80,65 dan fy = 36 ksi didapatkan nilai Fa = 15,24 ksi

Tegangan ijin lentur (Fb):

$$Lc = \frac{76.bf}{12.\sqrt{fy}} = 15{,}4 \text{ ft} \quad \text{.....(pers. 3.25)}$$

$$Lc = \frac{20000}{12.fy.\frac{d}{Af}} = 37{,}04 \text{ ft} \quad \text{.....(pers. 3.26)}$$

Nilai Lc diambil yang terkecil = 15,4 ft

Lb = 157,48 in = 13,123 ft < Lc = 15,4 ft

$$\frac{bf}{2.tf} = 9{,}3 < \frac{65}{\sqrt{fy}} = 10{,}8$$

$$\frac{d}{tw} = 29{,}2 < \frac{640}{\sqrt{fy}} = 106{,}6$$

Penampang adalah kompak

Fbx = 0,66.fy = 0,66.36 = 23,76 ksi .....(pers. 3.24)

$$\frac{fa}{Fa} = \frac{6{,}52}{15{,}24} = 0{,}43 > 0{,}15$$

$$Fe'x = \frac{12.\pi^2.E}{23.\left(\frac{kx.Lx}{rx}\right)^2} = \frac{12.\pi^2.29000}{23.(48{,}49)^2} = 63{,}43 \text{ ksi}$$

Karena portal bergoyang maka Cmx = 0,85

$$\frac{Cmx}{1-\frac{fa}{Fe'x}} = \frac{0{,}85}{1-\frac{6{,}52}{63{,}43}} = 0{,}95 < 1{,}0 \rightarrow \text{dipakai } 1{,}0$$

Karena beban termasuk beban gempa maka Fa dan Fb boleh dinaikkan sebesar 1/3 kali nilai semula (tabel AISC-ASD).

1,33.Fa = 1,33.15,24 = 20,27 ksi

1,33.Fbx = 1,33.23,76 = 31,6 ksi

Rumus AISC-ASD untuk $\frac{fa}{Fa} > 0,15$

$$\frac{fa}{Fa} + \frac{Cmx.fbx}{\left(1 - \frac{fa}{Fe'x}\right).Fbx} < 1,0 \quad \text{.....(pers. 3.35)}$$

$$\frac{6,52}{20,27} + \frac{1,0.10,45}{31,6} = 0,63 < 1,0 \rightarrow \textbf{Aman}$$

$$\frac{fa}{0,6.fy} + \frac{fbx}{Fbx} < 1,0 \quad \text{.....(pers. 3.36)}$$

$$\frac{6,52}{0,6.36} + \frac{10,45}{31,6} = 0,63 < 1,0 \rightarrow \textbf{Aman}$$

Akibat beban gravitasi

Pu = 151,9572 kip (lampiran 19, Portal 6 lantai)

Mu = 43,73 k.ft (lampiran 8, Portal 6 lantai)

Profil balok W14 x 82 (I = 882 in^4 , L = 354,33 in)

Dipakai profil W 14 X 99 (bf = 14,565; r_T = 4,0; $\frac{d}{Af}$ = 1,25; Sx = 157; ry = 3,71;

rx = 6,17; A = 29,1; $\frac{bf}{2.tf}$ = 9,3; $\frac{d}{tw}$ = 29,2; I = 1110 in^4

;

L = 157,48 in).

Tegangan yang terjadi :

Fa = 15,24 ksi

Fbx = 23,76 ksi

Fe'x = 63,43 ksi

Tegangan yang terjadi:

$$fa = \frac{151,9572}{29,1} = 5,2 \text{ ksi}$$

$$fbx = \frac{43,73 \cdot 12}{157} = 3,34 \text{ ksi}$$

$$\frac{Cmx}{1 - \frac{fa}{Fe'x}} = \frac{0,85}{1 - \frac{5,2}{63,43}} = 0,93 < 1,0 \rightarrow \text{dipakai } 1,0$$

$$\frac{fa}{Fa} = \frac{15,2}{15,24} = 0,34 > 0,15$$

Rumus AISC-ASD :

$$\frac{fa}{Fa} + \frac{Cmx.fbx}{\left(1 - \frac{fa}{Fe'x}\right).Fbx} < 1,0$$

$$\frac{5,2}{15,24} + \frac{1 \cdot 3,34}{23,76} = 0,5 < 1,0 \rightarrow \textbf{Aman}$$

$$\frac{fa}{0,6.fy} + \frac{fbx}{Fbx} < 1,0$$

$$\frac{5,2}{0,6.36} + \frac{3,34}{23,76} = 0,4 < 1,0 \rightarrow \textbf{Aman}$$

Jadi profil W14 x 99 dapat digunakan.

Kolom Interior

Akibat beban gravitasi dan gempa

Pu = 310,5062 kip (lampiran 19, Portal 6 lantai)

Mu = 133,5037 k.ft (lampiran 8, Portal 6 lantai)

Profil balok W14 x 82 (I = 882 in^4 , L = 354,33 in)

Asumsi profil kolom W18x76 (I = 1330 in^4 , L = 157,48 in)

$$G_A = \frac{\sum\left(\frac{I}{L}\right)_{kolom}}{\sum\left(\frac{I}{L}\right)_{balok}} = \frac{2\cdot\left(\frac{1330}{157,48}\right)}{0,67\cdot 2\cdot\left(\frac{882}{354,33}\right)} = 5,06$$

G_B = 1,0 (jepit)

Dari grafik Johnson dan Moreland , untuk portal bergoyang didapatkan nilai k = 1,7

Lb = 4 m = 157,48 in = 13,123 ft

$k \cdot l$ = 1,7 · 13,123 = 22,3 ft ; untuk portal bergoyang cm = 0,85.

Penentuan profil :

1) Untuk kl = 22,3 ft dan fy = 36 ksi, untuk asumsi pertama dari table AISC-ASD halaman 3.10 diambil m = 1,9 dan U = 3,0.
2) P_{eff} = Po + $Mx \cdot m$ + $My \cdot m \cdot l$ = 310,5062 + 133,5037 · 1,9 + 0 = 564,16 kips.
3) Dari tabel AISC-ASD halaman 3.19 – 3.34 untuk kl = 22,3 ft, P_{eff} = 564,16kips, dan fy = 36 ksi pilih profil W 14 X 120 dengan P_{kap} = 578 kips.
4) Dari table AISC-ASD untuk kl = 22,3 ft dan profil W 14 didapat m = 1,7 dan U = 2,48.
5) P_{eff} = 310,5062 + 133,5037 · 1,7 + 0 = 537,46 kips.
6) Dipilih profil W 14 X 120 dengan P_{kap} = 578 kips.

7) Didapat m = 1,7 dan U = 2,5.

8) P_{eff} = 310,5062 + 133,5037 · 1,7 + 0 = 537,46 kips.

Dipakai profil W 14 X 120 (bf = 14,67; r_T = 4,04; $\frac{d}{Af}$ = 1,05; Sx = 190; ry = 3,74;

rx = 6,24; A = 35,3; $\frac{bf}{2.tf}$ = 7,8; $\frac{d}{tw}$ = 24,5; I = 1380 in^4 ;

L = 157,48 in).

Tegangan yang terjadi:

$$fa = \frac{310,5062}{35,3} = 8,79 \text{ ksi}$$

$$fbx = \frac{133,5037.12}{190} = 8,43 \text{ ksi}$$

Tegangan desak ijin (Fa):

$$\frac{(k.L)_x}{rx} = \frac{1,7.157,48}{6,24} = 42,9$$

$$\frac{(k.L)_y}{ry} = \frac{1,7.157,48}{3,74} = 71,6$$

Dari tabel AISC-ASD didapatkan nilai Fa = 16,22 ksi

Tegangan ijin lentur (Fb):

$$Lc = \frac{76.bf}{12.\sqrt{fy}} = 15,5 \text{ ft}$$

$$Lc = \frac{20000}{12.fy.\frac{d}{Af}} = 44,1 \text{ ft}$$

Nilai Lc diambil yang terkecil = 15,5 ft

Lb = 157,48 in = 13,123 ft < Lc = 15,5 ft

$$\frac{bf}{2.tf} = 7,8 < \frac{65}{\sqrt{fy}} = 10,8$$

$$\frac{d}{tw} = 24,5 < \frac{640}{\sqrt{fy}} = 106,6$$

Penampang adalah kompak

Fbx = 0,66.fy = 0,66.36 = 23,76 ksi

1,33.Fb = 31,6 ksi

Karena kolom interior dan bentang antar kolom sama, maka gaya aksial akibat gempa tidak berpengaruh. Yang berpengaruh hanya gaya aksial akibat beban gravitasi. Jadi Fa *tidak dikalikan* dengan 1,33.

$$Fe'x = \frac{12.\pi^2.29000}{23.(42,9)^2} = 81,04 \text{ ksi}$$

$$\frac{Cmx}{\left(1-\frac{fa}{Fe'x}\right)} = \frac{0,85}{\left(1-\frac{8,79}{81,04}\right)} = 0,95 < 1,0 \rightarrow \text{dipakai } 1,0$$

$$\frac{fa}{Fa} = \frac{8,79}{16,22} = 0,54 > 0,15$$

$$\frac{fa}{Fa} + \frac{Cmx.fbx}{\left(1-\frac{fa}{Fe'x}\right).Fbx} = \frac{8,79}{16,22} + \frac{1,0.8,43}{31,6} = 0,8 < 1,0 \rightarrow \textbf{Aman}$$

$$\frac{fa}{0,6.fy} + \frac{fbx}{Fbx} = \frac{8,79}{0,6.36} + \frac{8,43}{31,6} = 0,7 < 1,0 \rightarrow \textbf{Aman}$$

Akibat beban gravitasi

Pu = 309,9304 kip (lampiran 19, Portal 6 lantai)

Mu = 0 (lampiran 8, Portal 6 lantai)

Profil balok W14 x 82 (I = 882 in^4 , L = 354,33 in)

Dipakai profil W 14 X 120 (bf = 14,67; r_T = 4,04; $\frac{d}{Af}$ = 1,05; Sx = 190; ry = 3,74;

rx = 6,24; A = 35,3; $\frac{bf}{2.tf}$ = 7,8; $\frac{d}{tw}$ = 24,5; I = 1380 in^4 ;

L = 157,48 in).

Tegangan yang terjadi :

Fa = 16,22 ksi

Fbx = 31,6 ksi

Fe'x = 81,04 ksi

$fa = \frac{309,9304}{35,3} = 8,78$ ksi

fbx = 0

$\frac{fa}{Fa} = \frac{8,78}{16,22} = 0,54 > 0,15$

Rumus AISC-ASD untuk kolom:

$$\frac{fa}{Fa} + \frac{Cmx.fbx}{\left(1 - \frac{fa}{Fe'x}\right).Fbx} = \frac{8,78}{16,22} + 0 = 0,54 < 1,0 \rightarrow \textbf{Aman}$$

$$\frac{fa}{0,6.Fa} + \frac{fbx}{Fbx} = \frac{8,78}{0,6.36} + 0 = 0,41 < 1,0 \rightarrow \textbf{Aman}$$

Jadi profil W14 x 120 dapat digunakan.

b. Metode LRFD (Portal Tepi)

Momen dan gaya aksial rencana kolom

Momen rencana dan gaya aksial rencana kolom eksterior

Contoh untuk kolom lantai 6.

Profil balok lantai 6 adalah W14x38 (d = 14,1 in; Zx = 61,5 in^3)

Mp = Zx. Fy = 61,5. 36 = 2214 k.in

Profil balok lantai 5 adalah W14x48 (d = 13,79 in; Zx = 78,4 in^3)

Asumsi profil kolom W18x76 (d = 18,21 in)

L balok = 9 m = 354,33 in

h kolom = 4 m = 157,48 in

Gaya aksial rencana (Pu):

$$Pu = 1{,}2\ P_D + 0{,}5\ P_L + \left(\frac{2.Mp}{L}\right)_{lantai.6} \quad \text{.....(pers. 3.14)}$$

$$= 1{,}2.10{,}02 + 0{,}5.\ 2{,}35 + \frac{2.2214}{354{,}33} = 25{,}7 \text{ kip}$$

Momen rencana (Mu):

Lc = 354,33 – 18,21 = 336,12 in

$$hc = 157{,}48 - \frac{14{,}10}{2} - \frac{13{,}79}{2} = 143{,}54 \text{ in}$$

$$Mu = Mp.\left(\frac{L}{Lc}\right).\left(\frac{hc}{2.h}\right) \quad \text{.....(pers. 3.16)}$$

$$= 2214.\left(\frac{354{,}33}{336{,}12}\right).\left(\frac{143{,}54}{2.157{,}48}\right) = 1063{,}68 \text{ k.in} = 88{,}64 \text{ k.ft}$$

Untuk kolom lantai 5.

Profil balok lantai 5 adalah W14x48 (Mp = 2822,4 k.in; d = 13,79 in)

Profil balok lantai 4 adalah W14x61 (d = 13,89 in)

Asumsi profil kolom W18x76 (d = 18,21 in)

Gaya aksial rencana (Pu):

$$Pu = 1{,}2\ P_D + 0{,}5\ P_L + \left(\frac{2.Mp}{L}\right)_{lantai.6} + \left(\frac{2.Mp}{L}\right)_{lantai.5} \quad \text{.....(pers. 3.14)}$$

$$= 1{,}2.\ 33{,}11 + 0{,}5.\ 7{,}83 + \frac{2.2214}{354{,}33} + \frac{2.2822{,}4}{354{,}33} = 72{,}07 \text{ kip}$$

Momen rencana (Mu):

$Lc = 354{,}33 - 18{,}21 = 336{,}12$ in

$$hc = 157{,}48 - \frac{13{,}89}{2} - \frac{13{,}79}{2} = 143{,}64 \text{ in}$$

$$Mu = 2822{,}4.\left(\frac{354{,}33}{336{,}12}\right).\left(\frac{157{,}48}{2.143{,}64}\right) = 1356{,}96 \text{ k.in} = 113{,}08 \text{ k.ft}$$

Momen dan gaya aksial rencana kolom interior

Kolom lantai 6

Gaya aksial rencana (Pu):

$Pu = 1{,}2\ P_D + 0{,}5\ P_L = 1{,}2.\ 16{,}75 + 0{,}5.\ 4{,}17 = 22{,}183$ kip .....(pers. 3.15)

Momen rencana (Mu):

$$Mu = 2.\ Mp.\left(\frac{L}{Lc}\right).\left(\frac{hc}{2.h}\right) \quad \text{.....(pers. 3.17)}$$

$$= 2.\ 2214.\left(\frac{354{,}33}{336{,}12}\right).\left(\frac{143{,}54}{2.157{,}48}\right) = 2127{,}36 \text{ k.in} = 177{,}28 \text{ k.ft}$$

Kolom lantai 5

$Pu = 1{,}2\ P_D + 0{,}5\ P_L = 82{,}297$ kip.....(pers. 3.15)

$Mu = 2.\ Mp \left(\frac{L}{Lc}\right)\left(\frac{hc}{2.h}\right) = 226{,}16$ k.ft.....(pers. 3.17)

Untuk selanjutnya momen dan gaya aksial kolom rencana akan ditabelkan.

Tabel 5.6 Kolom Eksterior, Mu dan Pu rencana

Lantai	Portal Tepi		Portal Tengah	
	Pu (Kip)	Mu (K.ft)	Pu (Kip)	Mu (K.ft)
6	25.700825	88.6387	36.73175	100.3795
5	72.072737	113.079	106.0488	165.5624
4	123.18318	147.0669	177.417	181.3166
3	173.91562	146.99	248.1863	181.228
2	226.77767	165.6375	320.7912	200.0308
1	277.98971	173.7438	395.4036	237.2138

Tabel 5.7 Kolom Interior, Mu dan Pu rencana

Lantai	Portal Tepi		Portal Tengah	
	Pu (Kip)	Mu (K.ft)	Pu (Kip)	Mu (K.ft)
6	22.183	177.2774	41.42	200.7589
5	82.297	226.158	132.377	331.1248
4	142.526	294.1337	223.699	362.6331
3	203.51	293.9801	316.218	362.456
2	265.517	331.2749	410.349	400.0616
1	329.629	347.4876	507.778	474.4277

Perencanaan Kolom (lantai 1)

Kolom Eksterior

Mu = 173,74 k.ft (lampiran 14, Portal 6 lantai)

Pu = 277,99 kip (lampiran 14, Portal 6 lantai)

Profil balok W14 x 68 (I = 723 in^4 , L = 354,33 in)

Asumsi profil kolom W18x76 (I = 1330 in^4 , L = 157,48 in)

$$G_A = \frac{\Sigma\left(\frac{I}{L}\right)_{kolom}}{\Sigma\left(\frac{I}{L}\right)_{balok}} = \frac{2\cdot\left(\frac{1330}{157,48}\right)}{0,67\cdot\left(\frac{723}{354,33}\right)} = 12,36$$

G_B = 1,0 (jepit)

Dari grafik Johnson dan Moreland , untuk portal bergoyang didapatkan nilai k = 1,9

Lb = 4 m = 157,48 in = 13,123 ft

$k \cdot l$ = 1,9 · 13,123 = 24,94 ft ; untuk portal bergoyang cm = 0,85.

Penentuan profil :

1) Untuk kl = 24,94 ft dan fy = 36 ksi, untuk asumsi pertama dari table AISC-LRFD halaman 3.12 diambil m = 1,3 dan U = 2,0.
2) P_{eff} = Pu + $Mux \cdot m + Muy \cdot m \cdot U$ = 277,99 + 173,74 · 1,3 + 0 = 503,85 kips.
3) Dari tabel AISC-LRFD halaman 3.16 – 3.33 untuk kl = 24,94 ft, P_{eff} = 503,85 kips, dan fy = 36 ksi pilih profil W 14 X 90 dengan P_{kap} = 589 kips.
4) Dari table AISC-LRFD untuk kl = 24,94 ft dan profil W 14 didapat m = 1,2 dan U = 2,02.
5) P_{eff} = 277,99 + 173,74 · 1,2 + 0 = 486,48 kips.
6) Dipilih profil W 14 X 90 dengan P_{kap} = 589 kips.
7) Didapat m = 1,2 dan U = 2,02

8) P_{eff} = 277,99 + 173,74 · 1,2 + 0 = 486,48 kips.

Dipakai profil W 14 X 90 (rx = 6,14; ry = 3,7; Zx = 157; Sx = 143; X_1 = 2900;

X_2 = 1750; A = 26,5)

$$\frac{(k.L)_x}{rx} = \frac{1,9.157,48}{6.14} = 48,7$$

$$\frac{(k.L)_y}{ry} = 80,87 \rightarrow \text{yang dipakai}$$

Dari tabel AISC-LRFD hal 6-147 didapatkan nilai ϕc.Pcr = 21,66 ksi

ϕ.Pn = ϕc.Pcr. A = 21,66. 26,5 = 573,99 kip

$$\text{Lp} = \frac{300 \cdot ry}{\sqrt{fy}} = \frac{300 \cdot 3,7}{\sqrt{36}} = 185 \text{ in}$$

Lb = 4 m = 157,48 in < Lp = 185 in

$$\frac{bf}{2tf} = 10,2 \leq \frac{65}{\sqrt{fy}} = \frac{65}{\sqrt{50}} = 10,83$$

$$\frac{h}{tw} = 25,9 \leq \frac{640}{\sqrt{fy}} = \frac{640}{\sqrt{50}} = 106,67$$

Jadi penampang adalah kompak

Mn = Mp = Zx. Fy = 157. 36 = 5652 k.in = 471 k.ft

0,9 Mn = 0,9 · 471 = 423,9 k ft > Mu = 173,74 k.ft

$$\frac{Pu}{\phi.Pn} = \frac{277,99}{573,99} = 0,48 > 0,2$$

Rumus AISC-LRFD:

$$\frac{Pu}{\phi.Pn} + \frac{8}{9}.\left(\frac{Mu}{\phi.Mn}\right) \quad \text{.....(pers. 3.12)}$$

$$\frac{277,99}{573,99}+\frac{8}{9}\left(\frac{173,74}{423,9}\right)=0,85<1,0\rightarrow \textbf{Aman}$$

Kolom Interior

Mu = 347,49 k.ft (lampiran 14, Portal 6 lantai)

Pu = 329,63 kip (lampiran 14, Portal 6 lantai)

Profil balok W14 x 68 (I = 723 in^4 , L = 354,33 in)

Asumsi profil kolom W18x76 (I = 1330 in^4 , L = 157,48 in)

$$G_A=\frac{\Sigma\left(\frac{I}{L}\right)_{kolom}}{\Sigma\left(\frac{I}{L}\right)_{balok}}=\frac{2\cdot\left(\frac{1330}{157,48}\right)}{0,67\cdot 2\cdot\left(\frac{723}{354,33}\right)}=6,2$$

G_B = 1,0 (jepit)

Dari grafik Johnson dan Moreland , untuk portal bergoyang didapatkan nilai k = 1,75

Lb = 4 m = 157,48 in = 13,123 ft.

$k\cdot l$ = 1,75 · 13,123 = 22,96 ft ; untuk portal bergoyang cm = 0,85.

Penentuan profil :

1) Untuk kl = 22,96 ft dan fy = 36 ksi, untuk asumsi pertama dari table AISC-LRFD halaman 3.12 diambil m = 1,3 dan U = 2,0.

2) P_{eff} = Pu + $Mux\cdot m+ Muy\cdot m\cdot U$ = 329,63 + 347,49 · 1,3 + 0 = 781,37 kips.

3) Dari tabel AISC-LRFD halaman 3.16 – 3.33 untuk kl = 22,96 ft, P_{eff} = 781,37 kips, dan fy = 36 ksi pilih profil W 14 X 120 dengan P_{kap} = 831 kips.

4) Dari table AISC-LRFD untuk kl = 22,96 ft dan profil W 14 didapat m = 1,2 dan U = 2,04.

5) P_{eff} = 329,63 + 347,49 · 1,2 + 0 = 746,62 kips.

6) Dipilih profil W 14 X 109 dengan P_{kap} = 752 kips.

7) Didapat m = 1,2 dan U = 2,02

8) P_{eff} = 329,63 + 347,49 · 1,2 + 0 = 746,62 kips.

Dipakai profil W 14 X 109 (rx = 6,22; ry = 3,73; Zx = 192; Sx = 173; X_1 = 3490; X_2 = 853; A = 32,0)

$$\frac{(k.L)_x}{rx} = \frac{1,75.157,48}{6,22} = 44,3$$

$$\frac{(k.L)_y}{ry} = 73,88 \rightarrow \text{yang dipakai}$$

Dari tabel AISC-LRFD hal 6-147 didapatkan nilai ϕc.Pcr = 22,94 ksi

ϕ.Pn = ϕc.Pcr. A = 22,94. 32 = 734,08 kip

$$Lp = \frac{300.ry}{\sqrt{fy}} = \frac{300.3,73}{\sqrt{36}} = 186,5 \text{ in}$$

Lb = 4 m = 157,48 in < Lp = 186,5 in

$$\frac{bf}{2tf} = 8,5 \leq \frac{65}{\sqrt{fy}} = \frac{65}{\sqrt{50}} = 10,83$$

$$\frac{h}{tw} = 21,7 \leq \frac{640}{\sqrt{fy}} = \frac{640}{\sqrt{50}} = 106,67$$

Jadi penampang adalah kompak

Mn = Mp = Zx. Fy = 192. 36 = 6912 k.in = 576 k.ft

0,9 Mn = 0,9 · 576 = 518,4 k ft

$$\frac{Pu}{\phi.Pn} = \frac{329,63}{734,08} = 0,45 > 0,2$$

Rumus AISC-LRFD:

$$\frac{Pu}{\phi.Pn} + \frac{8}{9}\left(\frac{Mu}{\phi.Mn}\right) = \frac{329,63}{734,08} + \frac{8}{9}\left(\frac{347,49}{518,4}\right) = 1,04 < 1,0 \rightarrow \textbf{Tidak Aman}$$

Dipakai profil W 14 X 120 (rx = 6,24; ry = 3,74; Zx = 212; Sx = 190; X_1 = 3830;

X_2 = 601; A = 35,3)

$$\frac{(k.L)_x}{rx} = \frac{1,75.157,48}{6,24} = 44,16$$

$$\frac{(k.L)_y}{ry} = 73,69 \rightarrow \text{yang dipakai}$$

Dari tabel AISC-LRFD hal 6-147 didapatkan nilai ϕc.Pcr = 22,94 ksi

ϕ.Pn = ϕc.Pcr. A = 22,94. 35,3 = 809,78 kip

$$\text{Lp} = \frac{300.ry}{\sqrt{fy}} = \frac{300.3,74}{\sqrt{36}} = 187 \text{ in}$$

Lb = 4 m = 157,48 in < Lp = 187 in

$$\frac{bf}{2tf} = 7,8 \leq \frac{65}{\sqrt{fy}} = \frac{65}{\sqrt{50}} = 10,83$$

$$\frac{h}{tw} = 19,3 \leq \frac{640}{\sqrt{fy}} = \frac{640}{\sqrt{50}} = 106,67$$

Jadi penampang adalah kompak

Mn = Mp = Zx. Fy = 212. 36 = 7632 k.in = 636 k.ft

0,9 Mn = 0,9 · 636 = 572,4 k ft

$$\frac{Pu}{\phi.Pn} = \frac{329,63}{809,78} = 0,41 > 0,2$$

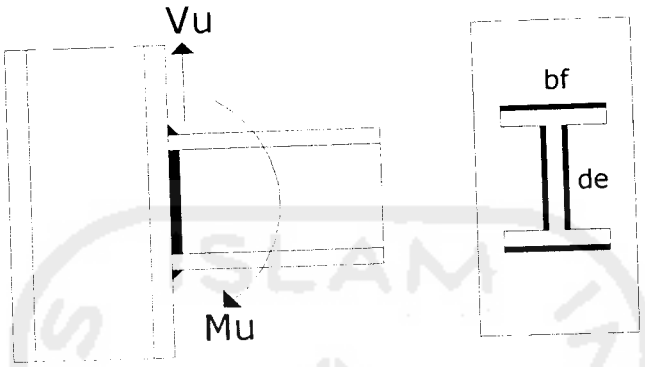
Rumus AISC-LRFD:

$$\frac{Pu}{\phi.Pn}+\frac{8}{9}.\left(\frac{Mu}{\phi.Mn}\right)=\frac{329{,}63}{809{,}78}+\frac{8}{9}\left(\frac{347{,}49}{572{,}4}\right)=0{,}95<1{,}0\rightarrow \textbf{Aman}$$

Untuk perencanaan kolom portal tengah rumusnya sama dengan perencanaan kolom portal tepi, yang berbeda hanya gaya – gaya dalam yang terjadi.

5.4 Perencanaan Sambungan

5.4.1 Perencanaan Sambungan Portal 18 Lantai



Gambar 5.17 Sambungan Las

a. Metode ASD (Portal Tepi)

Sambungan balok-kolom lantai 1

Kombinasi Beban Gempa dan Gravitasi

Profil balok W21x93 (bf = 8,42 in; d = 21,62 in; tf = 0,93 in)

Profil kolom eksterior W14x211 (bf = 15,8 in)

Profil kolom interior W14x257 (bf = 15,995 in)

Mu = 418,4 k.ft (lampiran 7, portal 18 lantai)

Vu = 48,06 kip (lampiran 12, portal 18 lantai)

A las = { 2. (d – 2.tf) + 2.bf }.te = { 2. (21,62 – 2. 0,93) + 2. 8,42 }.te = 56,32.te

de = d – 2.tf = 21,62 – 2.0,93 = 19,76 in

$$S = \left(bf.de + \frac{de^2}{3} \right).te = \left(8{,}42.19{,}76 + \frac{19{,}76^2}{3} \right).te = 296{,}53.\ \text{te in}^3$$

$$fy' = \frac{Vu}{A_{las}} = \frac{48,06}{56,32.te} = \frac{0,853}{te} \text{ ksi}$$

$$fx'' = \frac{Mu}{S} = \frac{418,4.12}{296,53.te} = \frac{16,93}{te} \text{ ksi}$$

Dipakai las E70XX, proses SAW.

$$fr = \sqrt{\frac{(16,93)^2 + (0,853)^2}{te^2}} = \frac{16,95}{te} \text{ ksi} \leq 1,33.\ 0,3.\ 70 = 27,93$$

$$te \geq \frac{16,93}{27,93} = 0,606 \text{ in}$$

Proses SAW → te = 0,606 in > 0,375 in

$$a = \frac{te - 0,11}{0,707} = \frac{0,606 - 0,11}{0,707} = 0,7 \text{ in}$$

Akibat beban gravitasi

Mu = 153,65 k.ft (lampiran 7, portal 18 lantai)

Vu = 29,19 kip (lampiran 12, portal 18 lantai)

A las = 56,32. te in^2

S las = 296,53. te in^2

$$fx' = \frac{Vu}{A_{las}} = \frac{29,19}{56,32.te} = \frac{0,52}{te} \text{ ksi}$$

$$fx'' = \frac{Mu}{S_{las}} = \frac{153,65.12}{296,53.te} = \frac{6,22}{te} \text{ ksi}$$

$$fr = \sqrt{\frac{(0,52)^2 + (6,22)^2}{te^2}} = \frac{6,24}{te} \text{ ksi} \leq 0,3.\ 70 = 21 \text{ ksi}$$

$$te \geq \frac{6,24}{21} = 0,3 \text{ in}$$

Proses SAW → te = 0,3 in < 0,375 in

a = te = 0,3 in

Jadi dipakai tebal las a = 0,7 in = 1,8 cm

b. Metode LRFD (Portal Tepi)

Sambungan balok – kolom lantai 1.

Profil balok W21x68 (bf = 8,27 in; tf = 0,685 in; d = 21,13 in; Zx = 160)

Profil kolom interior W14x233 (bf = 15,89 in; d = 16,04 in)

Profil kolom eksterior W14x233 (bf = 15,89 in; d = 16,04 in)

Mp balok = Zx. fy = 160. 36 = 5760 k.in

Lc balok = 354,33 – 16,04 = 338,29 in

Gaya geser rencana (Vu):

$$Vu = 1,2\ V_D + 0,5\ V_L + \frac{2.Mp_{balok}}{Lc} = 1,2.\ 23,33 + 0,5.\ 5,86 + \frac{2.5760}{338,29} = 64,98 \text{ kip}$$

Momen rencana (Mu):

Mu = Mp = 5760 k.in = 480 k.ft

A las = { 2. (d – 2.tf) + 2. bf }.te = { 2. (21,13 – 2. 0,685) + 2. 8,27 }.te

= 56,06.te in^2

de = d – 2.tf = 21,13 – 2. 0,685 = 19,76

$$S = \left(bf.de + \frac{de^2}{3} \right).te = \left(8,27.19,76 + \frac{19,76^2}{3} \right).te = 293,57.\text{te in}^3$$

$$fy' = \frac{Vu}{A_{las}} = \frac{64,98}{56,06.te} = \frac{1,16}{te} \text{ ksi}$$

$$fx'' = \frac{Mu}{S} = \frac{480.12}{293,57.te} = \frac{19,62}{te} \text{ ksi}$$

Dipakai las E70XX, proses SAW

$$fr = \sqrt{\frac{(1{,}16)^2 + (19{,}62)^2}{te^2}} = \frac{19{,}65}{te} \text{ ksi} < \phi.Rn = 0{,}75.(\ 0{,}6.\ 70\ ) = 31{,}5 \text{ ksi}$$

$$te \geq \frac{19{,}65}{31{,}5} = 0{,}62 \text{ in}$$

Proses SAW → te = 0,62 in > 0,375 in

$$a = \frac{te - 0{,}11}{0{,}707} = \frac{0{,}62 - 0{,}11}{0{,}707} = 0{,}72 \text{ in} = 1{,}82 \text{ cm}$$

5.4.2 Perencanaan Sambungan Portal 6 Lantai

a. Metode ASD (Portal Tepi)

Sambungan balok-kolom lantai 1

Kombinasi Beban Gempa dan Gravitasi

Profil balok W14 x 82 (bf = 10,13 in; d = 14,31 in; tf = 0,855 in)

Profil kolom eksterior W14 x 132 (bf = 14,725 in)

Profil kolom interior W14 x 120 (bf = 14,67 in)

Mu = 282,5235 k.ft (lampiran 3, portal 6 lantai)

Vu = 38,86 kip (lampiran 5, portal 6 lantai)

A las = { 2. (d – 2.tf) + 2.bf }.te = { 2. (14,31 – 2. 0,855) + 2. 10,13 }.te

= 45,46.te

de = d – 2.tf = 14,31 – 2.0,855 = 12,6 in

$$S = \left(bf.de + \frac{de^2}{3} \right).te = \left(10{,}13.12{,}6 + \frac{12{,}6^2}{3} \right).te = 180{,}56.\ te \text{ in}^3$$

$$fr = \sqrt{\frac{(10,77)^2 + (0,65)^2}{te^2}} = \frac{10,79}{te} \text{ ksi} \leq 0,3.\ 70 = 21$$

$$te \geq \frac{10,79}{21} = 0,51 \text{ in}$$

Proses SAW → te = 0,51 in > 0,375 in

$$a = \frac{te - 0.11}{0,707} = \frac{0,51 - 0.11}{0,707} = 0,57 \text{ in} = 1,45 \text{ cm.}$$

Jadi dipakai tebal las a = 0,79 in = 2 cm

b. Metode LRFD (Portal Tepi)

Sambungan balok – kolom lantai 1.

Profil balok W14 x 68 (bf = 10,035 in; tf = 0,72 in; d = 14,04 in; Zx = 115)

Profil kolom interior W14 x 132 (bf = 14,725 in; d = 14,66 in)

Profil kolom eksterior W14 x 109 (bf = 14,605 in; d = 14,32 in)

Mp balok = Zx. fy = 160. 36 = 4140 k.in

Lc balok = 354,33 – 0,5. 14,66 – 0,5.14,32 = 339,84 in

Gaya geser rencana (Vu):

$$Vu = 1,2\ V_D + 0,5\ V_L + \frac{2.Mp_{balok}}{Lc} \quad \text{.....(pers. 3.18)}$$

$$= 1,2.\ 23,73 + 0,5.\ 5,96 + \frac{2.4140}{339,84} = 55,82 \text{ kip}$$

Momen rencana (Mu):

Mu = Mp = 4140 k.in = 345 k.ft.....(pers. 3.19)

A las = { 2. (d – 2.tf) + 2. bf }.te = { 2. (14,04 – 2. 0,72) + 2. 10,035 }.te

= 45,27.te in^2

de = d – 2.tf = 14,04 – 2. 0,72 = 12,6

$$S = \left(bf.de + \frac{de^2}{3} \right).te = \left(10{,}035.12{,}6 + \frac{12{,}6^2}{3} \right).te = 179{,}361.\text{te in}^3$$

$$fy' = \frac{Vu}{A_{las}} = \frac{55{,}82}{45{,}27.te} = \frac{1{,}23}{te} \text{ ksi} \quad \text{.....(pers. 3.20)}$$

$$fx'' = \frac{Mu}{S} = \frac{345.12}{179{,}361.te} = \frac{23{,}08}{te} \text{ ksi} \quad \text{.....(pers. 3.21)}$$

Dipakai las E70XX, proses SAW

$$fr = \sqrt{\frac{(1{,}23)^2 + (23{,}08)^2}{te^2}} \quad \text{.....(pers. 3.22)}$$

$$= \frac{23{,}11}{te} \text{ ksi} < \phi.Rn = 0{,}75.(0{,}6. 70) = 31{,}5 \text{ ksi}$$

$$te \geq \frac{23{,}11}{31{,}5} = 0{,}73 \text{ in}$$

Proses SAW → te = 0,73 in > 0,375 in

$$a = \frac{te - 0.11}{0{,}707} = \frac{0{,}73 - 0.11}{0{,}707} = 0{,}88 \text{ in} = 2{,}24 \text{ cm.}$$