BAB V

PERHITUNGAN DESIGN

Pada bab ini akan diuraikan perhitungan desain,yang dasar perhitungannya telah dipaparkan pada bab sebelumnya. Bab ini meliputi desain awal, akhir, dan perhitungan sambungan.

5.1. Desain awal

5.1.1. Data struktur

1. Data umum

- Gedung untuk Perkantoran
- Wilayah gempa 3 (Indonesia)

2. Data Bahan

- *Fy* baja =50 Ksi
- *F'c* beton =35 ksi
- Profil frame *(WF)*
- Profil brace *2L*
- *High-strength bolt*: *ASTM A325*
- *Welding electrodes*: *SMAW E70XX*

5.1.2 Pembebanan

Denah pembebanan dapat dilihat pada *gambar1.5*

1. Atap

a. beban mati

-	pelat (12 cm)	=0.12 · 2.4	: 0.288 T/m^2
-	plafon	=0.011	: 0.011 T/m^2
-	finishing	=0.017	: 0.017 T/m^2
			Q_1 : 0.316 T/m^2

b. beban hidup

-	beban hidup atap	=0.1	
			Q_2 : 0.1 T/m^2
	total beban atap		Q_3 : 0.416 T/m^2

2. Lantai

a. Beban mati

-	pelat (12 cm)	=0.12 · 2.4	: 0.288 T/m^2
-	spesi (2 cm)	=0.02 · 2.1	: 0.042 T/m^2
-	berat ubin (2 cm)	= 0.02 · 2.4	: 0.048 T/m^2
-	berat pasir (1cm)	=0.01 · 1.6	: 0.016 T/m^2
-	berat plafond	=0.011	: 0.011 T/m^2
			Q_4 : 0.405 T/m^2

b. Beban Hidup = 0.25

Q_5 : 0.25 T/m^2

Beban total lantai Q_6 : 0.655 T/m^2

3. Frame

Asumsi awal:

Profil : - Balok : - Bentang 15 m ➔ W_{24x162} = 162 lb/ft =0.241 T/m'

- Bentang 10 m ➔ W_{24x94} = 94 lb/ft =0.140 T/m'

(Lihat sub.bab 5.1.7)

- Kolom I : W_{24x192}
- Kolom II : W_{24x370}
- Kolom III : W_{24x450}
- Kolom IV : W_{24x279} (Lihat sub.bab 5.1.8)

- Bracing : 2L4x4x3/4-3/4 (Lihat sub.bab 5.1.9)

- Balok bagi :Atap : -Bentang 15m ➔ W_{18x50}

- Bentang 10m ➔ W_{16x36}

Lantai : - Bentang 15m ➔ W_{18x71}

- Bentang 10m ➔ W_{16x36}

(Lihat sub.bab 5.1.6)

5.1.3 Perhitungan berat struktur

* Berat tingkat 1 s/d 9

- B. mati $= Q_4 \cdot (2b) \cdot L$

$= 0.405 \cdot (2 \cdot 7.5) \cdot 40$ $= 243$ T

- B. hidup reduksi $= R \cdot Q_5 \cdot (2b) \cdot L$

$= 0.3 \cdot 0.25 \cdot (2 \cdot 7.5) \cdot 40$ $= 45$ T

- Balok lintang $= n \cdot b \cdot W_{24x162}$

$= 8 \cdot 7.5 \cdot 0.241$ $= 14.460$ T

- Balok bagi $Q_{W18x71} \cdot n \cdot 15 + Q_{W16x36} \cdot n \cdot 10$

$= 0.106 \cdot 4 \cdot 15 + 0.054 \cdot 2 \cdot 10$ $= 7.44$ T

$W_1 = 309.90$ T

Tingkat 1 s/d 9 identik

* Berat tingkat 10

- B. mati $= Q_4 \cdot (2b) \cdot (L_2+L_3) + Q_1 \cdot (2b) \cdot (L_2)$

$= 0.405 \cdot (2 \cdot 7.5) \cdot (10+15) + 0.316 \cdot (2 \cdot 7.5) \cdot 15 = 222.975$ T

- B. hidup reduksi $= R \cdot [\, Q_5 \cdot (2b) \cdot (L_2+L_3) + Q_2 \cdot (2b) \cdot (L_2) \,]$

$= 0.3 \cdot [\, 0.25 \cdot (2 \cdot 7.5) \cdot (10+15) + 0.1 \cdot (2 \cdot 7.5) \cdot 15] = 34.875$ T

- Balok lintang $= n \cdot b \cdot W_{24x162} = 8 \cdot 7.5 \cdot 0.241$ $= 14.46$ T

- Balok bagi $= Q_{W18x71} \cdot n \cdot 15 + Q_{W16x36} \cdot n \cdot 10$

$= 0.106 \cdot 4 \cdot 15 + 0.054 \cdot 2 \cdot 10$ $= 7.44$

$W_2 = 279.75$ T

* Berat tingkat 11s/d14

- B. mati $= Q_4 \cdot (2b) \cdot (L_2+L_3)$

$= 0.405 \cdot (2 \cdot 7.5) \cdot 25$ $= 151.875$ T

- B. hidup reduksi $= R \cdot Q_5 \cdot (2b) \cdot (L_2+L_3)$

$= 0.3 \cdot 0.25 \cdot (2 \cdot 7.5) \cdot 25$ $= 28.125$ T

- Balok lintang $= n \cdot b \cdot W_{24x162}$

$= 6 \cdot 7.5 \cdot 0.241$ $= 10.845$ T

- Balok bagi $= Q_{W18x71} \cdot n \cdot 15 + Q_{W16x36} \cdot n \cdot 10$

$= 0.106 \cdot 2 \cdot 15 + 0.054 \cdot 2 \cdot 10$ $= 4.260$ T

$W_3 = 195.105$ T

Tingkat 11 s/d 14 identik

* Berat tingkat 15

- B. mati $= Q_4 \cdot (2b) \cdot L_2 + Q_1 \cdot (2b) \cdot L_3$

$= 0.405 \cdot (2 \cdot 7.5) \cdot 10 + 0.316 \cdot (2 \cdot 7.5) \cdot 15$ $= 131.85$T

- B. hidup reduksi $= R \cdot [\, Q_5 \cdot (2b) \cdot (L_2 + L_3) + Q_2 \cdot (2b) \cdot (L_2) \,]$

$= 0.3 \cdot [\, 0.25 \cdot (2 \cdot 7.5) \cdot 10 + 0.1 \cdot (2 \cdot 7.5) \cdot 15 \,]$ $= 18$ T

- Balok lintang $= n \cdot b \cdot W_{24x162}$

$= 6 \cdot 7.5 \cdot 0.241$ $= 10.845$ T

- Balok bagi $= W_{18x50} \cdot n \cdot 15 + Q_{W16x36} \cdot n \cdot 10$

$= 0.074 \cdot 2 \cdot 15 + 0.054 \cdot 2 \cdot 10$ $= 3.30$ T

$W_4 = 163.995$ T

* berat tingkat 16

- B. mati $= Q_4 \cdot (2b) \cdot L_2$

$= 0.405 \cdot (2 \cdot 7.5) \cdot 10$ $= 60.75$ T

- B. hidup reduksi $= R \cdot Q_5 \cdot (2b) \cdot L_2$

$= 0.3 \cdot 0.25 \cdot (2 \cdot 7.5) \cdot 10$ $= 11.25$ T

- Balok lintang $= n \cdot b \cdot W_{24x162}$

$= 4 \cdot 7.5 \cdot 0.241$ $= 10.845$ T

- Balok bagi $= Q_{W16x36} \cdot n \cdot 10$

$= 0.054 \cdot 2 \cdot 10$ $= 1.080$ T

$W_5 = 80.30$ T

Tingkat 16 s/d 19 identik

* Berat tingkat 20

- B. mati $= Q_1 \cdot (2b) \cdot L_2$

$= 0.316 \cdot (2 \cdot 7.5) \cdot 10$ $= 47.4$ T

- B. hidup reduksi $= R \cdot Q_2 \cdot (2b) \cdot L_2$

$= 0.3 \cdot 0.1 \cdot (2 \cdot 7.5) \cdot 10$ $= 4.5$ T

- Balok lintang $= n \cdot b \cdot W_{24x162}$

$= 4 \cdot 7.5 \cdot 0.241$ $= 7.23$ T

- Balok bagi $= W_{16x36} \cdot n \cdot 10$

$= 0.054 \cdot 2 \cdot 10$ $= 1.04$ T

$W_6 = 60.17$ T

5.1.4 Perhitungan letak pusat *mass*

Hasil perhitungan *mass* dapat dilihat pada *tabel 5.1*, dan letak pusat mass pada *gambar 5.1*

Table 5.1 Mass struktur

lantai	Berat (ton)	Mass (ton/dt²)	$\sum$ *berat* (ton)
20	60.17	6.134	60.17
19	80.3	8.186	140.47
18	80.3	8.186	220.77
17	80.3	8.186	301.07
16	80.3	8.186	381.37
15	163.995	16.717	545.365
14	195.105	19.888	740.47
13	195.105	19.888	935.575
12	195.105	19.888	1130.68
11	195.105	19.888	1325.785

10	279.75	28.517	1605.535
9	309.9	31.590	1915.435
8	309.9	31.590	2225.335
7	309.9	31.590	2535.235
6	309.9	31.590	2845.135
5	309.9	31.590	3155.035
4	309.9	31.590	3464.935
3	309.9	31.590	3774.835
2	309.9	31.590	4084.735
1	309.9	31.590	4394.635
jumlah	4394.635		

- *Mass* (translasi) = W/g

- Perhitungan diatas tidak termasuk berat dan mass struktur Frame

(Berat dan *Mass Frame* masuk dalam pemrograman)

* Lantai 1

$$X_1 = \frac{2b\ [Q_6 \cdot L_1 \cdot (1/2\ L_1) + Q_6 \cdot L_2 \cdot (L_1 + 1/2\ L_2) + Q_6 \cdot L_3 \cdot (L_1 + L_2 + 1/2\ L_3)\ ]}{2b \cdot Q_6 \cdot [L_1 + L_2 + L_3\ ]}$$

$$= \frac{(2 \cdot 7.5).\ [\ (0.655 \cdot 15 \cdot 7.5) + (\ 0.655 \cdot 10 \cdot (\ 15 + 5\ ) + \ (0.655 \cdot 15 \cdot (15 + 10 + 7.5)\ ]}{(2 \cdot 7.5)\ [\ (0.655 \cdot 15\ ) + (\ 0.655 \cdot 10\ ) + (0.655 \cdot 15\ )\ ]}$$

= 20 m ……lihat *gambar 5.1*

Lantai 1s/d 9 identik

* Lantai 10

$$X_2 = \frac{2b \cdot [Q_3 \cdot L_1 \cdot (1/2\ L_1) + Q_6 \cdot L_2 \cdot (L_1 + 1/2\ L_2) + Q_6 \cdot L_3 V (L_1 + L_2 + 1/2\ L_3)\ ]}{2b \cdot [Q_3 \cdot L_1 + Q_6 \cdot (L_2 + L_3\ ]}$$

$$= \frac{(2 \cdot 7.5) \cdot [\ (0.655 \cdot 15 \cdot 7.5) + (\ 0.655 \cdot 10 \cdot (\ 15 + 5\ ) + \ (0.655 \cdot 15 \cdot (15 + 10 + 7.5)\ ]}{(2 \cdot 7.5)\ [\ (0.416 \cdot 15\ ) + (\ 0.655 \cdot (10 + 15)\ ]}$$

= 21.9 m ……lihat *gambar 5.1*

* Lantai 11

$$X_3 = \frac{2b \cdot [Q_6 \cdot L_2 \cdot (1/2\ L_2) + Q_6 \cdot L_3 \cdot (L_2 + 1/2\ L_3)\ ]}{2b \cdot [Q_6 \cdot L_2 + Q_6 \cdot L_3\ ]}$$

$$= \frac{(2 \cdot 7.5) \cdot [\,(0.655 \cdot 10 \cdot 5) + (\,0.655 \cdot 15 \cdot 7.5\,)\,]}{(2 \cdot 7.5)\,[\,(0.655 \cdot 10\,) + (\,0.655 \cdot 15)\,]}$$

= 12.5 m .....lihat *gambar 5.1*

Lantai 11 s/d 14 identik

* Lantai 15

$$X_4 = \frac{2b \cdot [Q_6 \cdot L_2 \cdot (1/2\,L_2) + Q_3 \cdot L_3 \cdot (L_2 + 1/2\,L_3)\,]}{2b \cdot [Q_6 \cdot L_2 + Q_3 \cdot L_3\,]}$$

$$= \frac{(2 \cdot 7.5) \cdot [\,(0.655 \cdot 10 \cdot 5) + (\,0.416 \cdot 15 \cdot 7.5\,)\,]}{(2 \cdot 7.5)\,[\,(0.655 \cdot 10\,) + (\,0.416 \cdot 15)\,]}$$

= 11.09 m .....lihat *gambar 5.1*

* Lantai 16

$$X_4 = \frac{2b \cdot [Q_6 \cdot L_2 \cdot (1/2\,L_2)]}{2b \cdot [Q_6 \cdot L_2\,]}$$

$$= \frac{(2 \cdot 7.5) \cdot [\,(0.655 \cdot 10 \cdot 5)\,]}{(2 \cdot 7.5)\,[\,(0.655 \cdot 10\,)\,]}$$

= 5m .....lihat *gambar 5.1*

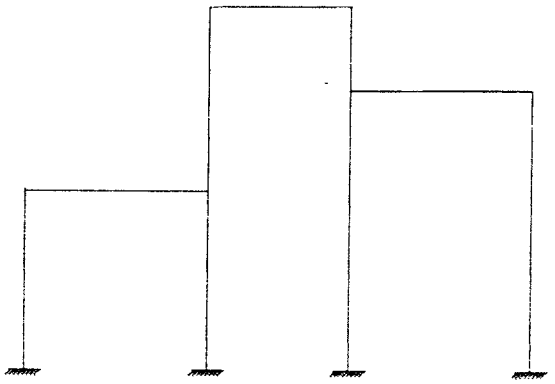
Lantai 16 s/d 19 identik

* Lantai 20..

$$X_4 = \frac{2b \cdot [Q_3 \cdot L_2 \cdot (1/2\,L_2)]}{2b \cdot [Q_6 \cdot L_2\,]}$$

$$= \frac{(2 \cdot 7.5) \cdot [\,(0.416 \cdot 10 \cdot 5)\,]}{(2 \cdot 7.5)\,[\,(0.416 \cdot 10\,)\,]}$$

= 5m .....lihat *gambar 5.1*



Gambar 5.1 Letak pusat *mass*

5.1.5 Pembebanan (gravitasi)

* Beban merata balok lantai bentang 15m

q_1 = 2 [$Q_4 \cdot 1/2$ b + $R_h \cdot Q_5 \cdot 1/2$ b + q_{w18x71}]

= 2 [0.405 ·7.5 + 0.75 ·0.25 · 7.5 + 0.106] = 9.10 T/m'

* Beban merata balok lantai bentang 10m

q_2 = 2 [$Q_4 \cdot 1/2$ b + $R_h \cdot Q_5 \cdot 1/2$ b + q_{w16x36}]

= 2 [0.405 ·7.5 + 0.75 ·0.25 · 7.5 + 0.054] = 8.996 T/m'

* Beban merata balok atap bentang 15m

q_3 = 2 [$Q_1 \cdot 1/2$ b + $R_h \cdot Q_2 \cdot 1/2$ b + q_{w18x50}]

= 2 [0.316 ·7.5 + 0.75 ·0.1 · 7.5 + 0.074] = 6.013 T/m'

* Beban merata balok atap bentang 10 m

q_4 = 2 [Q_1 ·1/2 b + R_h · Q_2 ·1/2 b + q_{w16x36}]

= 2 [0.316 ·7.5 + 0.75 ·0.1 · 7.5 + 0.054] = 5.973 T/m'

Beban Titik

P_1 = $q_{w24x261}$ · 2 · ½ b

= 0.241· 2 · ½ · 15 =3.615 T

5.1.6 Perhitungan awal balok bagi

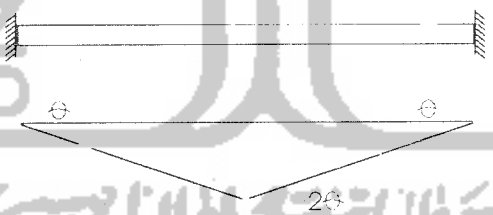
1. Balok bagi lantai

* Bentang 15 m

Dicoba Profil W_{18x71} ➔ Z_x =145 in^3

W = (Q_6 2 ½ b') + Q_{W18x71}

= (0.655 2 ½ 5) + 0.106 = 3.381 T/m'



Gambar 5.2 Mekanisme keruntuhan pada balok

Mekanisme keseimbangan *(Gambar 5.2)* :

$$I_w = M_p \cdot \theta$$

$$E_w = F \cdot \Delta$$

$$I_e = M_p \cdot \theta + M_p \cdot 2 \cdot \theta + M_p \cdot \theta$$

$$E_e = \tfrac{1}{8} \cdot q \cdot L^2 \cdot 2\theta$$

$I_w = E_w$

$M_p \cdot 4\theta = \frac{1}{8} \cdot q \cdot L^2 \cdot 2\theta$

$M_p = \frac{1}{16} \cdot q \cdot L^2$

$Mp = 1/16\ (1.7\ W)\ L^2$

$= 1/16\ (1.7\ 3.381\ )\ 15^2 = 80.819$ t/m' $= 7014.733$ kips-in

$$Z_x = \frac{Mp}{F_y} = \frac{7014.733}{50} = 140.295 \text{ in}^3 < Z_x = 145 \text{ in}^3 \ldots\ldots\ldots\ldots\ldots\text{Ok}$$

➔ Profil W_{18x71} dapat dipakai sebagai balok bagi pada lantai bentang 15m

* Bentang 10 m

Dicoba Profil W_{16x36} ➔ $Z_x = 64$ in^3

$W = (Q_6\ 2\ ½\ b'\ ) + Q_{W16x36}$

$= (0.655\ 2\ ½\ 5\ ) + 0.054 = 3.329$ T/m'

$Mp = 1/16\ (1.7\ W)\ L^2$

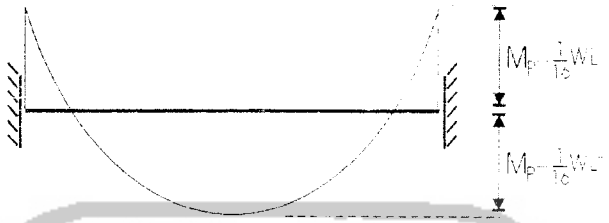
$= 1/16\ (1.7\ 3.329\ )\ 10^2 = 35.366$ T/m' $= 3069.630$ kips-in

$$Z_x = \frac{Mp}{F_y} = \frac{3039.630}{50} = 61.393 \text{ in}^3 < Z_x = 64 \text{ in}^3 \ldots\ldots\ldots\ldots\ldots\text{Ok}$$

➔ Profil W_{16x36} dapat dipakai sebagai balok bagi pada lantai bentang 10m

2. Balok bagi atap

* Bentang 15 m



Gambar 5.3 Balok dukungan jepit-jepit dengan $Mp = 1/16\ w\ l^2$

Dicoba Profil W_{18x50} ➔ $Z_x = 101\ in^3$

$W = (Q_3\ 2\ ½\ b') + Q_{W18x50}$

$= (0.416\ 2\ ½\ 5) + 0.0.074 = 2.154 T/m'$

$Mp = 1/16\ (1.7\ W)\ L^2$

$= 1/16\ (1.7\ 2.154)\ 15^2 = 51.504\ T/m' = 4470.309\ kips\text{-}in$

$$Z_x = \frac{Mp}{F_y} = \frac{4470.309}{50} = 99.406\ in^3 > Z_x = 101\ in^3 \quad \text{.....ok}$$

➔ Profil W_{18x50} dapat dipakai sebagai balok bagi pada atap bentang 15m

* Bentang 10 m

Dicoba Profil W_{16x36} ➔ $Z_x = 64\ in^3$

$W = (Q_3\ 2\ ½\ b') + Q_{W16x36}$

$= (0.416\ 2\ ½\ 5) + 0.054 = 2.134\ T/m'$

$Mp = 1/16\ (1.7\ W)\ L^2$

$= 1/16\ (1.7\ 2.134)\ 10^2 = 22.669\ T/m' = 1967.592\ kips\text{-}in$

$$Z_x = \frac{Mp}{F_y} = \frac{1967.592}{50} = 39.352 \text{ in}^3 < Z_x = 64 \text{ in}^3 \quad \ldots\ldots\ldots\ldots\ldots\text{Ok}$$

5.1.7.Perhitungan Awal Balok Induk (gravitasi)

1. Balok Bentang 15m

Dicoba Profil W_{18x192} ➔ $Z_x = 442 \text{ in}^3$

$W = (Q_6\ 2\ ½\ b) + 2\ Q_{W18x71} + Q_{W18x192}$

$= (0.655\ 2\ ½\ 15) + 2\ 0.106 + 0.286 = 10.323$ T/m'

$Mp = 1/16\ (1.7\ W)\ L^2$

$= 1/16\ (1.7\ 10.323)\ 15^2 = 246.777$ T/m' $= 21419.252$ kips-in

$$Z_x = \frac{Mp}{F_y} = \frac{21419.252}{50} = 428.385 \text{ in}^3 < Z_x = 442 \text{ in}^3 \quad \ldots\ldots\ldots\ldots\ldots\text{Ok}$$

➔ Profil W_{18x192} dapat dipakai sebagai asumsi awal balok bentang 15m

2. Balok Bentang 10m

Dicoba Profil $W_{184x130}$ ➔ $Z_x = 291 \text{ in}^3$

$W = (Q_3\ 2\ ½\ b) + 2\ Q_{W16x36} + Q_{W184x130}$

$= (0.655\ 2\ ½\ 15) + 2\ 0.054 + 0.193 = 6.541$ T/m'

$Mp = 1/16\ (1.7\ W)\ L^2$

$= 1/16\ (1.7\ 6.541)\ 10^2 = 69.503$ T/m' $= 6032.565$ kips-in

$$Z_x = \frac{Mp}{F_y} = \frac{6032.565}{50} = 120.631 \text{ in}^3 < Z_x = 291 \text{ in}^3 \quad \ldots\ldots\ldots\ldots\ldots\text{Ok}$$

➔ Profil W_{18x130} dapat dipakai sebagai asumsi awal balok bentang 10 m

5.1.8 Perhitungan dimensi kolom (gravitasi).

1. Kolom ***I***

Trial profil W_{24x192} (tinjauan kolom dasar)

Gaya aksial yang diterima kolom 1

P_1 : -B.Plat $= Q_6 \cdot \frac{1}{2} L_1 \cdot \frac{1}{2} \cdot 2 \cdot b$

$= 0.655 \cdot \frac{1}{2} \cdot 15 \cdot \frac{1}{2} \cdot 2 \cdot 15$ $= 73.6875$ T

- B.bagi $= q\, w_{18x71} \cdot 2 \cdot 1/2 \cdot L_1$

$= 0.106 \cdot 2 \cdot \frac{1}{2} \cdot 15$ $= 1.59$ T

- B.induk $= q\, w_{18x192} \cdot \frac{1}{2} \cdot (2b + L_1)$

$= 0.286 \cdot \frac{1}{2} \cdot (2 \cdot 15 + 15)$ $= \frac{6.435}{81.7125} +$

P_2 : -B.Plat $= Q_3 \cdot \frac{1}{2} L_1 \cdot \frac{1}{2} \cdot 2 \cdot b$

$= 0.416 \cdot \frac{1}{2} \cdot 15 \cdot \frac{1}{2} \cdot 2 \cdot 15$ $= 46.8$ T

- B.bagi $= q\, w_{18x50} \cdot 2 \cdot 1/2 \cdot L_1$

$= 0.074 \cdot 2 \cdot \frac{1}{2} \cdot 15$ $= 1.11$ T

- b.induk $= q\, w_{18x192} \cdot \frac{1}{2} \cdot (2b + L_1)$

$= 0.286 \cdot \frac{1}{2} \cdot (2 \cdot 15 + 15)$ $= \frac{6.435}{54.345} +$

Trial kolom W_{24x192} q = 0.286 T/m'

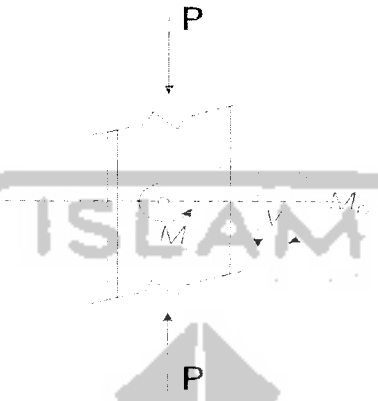
d = 25.47'' rx=10.5'' ry=3.07'' Mp=2330 Kip-ft =321.540 T-m

Py=2820 Kip =1279.131 T

H_{kolom} = 4m =157.48''

$\Sigma P = 9 \cdot P_1 + P_2 + (q_{w24x192} \cdot 4) \cdot 10$

$= 9 \cdot 81.7125 + 54.345 + 0.286 \cdot 4 \cdot 10 = 801.185$ t-m



Gambar 5.4. Distribusi kapasitas balok pada kolom I

Distribusi kapasitas balok pada kolom I *(Gambar 5.4) :*

$Mj = Mp_{balok} + 1/2 \cdot d \cdot Vp'$

$= 246.777 + 1/2 \cdot (20.35.0254) \cdot (1.7 \cdot 1/2 \cdot 15 \cdot (1/2 \cdot 2 \cdot 15) \cdot 0.655) = 279.152$ T-m

$Mc = 1/2 \cdot Mj$

$= 1/2 \cdot 279.152 = 139.576$ T-m

$$\left(\frac{h}{r_y}\right)_{aktual} = \left(\frac{h}{r_y}\right)_{equivalent} \cdot \sqrt{\frac{Fy}{36}}$$

$$\left(\frac{h}{r_y}\right)_{aktual} = \left(\frac{157.48}{3.07}\right)_{equivalent} \cdot \sqrt{\frac{50}{36}} = 60.453$$

$$\frac{\Sigma P}{Py} = \frac{801.185}{1279.131} = 0.626$$

$$Mpc = 1.18 \cdot \left(1 - \frac{\Sigma P}{Py}\right) \cdot Mp$$

$=1.18\cdot(1-0.626)\cdot 321.540$ = 141.769 T-m

➔*Lampiran E*, dengan q=+1 didapat

$$\frac{M}{Mpc}=1.0$$

M = 1.0 ·141.769 =141.759 T-m >Mc=139.576 T-m .....Ok

➔ Profil W_{24x192} dapat dipakai sebagai asumsi kolom ***I***

2. Kolom ***II***

Trial profil W_{24x370} (tinjauan kolom dasar)

Gaya axial Yang diterima kolom

P_3 : -B.Plat = $(Q_6 \cdot ½\, L_1 \cdot ½ \cdot 2 \cdot b) + (Q_6 \cdot ½\, L_2 \cdot ½ \cdot 2 \cdot b)$

= $(0.655 \cdot ½ \cdot 15 \cdot ½ \cdot 2 \cdot 15) + (0.655 \cdot ½ \text{ x } 10 \cdot ½ \cdot 2 \cdot 15)$

=122.8125 T

- B.bagi = $(q\, w_{18x71} \cdot 2 \cdot 1/2 \cdot L_1) + q\, w_{16x36} \cdot 2 \cdot 1/2 \cdot L_2$

= $(0.106 \cdot 2 \cdot ½ \cdot 15) + (0.054 \cdot 2 \cdot ½ \cdot 10)$ = 2.130 T

- B.induk= $(q\, w_{18x192} \cdot ½ \cdot (2b + L_1) + (q\, w_{18x130} \cdot ½ \cdot L_2)$

= $(0.286 \cdot ½ \cdot (2 \cdot 15 + 15) + 0.193 \cdot ½ \cdot (10)$ = $\frac{7.40}{132.3425}$ +

P_4 : -B.Plat = $(Q_3 \cdot ½\, L_1 \cdot ½ \cdot 2 \cdot b) + (Q_6 \cdot ½\, L_2 \cdot ½ \cdot 2 \cdot b)$

= $(0.416 \cdot ½ \cdot 15 \cdot ½ \cdot 2 \cdot 15) + (0.655 \cdot ½ \cdot 10 \cdot ½ \cdot 2 \cdot 15)$

= 122.455 T

- B.bagi = $q\, w_{18x50} \cdot 2\ 1/2 \cdot L_1) + (q\, w_{16x36} \cdot 2 \cdot 1/2 \cdot L_2$

= $0.074 \cdot 2 \cdot ½ \cdot 15 + 0.054 \cdot 2 \cdot 1/2 \cdot 10$ = 1.650 T

- B.induk= $(q\,w_{18x192} \cdot ½ \cdot (2b + L_1) + (q\,w_{18x130} \cdot ½ \cdot L_2)$

$= (0.286 \cdot ½ \cdot (2 \cdot 15 + 15) + 0.193 \cdot ½ \cdot (10) = \frac{7.40}{131.505} +$

P_5 : -B.Plat $= Q_6 \cdot ½\, L_2 \cdot ½ \cdot 2 \cdot b$

$= 0.655 \cdot ½ \cdot 10 \cdot ½ \cdot 2 \cdot 15 = 49.125$ T

- B.bagi $= q\,w_{16x36} \cdot 2 \cdot ½ \cdot L_2$

$= 0.054 \cdot 2 \cdot ½ \cdot 10 = 0.540$ T

- b.induk $= q\,w_{18x130} \cdot ½ \cdot (2b + L_2)$

$= 0.193\ ½ \cdot (2 \cdot 15 + 10) = \frac{3.86}{53.525} +$

P_6 : -B.Plat $= Q_3 \cdot ½\, L_2 \cdot ½ \cdot 2 \cdot b$

$= 0.416 \cdot ½ \cdot 10 \cdot ½ \cdot 2 \cdot 15 = 31.2$ T

- B.bagi $= q\,w_{16x36} \cdot 2 \cdot ½ \cdot L_2$

$= 0.054\ 2 \cdot ½ \cdot 10 = 0.540$ T

- b.induk $= q\,w_{18x130} \cdot ½ \cdot (2b + L_2)$

$= 0.193 \cdot ½ \cdot (2 \cdot 15 + 10) = \frac{3.86}{35.60} +$

Trial kolom W_{24x370} $q = 0.551$ T/m'

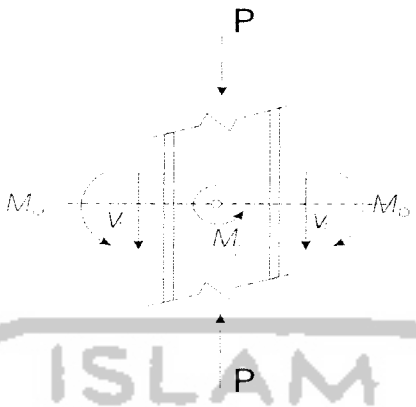
$d = 27.99''$ $rx = 11.1''$ $ry = 3.28''$ $Mp = 4670$ Kip-ft $= 644.460$ T-m

$Py = 5400$ Kip $= 2449.399$ T

$H_{kolom} = 4$m $= 157.48''$

$\sum P = 9 \cdot P3 + P4 + 9 \cdot P5 + P6 + (q_{w24x370} \cdot 4) \cdot 20$

$= 9 \cdot 132.3425 + 131.505 + 9 \cdot 53.525 + 35.60 + 0.551 \cdot 4 \cdot 20 = 1883.957$ T-m



Gambar.5.5. Distribusi kapasitas balok pada kolom II

Distribusi kapasitas balok pada kolom II *(Gambar 5.5) :*

$Mj = Mp' + ½ \cdot d \cdot V' - Mp'' - ½ \cdot d \cdot V''$

$=246.777 + 1/2 \cdot (20.35x0.0254) \cdot (1.7 \cdot 1/2 \cdot 15 \cdot (1/2 \cdot 2 \cdot 15) \cdot 0.655) - 69.503 - ½ \cdot (19.25x0.0254) \cdot 1.7 \cdot ½ \cdot 10 \cdot 1/2 \cdot 2 \cdot 15$

$= 196.682$ t-m

$Mc = 1/2 \cdot Mj$

$=1/2 \cdot 196.682$

$= 98.341$ t-m

$$\left(\frac{h}{r_y}\right)_{aktual} = \left(\frac{h}{r_y}\right)_{equivalent} \cdot \sqrt{\frac{Fy}{36}}$$

$$\left(\frac{h}{r_y}\right)_{aktual} = \left(\frac{157.48}{3.28}\right)_{equivalent} \cdot \sqrt{\frac{50}{36}} = 57.610$$

$$\frac{\Sigma P}{Py} = \frac{1883.957}{2449.399} = 0.769$$

$$Mpc = 1.18 \cdot \left(1 - \frac{\Sigma P}{Py}\right) \cdot Mp$$

$= 1.18 \cdot (1 - 0.769) \cdot 644.460$ = 175.552 T-m

➔*Lampiran E*, dengan q=+1 didapat

$$\frac{M}{Mpc} = 0.9$$

$M = 0.9 \cdot 175.552$ =157.997 T-m >Mc=98.341 T-m .....Ok

➔ Profil W_{24x370} dapat dipakai sebagai asumsi awal kolom ***II***

3. Kolom ***III***

Trial profil W_{24x450} (tinjauan kolom dasar)

Gaya axial Yang diterima kolom

P_3 = 132.3425

P_4 = 131.505

P_5 = 53.525

P_6 = 35.600

Trial kolom W_{24x450} q = 0.670 T/m'

d = 29.09'' rx=11.4'' ry=3.36'' Mp=5880 Kip-ft =811.44 T-m

Py=6600 Kip =2993.710 T

H_{kolom} = 4m =157.48''

$\Sigma P = 14 \cdot P_3 + P_4 + 4 \cdot P_5 + P_6 + (q_{w24x450} \cdot 4) \cdot 20$

$= 14 \cdot 132.3425 + 131.505 + 4 \cdot 53.525 + 35.60 + 0.670 \cdot 4 \cdot 20 = 2287.568$ t-m

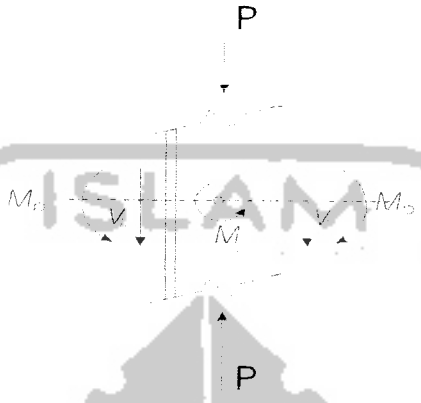
Distribusi kapasitas balok pada kolom III *(Gambar 5.6) :*

$Mj = Mp' - \frac{1}{2} \cdot d \cdot V' - Mp'' - \frac{1}{2} \cdot d \cdot V''$

=246.777 +1/2 · (20.35x0.0254) · (1.7·1/2·15· (1/2·2·15) ·0.655) - 69.503– ½

·(19.25x0.0254) · 1.7 · ½ ·10 · 1/2·2·15

= 196.682 t-m



Gambar 5.6. Distribusi kapasitas balok pada kolom III

$Mc = 1.2 \cdot Mj$

=1/2·196.682

= 98.341 t-m

$$\left(\frac{h}{r_y}\right)_{aktual} = \left(\frac{h}{r_y}\right)_{equivalent} \cdot \sqrt{\frac{Fy}{36}}$$

$$\left(\frac{h}{r_y}\right)_{aktual} = \left(\frac{157.48}{3.36}\right)_{eqrivalent} \cdot \sqrt{\frac{50}{36}} = 55.937$$

$$\frac{\Sigma P}{Py} = \frac{2287.568}{2293.710} = 0.764$$

$$Mpc = 1.18 \cdot \left(1 - \frac{\Sigma P}{Py}\right) \cdot Mp$$

$$= 1.18 \cdot (1 - 0.764) \cdot 811.440 = 225.850 \text{ T-m}$$

➔*Lampiran E*, dengan q=+1 didapat

$$\frac{M}{Mpc} = 0.7$$

$M = 0.7 \cdot 225.850$ =158.095 T-m > Mc=98.341 T-m .....Ok

➔ Profil W_{24x450} dapat dipakai sebagai asumsi awal kolom ***III***

4. Kolom ***IV***

Trial profil W_{24x279} (tinjauan kolom dasar)

Gaya axial Yang diterima kolom

P_1 =81.7125

P_2 = 54.345

Trial kolom W_{24x279} q = 0.415 T/m'

d = 26.02'' rx=10.7'' ry=3.11'' Mp=3480 Kip-ft =480.240 T-m

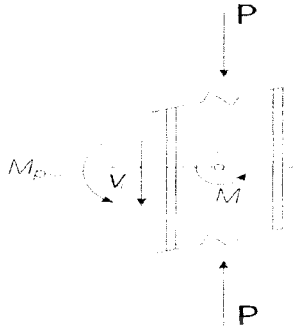
Py=4100 Kip =1859.729 T

H_{kolom} = 4m =157.48''

$\sum P = 14 \cdot P_1 + P_2 + (q_{w24x279} \cdot 4) \cdot 15$

= 14·81.7125 + 54.345 +0.415·4·15

= 1223.229 t-m



Gambar 5. 7. Distribusi kapasitas balok pada kolom IV

Distribusi kapasitas balok pada kolom IV *(Gambar 5.7) :*

$Mj = Mp_{balok} + 1/2 \cdot d \cdot Vp'$

$=246.777 + 1/2 \cdot (20.35x0.0254) \cdot (1.7 \cdot 1/2 \cdot 15 \cdot (1/2 \cdot 2 \cdot 15) \cdot 0.655)$

$= 279.152$ t-m

$Mc = 1/2 \cdot Mj$

$=1/2 \cdot 279.152 \qquad = 139.576$ t-m

$$\left(\frac{h}{r_y}\right)_{aktual} = \left(\frac{h}{r_y}\right)_{equivalent} \cdot \sqrt{\frac{Fy}{36}}$$

$$\left(\frac{h}{r_y}\right)_{aktual} = \left(\frac{157.48}{3.11}\right)_{equivalent} \cdot \sqrt{\frac{50}{36}} = 59.676$$

$$\frac{\Sigma P}{Py} = \frac{1223.229}{1859.729} = 0.658$$

$$Mpc = 1.18 \cdot \left(1 - \frac{\Sigma P}{Py}\right) \cdot Mp$$

$$=1.18 \cdot (1 - 0.658) \cdot 480.240 \qquad = 193.950 \text{ T-m}$$

➔*Lampiran E*, dengan q=+1 didapat

$$\frac{M}{Mpc} = 1.0$$

$M = 1.0 \cdot 193.950$ =193.950 T-m >Mc=139.576 T-m .....Ok

➔ Profil W_{24x279} dapat dipakai sebagai kolom ***IV***

5.1.9 Desain awal bracing

* Dimensi awal bracing

- Balok bentang 10m Profil W_{18x130} *(Gambar 5.8)* :

$A = 38.2$ in^2 $d = 19.25$ in $tw = 0.670$ in

$b_f = 11.160$ in $t_f = 1.20$ $Zx = 291$ in^3

Gambar 5.8 Profil balok pada bentang Link

* Asumsi penentuan awal lebar link

$e = 1.6 Ms/Vs$.

$M_s = F_y \cdot Z_x$ = 50 x 291 =14550 Kip-in

$V_s = 0.55 \cdot F_y \cdot d \cdot t_w$ =0.55 x 50 x 19.25 x 0.670 = 354.681 kips

$$e \le 1.6 \cdot \frac{14550}{354.681} = 65.636 \text{ in} \qquad = 1.667 \text{ m}$$

Dipakai ***e= 0.75 m = 29.528 in***

h = 4m = 157.48 in

$$Lx = \frac{10 - 0.5}{2} = 4.75 \text{ m}$$

$$L_{br} = \sqrt{4.75^2 + 4^2} = 6.2 \text{ m} \quad = 244.09 \text{ in}$$

$$Tg\alpha = \frac{4}{4.75} \quad \rightarrow \alpha = 40.1^\circ \qquad 35^\circ \le \alpha \le 65^\circ \quad \text{.....oke}$$

$$* V_{br} = 1.25 \cdot \left(V_b + V_s^{'}\right)$$

$$M_{rs} = Z_x \cdot (Fy - Fa) = 291 \cdot (50 - 0) = 14550 \text{ kips-in}$$

$$V_{rs} = \frac{2 \cdot M_{rs}}{e} = \frac{2 \cdot 14550}{29.528} = 985.505 \text{ kips} \qquad \text{.....1}$$

$$V_s = 0.55 \cdot Fy \cdot d \cdot tw = 0.55 \cdot 50 \cdot 19.25 \cdot 0.670 = 354.681 \text{ Kips} \qquad \text{.....2}$$

$$V_s^{'} = 354.681 \text{ kips}$$

$$M_s = \frac{V_s^{'} \cdot e}{2} = \frac{354.681 \cdot 29.528}{2} = 5236.51 \text{ Kips-in}$$

$$V_b = \frac{M_s}{(L - e)/2} = \frac{5236.51}{(244.09 - 29.528)/2} = 22.834 \text{ kips}$$

$$V_{br} = 1.5 \cdot \left(V_b + V_s^{'}\right) = 1.25 \cdot (22.834 + 354.681) = 471.894 \text{ kips}$$

$$P_{br} = V_{br} \cdot \left(\frac{L_{br}}{h}\right) = 471.894 \cdot \left(\frac{244.09}{157.48}\right) = 731.424 \text{ kips}$$

* Berdasarkan kuat tarik

$$Py = Fy \cdot An$$

$$An = \frac{P}{Fy} \qquad = \frac{731.424}{50} \qquad = 14.628 \text{ in}^2$$

* Berdasarkan kuat tekan

Dicoba Profil 2L8x8x1-3/4 *(Gambar 5.9)* :

$Ry = 3.67$

$$kl/ry = \frac{1 \cdot 244.09}{3.67} = 66.51$$

$$Cc = \sqrt{\frac{2 \cdot \pi^2 \cdot E}{Fy}} = \sqrt{\frac{2 \cdot \pi^2 \cdot 29000}{50}} = 106.94 \qquad ; kl/ry > Cc$$

Dari tabel AISC halaman 3-17 untuk $kl/r = 66.51$ didapat nilai $F_a = 21.578$ *ksi*

$$Ab = \frac{P}{F \cdot Fa} = \frac{731.424}{1.7 \cdot 21.578} = 19.939 \text{ in}^2 \quad < Ab \text{ } 2L8x8x1\text{-}3/4 = 30 \text{ in}^2 \quad \text{....Ok}$$

Profil *2L8x8x1-3/4* Dapat dipakai sebagai asumsi awal bracing

Gambar 5.9 Profil bracing

5.2 Desain akhir

Berdasarkan profil yang di dapat dalam desain awal , maka profil tersebut dipergunakan sebagai asumsi awal dalam analisis elastis struktur dan dari hasil tersebut akan kembali didesain akhir, yang hasilnya sebagai berikut :

1. Cek defleksi struktur dan gaya geser dasar struktur

   Hasil output SAP 2000 (***lampiran A***), simpangan relatif tiap tingkat < 2 cm

   Gaya geser dasar struktur = 167.039 tm < $V_{ds} = 0.9 \cdot C \cdot I \cdot K \cdot W_t$

   $$T = \frac{0.09 \cdot H}{\sqrt{B}} = \frac{0.09 \cdot 80}{\sqrt{40}} = 1.138$$

   ➔ Dari *Gambar 3.5* didapat nilai C = 0.065

   $V_{ds} = 0.9 \cdot 0.065 \cdot 1.5 \cdot 2.5 \cdot 5614.21 = 1231.617$ tm $< V_d = 6997.237$ tm ...ok

2. Hitung ukuran *link* (*link size*)

   Web shear tidak melebihi 0.8 kuat geser yang bekerja, guna mendesain *link* terhadap batas stress yang diijinkan

   $$V_L \leq 0.8\ V_S$$

   $$\text{d.}tw_{\min} = \frac{V_L}{0.8x(0.55)xFy} \qquad \textit{(Hasil perhitungan Tabel 5.2)}$$

   Trial profil

   Untuk semua tingkat dipakai profil *W21x50*, pada bagian link

   $d.tw = 7.915$ in² $\qquad b_f = 6.53$ in. $\quad t_f = 0.535$ in.

   $d = 20.83$ in. $\qquad t_w = 0.380$

Tabel 5.2 Luas geser min badan link

balok tingkat ke-n	v_l	$d.t_w$
	kips	In^2
tingkat 1-5	143.102	6.505
tingkat 6-10	120.241	5.465
tingkat 11-15	89.559	4.071
tingkat 16-20	46.328	2.106

3. Cek kekompakan *web* dan *flange* untuk mencegah ketidakstabilan balok yang mungkin terjadi

   a. Mencegah terhadap kerusakan tekuk lokal

   $$\frac{b_f}{2.t_f}\max = 7.0 \qquad \rightarrow \frac{b_f}{2.t_f} = \frac{6.53}{2x0.535} = 6.103 \leq 7.0 \text{ ok}$$

   b. Mencegah terhadap tekuk lateral

   $$\frac{d}{tw} \max = 58.3 \qquad \rightarrow \frac{d}{tw} = \frac{20.83}{0.380} = 7.915 \leq 58.3 \text{ ok}$$

   pada tahap ini link dirancang agar merupakan bagian terlemah dari frame

4. Pastikan *link* mengalami mekanisme inelastik, dimana seluruh komponen diluar link memiliki kekuatan lebih dari *link*, maka harus ditentukan faktor kuat *link* yang menjamin kekuatan element struktur yang lainnya.

   $V_S = 0.55.\ Fy.d.tw$

   ϕ = *link strength factor* ; *(Hasil perhitungan Tabel 5.3)*

   = kekuatan lebih yang diperlukan diluar elemen EBF

   $$= \frac{V_S}{V_L}$$

$$\phi_{\min} = \frac{1}{\phi_v} = \frac{1}{0.9} = 1.111 \quad \text{.....(UBC 1997)}$$

Tabel 5.3 Strength factor link

balok tingkat ke-n	V_L	$\phi > \phi_{min} = \frac{1}{0.9}$
	kips	
tingkat 1-5	143.102	1.521
tingkat 6-10	120.241	1.810
tingkat 11-15	89.559	2.431
tingkat 16-20	46.328	4.699

5. Memastikan panjang *link* agar terjadi *shear ductility*

$M_s = z_x . Fy$ =110x50 = 5500 kips

$V_S = 0.55 . Fy.d.tw$ =0.55x50x20.83x0.38

= 217.674 kips

$$e \leq 1.6\frac{M_S}{V_S} = 1.6\frac{5500}{217.674} = 40.427 \text{ in} = 1.0268 \text{ m}$$

$$e_{awal} = 0.75 \text{ meter} \leq 1.6\frac{M_S}{V_S}$$, dipakai e = 0.75 m

6. Kontrol kapasitas *link*

Untuk memastikan *link* mengalami kegagalan geser sebelum terjadi kerusakan akibat lentur, maka harus dipastikan kapasitas geser lebih rendah dibandingkan kapasitas lentur dan aksial yang terjadi.

$P_{LU} = \phi . P_L$

$$M_{LU} = \frac{\phi . V_L . e}{2}$$

profil pilihan link: $Af = bf. tf$

= 6.53x0.535 = 3.494 in²

$Z_f = (d - t_f) b_f . t_f$

(20.83-0.535)6.53x0.535 = 70.911 in³

cek $\frac{P}{2A_f} + \frac{M}{Z_f} = \ldots . \leq Fy$, kontrol *web* kuat menahan geser dan *flange* kuat menahan aksial dan lentur *(Tabel 5.4)*

Tabel 5.4 Kontrol kapasitas balok link

balok tingkat ke-n	V_L	P_L	ϕ	P_{LU}	M_{LU}	Cek < Fy=50 ksi
	kips	kips		kips	ksi	ksi
tingkat 1-5	143.102	0	1.521	0	3213.45	45.31
tingkat 6-10	120.241	0	1.810	0	3213.12	45.312
tingkat 11-15	89.559	0	2.431	0	3214.33	45.329
tingkat 16-20	46.328	0	4.699	0	3213.49	45.324

7. Memastikan besarnya *link stregth factor*

$V_S = 0.55 \, . \, Fy.d.tw$ =0.55x50x20.83x0.38 =217.674 kips

$M_{rs} = Zx. \, (Fy\text{-}fa)$ = 110x(50-0) = 5500 kips-in

$V_{rs} = \frac{2M_{rs}}{e} = \frac{2x5500}{0.75}$ = 14666.667 , diambil nilai terkecil dari V_S dan V_{RS}

$V_{\min}$ = 217.674 kips-in

$\phi = \frac{V_{\min}}{V_{link}}$ *(Tabel 5.5)*

Tabel 5.5 : Strength factor link

balok tingkat ke-n	V_L	ϕ
	kips	
tingkat 1-5	143.102	1.521
tingkat 6-10	120.241	1.810
tingkat 11-15	89.559	2.431
tingkat 16-20	46.328	4.699

8. Cek rotasi pada link

Guna mendapatkan struktur yang daktail pada EBF, maka diperlukan *inelastik deformation* pada *link*. Deformasi ini diakibatkan oleh rotasi pada *link*, dan UBC1997 memberikan batasan rotasi pada *link* tersebut (lihat sub.bab 4.1)

$$\theta = \frac{\Delta}{h}(1+\frac{2a}{e}) < \theta_{max}=0.06\text{rad} \qquad \textit{(Tabel 5.6)}$$

Tabel 5.6 Rotasi pada link

balok tingkat ke-n	simpangan max tiap 5 tngkat	$\theta < \theta_{max}$ =0.06 rad
	m	rad
tingkat 1-5	0.0011	0.004
tingkat 6-10	0.0013	0.004
tingkat 11-15	0.0015	0.005
tingkat 16-20	0.0016	0.005

9. cek minimum *link*

$$\theta_{max} = \frac{\Delta}{h}(1+\frac{2a}{e_{min}})$$

$$= \frac{\Delta}{h}(\frac{L}{e_{min}})$$

$$e_{min} = \frac{\Delta}{h}.\frac{L}{\theta_{max}} < e_{rencana}=0.75\text{ m} \qquad \textit{(Tabel 5.7)}$$

Tabel 5.7 Panjang link minimum

balok tingkat ke-n	simpangan max tiap 5 tngkat	$e_{min} < e_{rencana} = 0.75m$
	m	m
tingkat 1-5	0.0011	0.046
tingkat 6-10	0.0013	0.054
tingkat 11-15	0.0015	0.063
tingkat 16-20	0.0016	0.067

10. Analisis balok.

profil balok W_{21x50}

$d.tw$ = 7.915 in^2 b_f= 6.53 in. t_f = 0.535 in. A =14.7 in^2

d =20.83 in. tw = 0.380 in. rx = 8.18 in ry = 1.3 in

cek terhadap momen :

$M_{bu} \langle M_p$

cek terhadap geser :

$V_{su} = \frac{1}{\phi_v}.V_b \langle V_S$; dengan ϕ_v=shear resistance factor = 0.9

Hasil perhitungan dapat dilihat pada *Tabel 5.8*

$M_{p\ W21x50}$ = 458 kips-ft = 63.321 ton-m =5495.946 kips-in

V_s = 217.674 ton

Tabel 5.8 Cek kapasitas balok

balok tingkat ke-n	V_b	M_{be}	Cek $V_{su} < V_s$	$M_{be} < M_p$
	kips	t-m	kips	kips-in
tingkat 1-5	33.3148	40.3186	37.0164	3492.1552
tingkat 6-10	35.1649	36.483	39.0721	3159.9386
tingkat 11-15	36.2939	31.0478	40.3266	2689.1741
tingkat 16-20	35.1872	26.1955	39.0969	2268.8970

11. Cek pemberian pengaku diluar link pada balok untuk mencegah *lateral buckling*

$$L_{CR} = ry.\left(\frac{1375}{Fy} + 25\right) \qquad \rightarrow \frac{M}{M_p} < 0.5$$

$$L_{CR} = ry.\left(\frac{1375}{Fy}\right) \qquad \rightarrow \frac{M}{M_p} > 0.5$$

Hasil perhitungan dapat dilihat pada *Tabel 5.9*

Table 5.9 Jarak pengaku badan balok link

balok tingkat ke-n	Mbe	M/Mp	Lcr
	Kips-in		in
tingkat 1-5	3492.1552	0.63494	35.750
tingkat 6-10	3159.9386	0.57453	35.750
tingkat 11-15	2689.1741	0.48894	68.250
tingkat 16-20	2268.897	0.41253	68.250

12. Brace analysis

Bracing mempunyai kuat tekan 1.25 kali dari axial force yang bekerja.

P_{br1} = aksial pada bracing

$P_{br2} = 1.25\phi . V_L$; diambil yang terbesar sebagai P_{br}

asumsi : bracing $2L\ 8x8x8\frac{1}{8} - \frac{3}{8}$

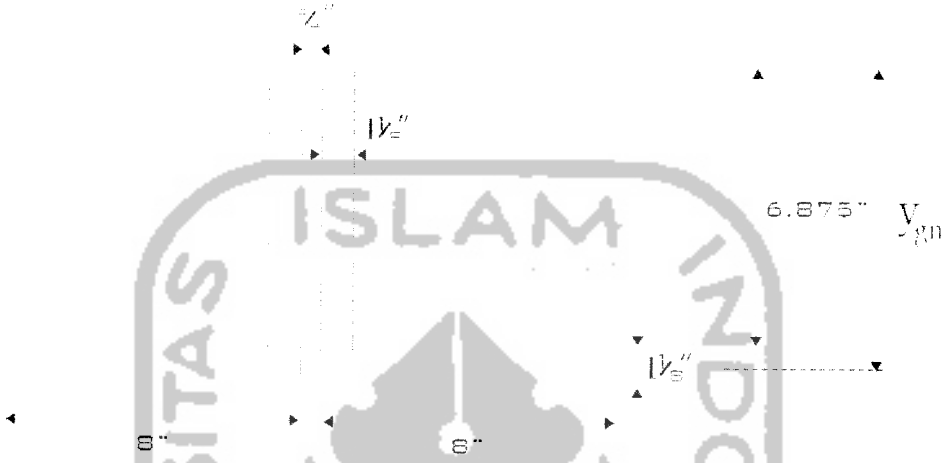
$$kl/r = \frac{1x244.09}{3.67} = 66.51$$

dari tabel AISC halaman 3-17 didapat nilai $F_a = 22.098$ *kips*

$P_{cr} = 1.7\ F_a\ A = 1.7x22.098x33.5 = 1258.481\ kips$

$P_Y = F_Y.A = 50x33.5 = 1675$ kips

Mencari modulus plastis bracing $2L\ 8x8x8\frac{1}{8} - \frac{3}{8}$ *(Gambar 5.10)*



Gambar 5.10 Penampang profil bracing

Letak garis netral pada keadaan plastis :

$2\frac{1}{4} \cdot 6.875 + 16 \cdot Y_{gn} = \frac{1}{2}.33.5$

$2\frac{1}{4}.Y_{gn} = \frac{1}{2}.33.5 \quad \Rightarrow Y_{gn} = 7.4375$ "

modulus plastis $(Z_x) = \left(2\frac{1}{4}x6.875\right)\left(7.4375 - \frac{6.875}{2}\right) + \left(12x1\frac{1}{8}x0\right) = 61.875\ in^3$

$M_P = F_y.Z_x = 50x61.875 = 3093.75\ kips - in$

Hasil perhitungan dapat dilihat pada *Tabel 5.10*

Tabel 5.10 Cek kapasitas bracing

tingkat ke-n	ϕ	Pbr1	Pbr2	Pbr <Pcr
		kips	kips	kips
tingkat 1-5	1.942	330.4954	272.0716	330.4954
tingkat 6-10	2.635	291.5590	272.0448	291.5590
tingkat 11-15	3.529	242.6987	272.1472	272.1472
tingkat 16-20	5.252	182.0276	331.2890	331.2890

13. Analisis kolom

$P_{cu\,1}$= aksial pada kolom

$P_{cu\,2}$= $1.25\,\phi\,V_L$; diambil yang terbesar sebagai P_{cu}

$M_{cu\,1}$= momen pada kolom

$M_{cu\,2}$= $\dfrac{1.25\,\phi\,V_L.\,e}{2}$; diambil yang terbesar sebagai M_{cu}

$P_{cr} = 1.7\,Fa.A$

$P_e = 1.92\,F_e'.A$

$$F_e' = \frac{\pi^2 E}{1.92\left(\frac{kl}{r}\right)^2}$$

$P_y = F_y.A$

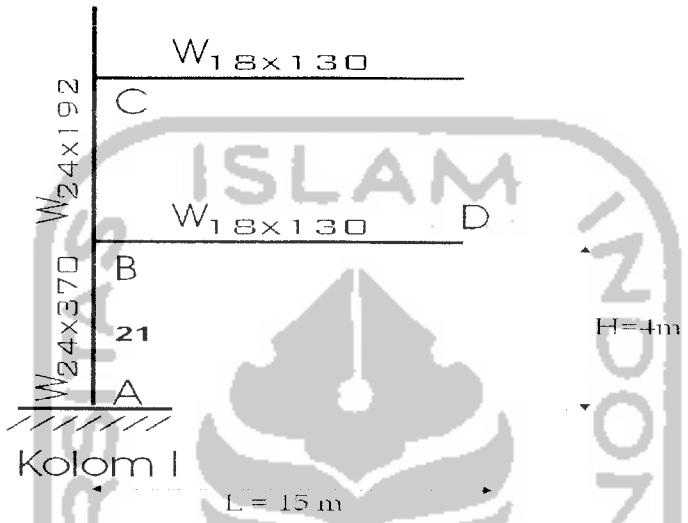
$$Mm = \left[1.07 - \frac{\left(\frac{l}{r_y}\right)\sqrt{F_y}}{3160}\right] M_p \quad \leq M_p = Fy.Z_x$$

Cek aksial lentur :

$$\frac{P_{cu}}{P_{cr}} + \frac{C_m}{\left(1 - \frac{P_{cu}}{P_{cr}}\right) M_m} < 1.0$$

$$\frac{P_{cu}}{P_y} + \frac{M_{cu}}{1.18M_p} < 1.0$$

analisis kekakuan kolom I-frame 1 (Gambar 5.11) :



Gambar 5.11 Profil kolom I dan balok bentang L1

$I_x\, w_{24x192}$ =6260 in^2

$I_x\, w_{18x130}$ = 2460 in^2

H = 4 m = 157.48 in

L = 15 m = 590.551 in

$$I/L_{AB} = I/L_{BC} = \frac{6260}{157.48} = 39.751$$

$$I/L_{BD} = \frac{2460}{590.551} = 4.166$$

$G_A = 1.0$

$$G_D = \frac{2x39.751}{2x4.166} = 9.484$$

Dari grafik pencarian nilai K AISC hal 3-5, didapat K = 0.85 untuk portal tak bergoyang.

Profil kolom W_{24x370} :

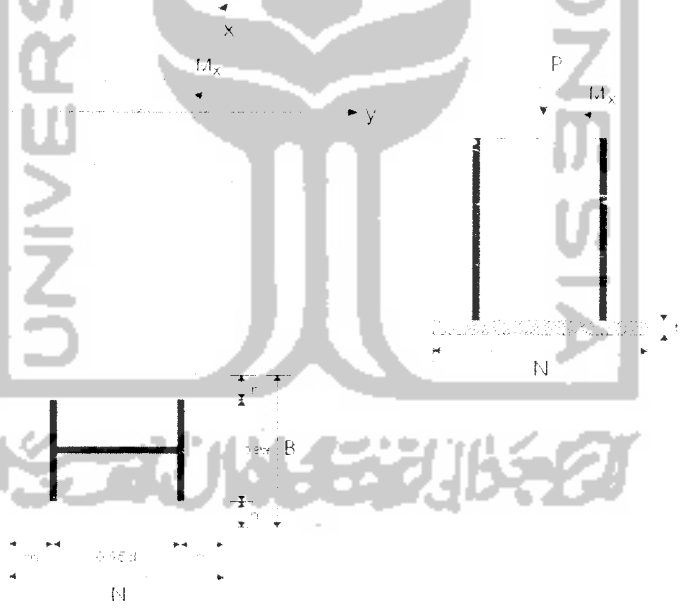
$A = 108\text{in}^2$ $Z_x = 1120\text{in}^3$ $r_x = 11.1$ in $I_x = 13400\ \text{in}^4$

$$\frac{kl}{r} = \frac{0.85x157.48}{11.1} = 12.748$$

dari tabel AISC hal 3-17 didapat nilai $F_a = 29.013$ ksi

Hasil perhitungan dapat di lihat pada ***lampiran B***

14. Desain pelat dasar *(Gambar 5.12)*



Gambar 5.12 Pelat dasar pondasi

$f_c^{'} = 35\ ksi$

$F_P = tegangan\ ijin\ pelat = 0.35x\ f_c^{'} = 0.35x35 = 12.25\ ksi$

$$f_p = tegangan\ beton\ pada\ beton = \frac{P}{BxN} + \frac{M}{\frac{1}{6}xBxN^2} \leq F_P$$

$$m = \frac{N - 0.95d}{2}$$

$$n = \frac{B - 0.8b_f}{2}$$

tebal pelat :

$$t_m = 2m\sqrt{\frac{f_p}{F_y}} \qquad : \qquad t_n = 2n\sqrt{\frac{f_p}{F_y}}$$

Diambil yang terbesar sebagai tebal pelat

Tabel 5.11 kolom tingkat dasar

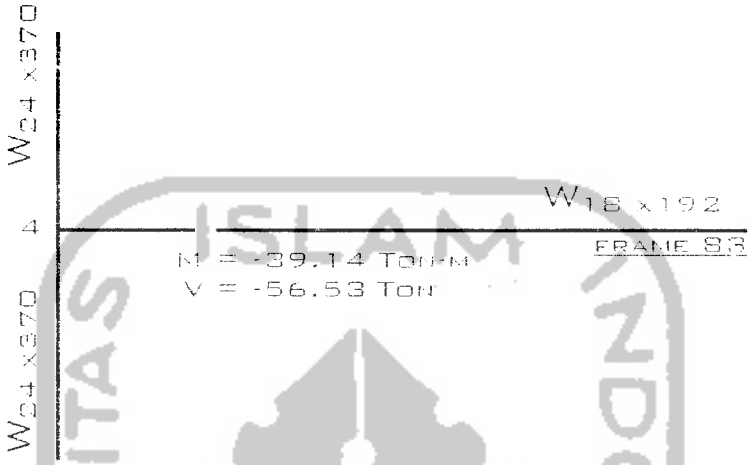
Kolom	profil	d	b_f	M	P
		in	in	kips-in	kips
1	**W24x370**	27.99	13.66	7007.939	2175.89
2	**W30x581**	35.39	16.2	11632.260	5921.21
3	**W30x581**	35.39	16.2	11547.378	6766.39
4	**W24x370**	27.99	13.66	7047.781	3320.15

Tabel 5.12 Dimensi plat dasar

N	B	N	B	cek< f_p	tebal	Ukuran pelat
cm	cm	in	in		cm	cm
80	60	31.4961	23.6220	4.7189	15.96	80x60x16
100	80	39.3701	31.4961	6.2048	23.30	100x80x24
100	80	39.3701	31.4961	6.8760	23.30	100x80x24
80	60	31.4961	23.6220	6.2671	15.96	80x60x16

5.3 Desain sambungan

5.3.1 Sambungan perpanjangan balok



Gambar 5.13 Sambungan perpanjangan balok

Contoh perhitungan sambungan perpanjangan :

Balok W_{18x192} *(Gambar 5.13)*

A = 56.4 in^2	Ix = 3870 in^4	rx = 8.28 in
d = 20.35 in	Iy = 440 in^4	ry = 2.79 in
tw = 0.96 in	Sx = 380 in^3	Zx = 442 in^3
bf = 11.455in	Sy =76.8 in^3	Zy = 119 in^3
tf =1.75 in	K = $2\frac{7}{16}$ in	K =15/16 in

T =$15\frac{1}{2}$ in

1. Distribusi Gaya pada Balok

Terjadi momen =3449.237 k-in

geser =124.626 kips

Momen yang diterima badan

$$M_{bdn} = \frac{I_b}{I_p} \cdot M_a$$

$$= \frac{1/12 \cdot tw \cdot (d - 2tf)^3}{Ix} \cdot M_a$$

$$= \frac{1/12 \cdot 0.96 \cdot (20.35 - 2 \cdot 1.75)^3}{3870} \cdot 3449.237$$

=341.115 k-in

momen sayap = $M_a - M_{bdn}$

= 3449.237 - 341.115

= 3108.122 k-in

2. Sambungan pada Badan

$$d \cdot tw = Ap = \frac{V}{0.55 \cdot Fy}$$

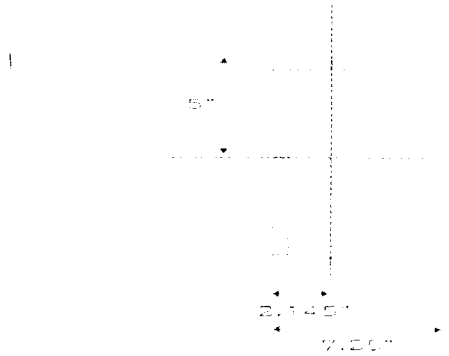
$$= \frac{124.626}{0.55 \cdot 50}$$

$$= 4.53\ in^2$$

dipakai plat ukuran $P_l = 10x\frac{1}{2}in^2$

Dipakai asumsi panjang plat = 15 in

Jarak Splice =0.5 in



Gambar 5.14 Pelat badan dan model las fillet

Sambungan las :

$$X = \frac{b \cdot a \cdot 1/2b + h \cdot a \cdot 0 + b \cdot a \cdot 1/2b}{2 \cdot a \cdot b + a \cdot h}$$

$$= \frac{7.25 \cdot 1 \cdot 3.625 + 10 \cdot 1 \cdot 0 + 7.25 \cdot 1 \cdot 3.625}{2 \cdot 1 \cdot 7.25 + 1 \cdot 10} = 2.145 \text{ in}$$

$X^1 = b - X$ $= 7.25 - 2.145 = 5.105$ in

$Y^1 = h - 1/2h$ $= 10 - 5 = 5$ in

$$I_x = 1/12 \cdot a \cdot h^3 + a \cdot h \cdot y_1^2 + 2 \cdot \left[\left(1/12 \cdot a^3 \cdot b + b \cdot (1/2 \cdot b)^2\right)\right]$$

$$= 1/12 \cdot 1 \cdot 10^3 + 1 \cdot 10 \cdot 0^2 + 2 \cdot \left[\left(1/12 \cdot 1^3 \cdot 7.25 + 7.25 \cdot (3.625)^2\right)\right]$$

$$= 83.333 + 191.747 = 275.08 \text{ in}^4$$

$$I_y = 1/12 \cdot a^3 \cdot h + a \cdot h \cdot x_1^2 + 2 \cdot \left[\left(1/12 \cdot a \cdot b^3 + b \cdot (1/2b - X)^2\right)\right]$$

$$= 1/12 \cdot 1^3 \cdot 10 + 1 \cdot 10 \cdot 2.145^2 + 2 \cdot \left[\left(1/12 \cdot 1 \cdot 7.25^3 + 7.25 \cdot (1/2 \cdot 7.25 - 2.145)^2\right)\right]$$

$$= 46.843 + 95.27 = 43.025 \text{ in}^4$$

$I_p = I_x + I_y$ $= 275.08 + 43.025 = 417.196$ in^4

Gaya geser yang bekerja :

$$V_1 = \frac{V}{L_{las}} = \frac{124.626}{(10 + 2 \cdot 7.25)} = 5.087 \text{ kips}$$

$$V_2 = \frac{M \cdot X^1}{I_p} = \frac{341.115 \cdot 5.105}{417.196} = 4.174 \text{ ksi/in}$$

$$H_2 = \frac{M \cdot Y^1}{I_p} = \frac{341.115 \cdot 5}{417.196} = 4.088 \text{ ksi/in}$$

$$f_v = \sqrt{\left((V_1 + V_2)^2 + H^2\right)} = \sqrt{\left((5.087 + 4.174)^2 + 4.088^2\right)} = 10.123 \text{ksi/in}$$

Kuat geser las ijin plastis :

$$F_v = 1.7 \cdot 0.3 \cdot F_u \cdot 0.707 = 1.7 \cdot 0.3 \cdot 70 \cdot 0.707 = 25.24 \text{ ksi}$$

$$a_{las} = \frac{10.123}{25.24} = 0.315 \text{ in}$$

tebal plat=0.5 in ➔ $a_{min} = 3/16$ in

dipakai $a = 1/2$ in pada badan *(Gambar 5.14)*

3. Sambungan Momen pada Sayap

$M = 3108.122$ k-in

$$T = \frac{M}{d} = \frac{3108.22}{20.35} = 152.733 \text{ kips}$$

Dimensi plat :

$$Ab = \frac{T}{0.6Fy} = \frac{152.733}{0.6 \cdot 50} = 5.091 \text{ in}^2$$

Dipakai ukuran plat *Pl = 10 x* 3/4 in^2 *(Gambar 5.15)*

Asumsi panjang plat =15 in

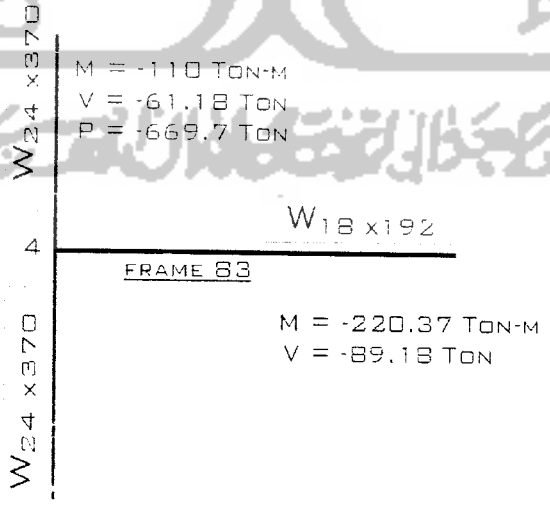
Menggunakan model las fillet

$$\text{Tebal las } a = \frac{T}{Fv} = \frac{152.733}{1.7 \cdot 0.3 \cdot 70 \cdot 0.707 \cdot (10 + 2 \cdot 7.25)}$$

$a_{las} = 3/8''$

Gambar 5.15 Pelat sayap dan model las fillet

5.3.2 Sambungan balok-kolom



Gambar 5.16 Model sambungan dan gaya yang bekerja

Contoh perhitungan sambungan balok-kolom *(Gambar 5.16)* :

Balok W_{18x192}

A = 56.4 in^2 Ix = 3870 in^4 rx = 8.28 in

d = 20.35 in Iy = 440 in^4 ry = 2.79 in

tw = 0.96 in Sx = 380 in^3 Zx = 442 in^3

bf = 11.455 in Sy =76.8 in^3 Zy = 119 in^3

tf =1.75 in K = $2\frac{7}{16}$ in K_1 =15/16 in T =$15\frac{1}{2}$ in

Kolom W_{24x370}

A = 108 in^2 Ix = 13400 in^4 rx = 11.1 in

d = 27.99 in Iy = 1160 in^4 ry = 3.28 in

tw = 1.52 in Sx = 957 in^3 Zx = 1120 in^3

bf = 13.66 in Sy =170 in^3 Zy = 300 in^3

tf =2.72 in K = $3\frac{1}{2}$ in K_1 =15/16 in T =21 in

1. Kapasitas kolom

* Check disribusi tarik sayap balok terhadap badan kolom

a. $Fy_b \cdot Af_b$ = 50x(11.455.x1.75.) =1002.312

b. $Fy_k \cdot tw_k \cdot (tf_k + 5k)$ =50x1.52x(2.72 +5x3 $\frac{1}{2}$) =1536.72

chek : bila a.< b. ➔ Tidak perlu pengaku horizontal untuk badan kolom

a.> b. ➔ perlu pengaku horizontal untuk badan kolom

➔ Tidak perlu pengaku pada badan kolom

- Check disribusi tekan sayap balok terhadap sayap kolom

a. $0.4 \cdot \sqrt{Af_b \cdot \frac{Fy_b}{Fy_k}} = 0.4 \cdot \sqrt{(11.455x1.75) \cdot \frac{50}{50}} = 1.79$

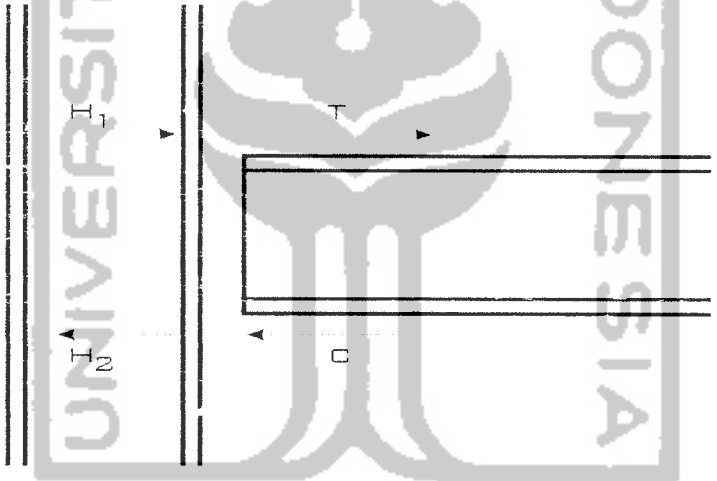
b. $tf_k = 2.72$ in

chek : bila a.< b. ➔ Tidak perlu pengaku horizontal untuk badan kolom

a.> b. ➔ perlu pengaku horizontal untuk badan kolom

➔ Tidak perlu pengaku pada sayap kolom

* Check disribusi geser – momen terhadap badan kolom *(Gambar 5.17)*



Gambar 5.17 Distribusi geser dan momen balok terhadap kolom

Vb =196.606 kips Mb =19127.036 k-in

H_1 = 134.877 kips H_2 = 134.877 kips

momen yang diterima badan balok :

$$M_{bd} = \frac{I_b}{Ix} \cdot M = \frac{1/12 \cdot tw \cdot (d - 2tf)^3}{Ix}$$

$$= \frac{1/12 \cdot 0.96 \cdot (20.35 - 2 \cdot 1.75)^3}{3870} \text{ x } 19127.036 \quad = 1891.587 \text{ k-in}$$

Momen yang diterima sayap balok :

$M_{sy} = M - M_{bd}$ = 19127.036 -1891.587 =17235.448 k-in

axial akibat momen pada sayap balok :

$$T = \frac{M_{sy}}{d} = \frac{17235.448}{20.35} = 846.951 \text{ kips}$$

a. $H_1 + T_1$ = 134.877 + 846.951 = 981.8278 kips

b. $V = 0.55 \cdot Fy \cdot tw_k \cdot d_k$ =0.55x50x1.52x27.99 =1169.982 kips

chek : bila a.< b. ➔ Tidak perlu pengaku vertikal untuk badan kolom

a.> b. ➔ perlu pengaku vertikal untuk badan kolom

➔ Tidak perlu pengaku

Bila diperlukan pengaku maka langkah pendimensian pengaku adalah sebagai berikut :

* dimensi pengaku :

a. Pengaku horizontal Terhadap Tekan sayap balok pada badan kolom

$$A_{ph} = \frac{Fy_b \cdot Af_b - Fy_k \cdot tw_k \cdot (tf_k + 5k)}{Fy_p}$$

Sambungan lasnya :

$$C = \frac{Fy_b \cdot Af_b - Fy_k \cdot tw_k \cdot (tf_k + 5k)}{2}$$

$$a_{las} = \frac{C}{1.7 \cdot 0.3 \cdot Fu \cdot 0.707 \cdot L_{las}}$$

b. Pengaku horizontal Terhadap tarik sayap balok pada badan kolom

$$T = (H_1 + T_1) - (0.55 \cdot Fy \cdot tw_k \cdot d_k)$$

$$A_{ph} = \frac{T}{Fy_p}$$

Sambungan lasnya :

$$a_{las} = \frac{T}{1.7 \cdot 0.3 \cdot Fu \cdot 0.707 \cdot L_{las}} \text{ in}^2$$

2. Sambungan sayap balok-sayap kolom

* Dipergunakan las *groove*

Panjang las = min (bf_{balok} ; bf_{kolom})

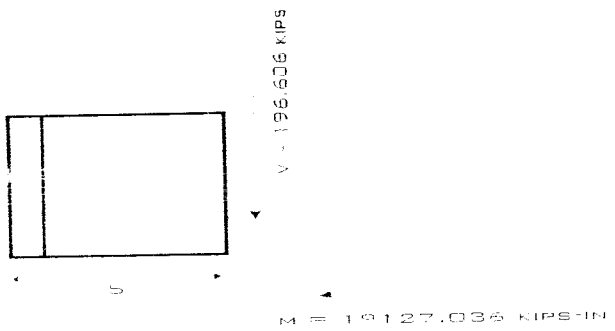
$$T = \frac{M_{sv}}{d} = 846.951 \text{ kips}$$

tebal las *groove* :

$$t_e = a = \frac{T}{bf_{min} \cdot Fu} = \frac{846.951}{11.455 \cdot 1.7 \cdot 70} = 0.621 \text{ in}$$

dipakai $te = \frac{3}{4}$ in

3. Sambungan badan balok-sayap kolom



Gambar 5.18 Distribusi gaya pada sambungan

Gaya yang bekerja pada sambungan *(Gambar 5.18)* :

* sambungan badan balok - conection

- Dicoba dipakai *angel connection* 2L5x5x1/2

panjang = 15'' $< (T) = 15\,1/2$ in .....Ok

- Las fillet E70

Check geser conection

$V = 0.55 \cdot Fy \cdot Ab$ =0.55 x50x(2x15x0.5 =412.5 $> Pv$= 196.606 kips ...Oke

* Sambungan las badan balok – conection

$Ip = Ix + Iy$

$Y = 1/2 \cdot L_2$ =1/2·15 =7.5 in

$$X = \frac{1 \cdot L_2 \cdot x_1 + 1 \cdot L_1 \cdot x_2 + 1 \cdot L_3 \cdot x_2}{L_1 + L_2 + L_3}$$

$$= \frac{1 \cdot 15 \cdot 5 + 1 \cdot 5 \cdot 2.5 + 1 \cdot 5 \cdot 2.5}{1 \cdot (15 + 5 + 5)} = 4 \text{ in}$$

$$Ix = 1/12 \cdot 1 \cdot L_2^3 + 1 \cdot L_2 \cdot y_1^2 + 2 \cdot \left(1/12 \cdot L_1 \cdot 1^3 + L_1 \cdot 1 \cdot y_2^2\right)$$

$$= 1/12 \cdot 1 \cdot 15^3 + 1 \cdot 15 \cdot 0^2 + 2 \cdot \left(1/12 \cdot 5 \cdot 1^3 + 5 \cdot 1 \cdot 7.5^2\right) = 844.583 \text{ in}^4$$

$$Iy = 1/12 \cdot L_2 \cdot 1^3 + 1 \cdot L_2 \cdot x_1^2 + 2 \cdot \left(1/12 \cdot 1 \cdot L_1^3 + L_1 \cdot 1 \cdot x_2^2\right)$$

$$= 1/12 \cdot 15 \cdot 1^3 + 1 \cdot 15 \cdot (5-4)^2 + 2 \cdot \left(1/12 \cdot 1 \cdot 5^3 + 5 \cdot 1 \cdot (4 - 0.5 \cdot 5)^2\right) = 59.583 \text{ in}^4$$

Ip=2 x(844.583 +59.583) =1808.326 in^4

* Gaya geser yang bekerja :

$$V_1 = \frac{V}{L_{las}} = \frac{196.606}{2 \cdot (15 + 5 + 5)} = 3.932 \text{ kips}$$

$$V_2 = \frac{M_{bd} \cdot X}{Ip} = \frac{1891.587 \cdot 4}{1808.326} = 4.184 \text{ kips}$$

$$H_1 = \frac{M_{bd} \cdot Y}{Ip} = \frac{1891.587 \cdot 7.5}{1808.326} = 7.845 \text{ kips}$$

Kombinasi geser :

$$fv = \sqrt{(V^2 + H^2)} = \sqrt{((3.932 + 4.184)^2 + 7.845^2)} = 11.287 \text{ kips}$$

tebal las :

$$a = \frac{fv}{1.7 \cdot 0.3 \cdot Fu \cdot 0.707} = \frac{11.287}{1.7 \cdot 0.3 \cdot 70 \cdot 0.707} = 0.447 \text{ in}$$

dipakai $a_{las} = 1/2$ in

* Sambungan baut connection - sayap kolom

- dicoba Baut $A_{325}x$ ➔ϕ -1'' $A_{baut} = 0.785$ in^2

$Ft = 44$ ksi $Fv = 21$ ksi

- Baut mengalami geser dan tarik

$$Ft = 1.7 \cdot \sqrt{(44^2 - 2.15 \cdot fv^2)}$$

- jarak : tepi-baut =1.5ϕ s/d 3ϕ ➔1.5'' s/d 3''

baut – baut = 2.5ϕ s/d 7ϕ ➔2.5'' s/d 7''

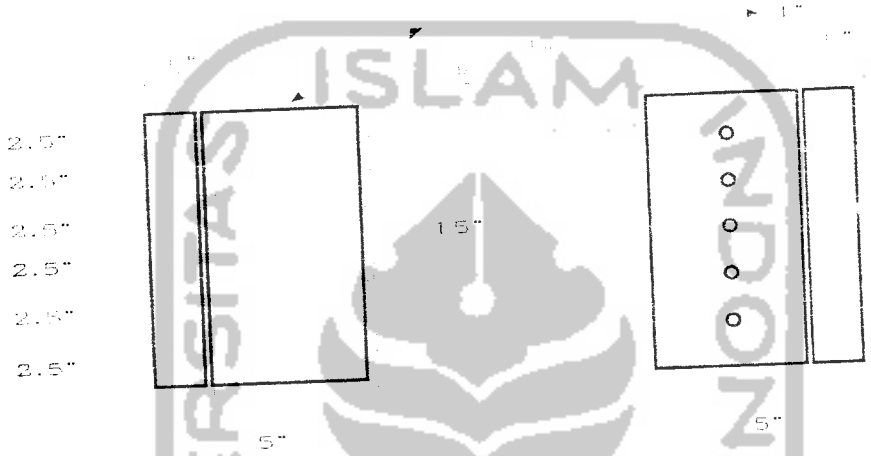
-Dicoba dipakai 5 baut ϕ -i'' *(Gambar 5.19)*

$$fv = \frac{V}{2 \cdot n \cdot A_{baut}} = \frac{196.606}{2 \cdot 5 \cdot 0.785} = 25.045$$

$$Ft = 1.7 \cdot \sqrt{(44^2 - 2.15 \cdot fv^2)} = 1.7 \cdot \sqrt{(44^2 - 2.15 \cdot 25.045^2)} = 41.202 \text{ kips}$$

$$T = \frac{M_{bd}}{L} = \frac{1891.587}{15} = 126.106 \text{ kips}$$

$$ft = \frac{T}{n \cdot \phi_{baut}} = \frac{126.106}{5 \cdot 0.785} = 32.128 \text{ kips} \quad < Ft = 41.202 \text{ kips} \quad \text{.....Ok}$$

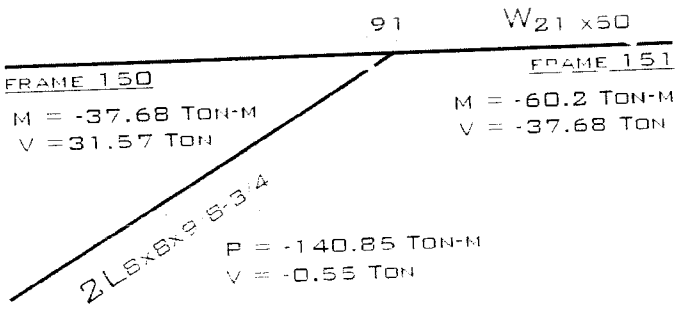


Gambar 5.19 Tampang sambungan dan pembautannya

5.3.3 Sambungan balck - brace

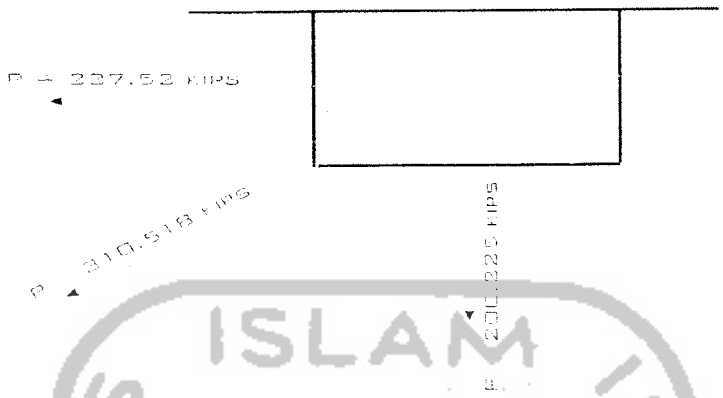
Distribusi gaya pada joint 91 dapat di lihat pada *gambar 5.20*

- dipakai tebal plat =3/4 " ➔ *Fy*=50 ksi



Gambar 5.20 Sambungan balok-brace dan gaya yang bekerja

1. Sambungan plat sayap- balok *(Gambar 5.21)*



Gambar 5.21 Gaya pada joint

Transfer gaya *(Gambar 5.21)* :

$X = P \cdot Cos\alpha = 310.518 \cdot Cos40.1 = 237.52$ kips

$Y = P \cdot Sin\alpha = 310.518 \cdot Sin40.1 = 200.225$ kips

$V_1 = \frac{X}{L_{las}} = \frac{237.52}{20} = 11.876$ kips

$H_1 = \frac{y}{L_{las}} = \frac{200.225}{20} = 10.112$ kips

Kombinasi geser :

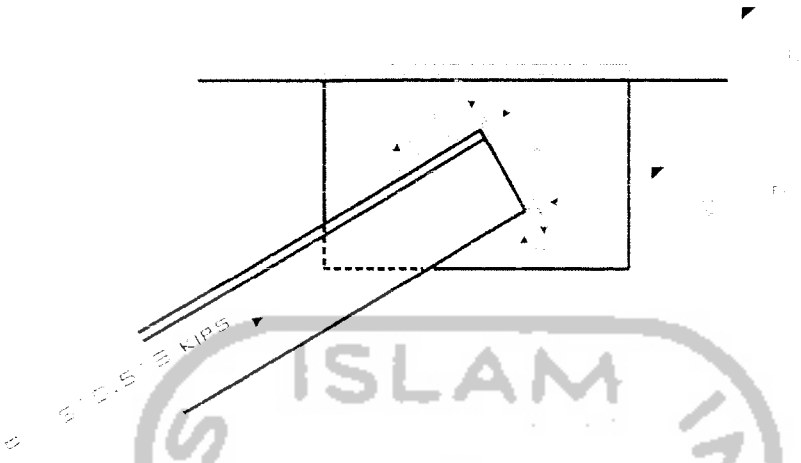
$fv = \sqrt{(V^2 + H^2)} = \sqrt{(11.876^2 + 10.112^2)} = 15.598$ kips

tebal las *groove* :

$a = \frac{fv}{1.7 \cdot 0.3 \cdot Fu} = \frac{15.598}{1.7 \cdot 0.3 \cdot 70} = 0.437$ in

dipakai $a_{las} = 1/2$ in *(Gambar 5.22)*

2. Sambungan plat –Brace (sambungan las sentris)



Gambar 5.22. Model brace dengan las sentris

Dicoba a_{las} = 3/8 '' las *Fillet*

Panjang kebutuhan las :

$$L_{las} = \frac{P}{1.7 \cdot 0.3 \cdot Fu \cdot 0.707 \cdot a_{las}} = \frac{310.518/2}{1.7 \cdot 0.3 \cdot 70 \cdot 0.707 \cdot 3/8} = 16.403 \text{ in}$$

L_2 =8 in

$L_1 \cdot y_1 + L_2 \cdot y_2 + L_3 \cdot y_3 = L_{las} \cdot Y$

$L_1 \cdot 0 + L_2 \cdot (1/2 \cdot 8) + L_3 \cdot 8 = 16.403 \cdot 2.41$

$L_3 = 0.94$ in ≈ 1.5 in

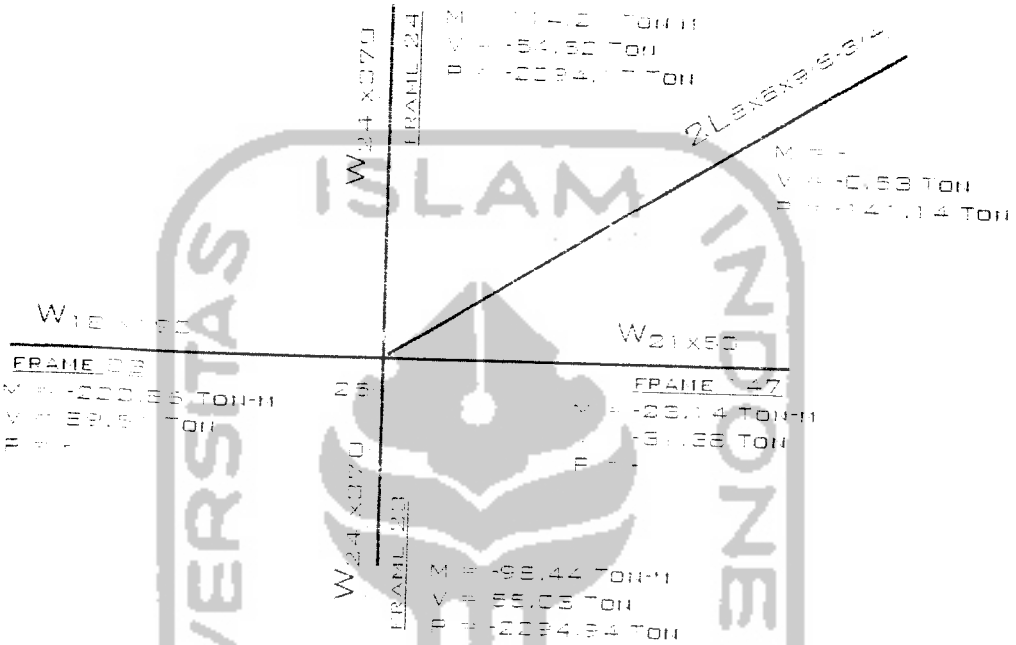
$L_1 + L_2 + L_3 = L_{las}$

$1.5 + 8 + L_3 = 16.403$

➔ $L_1 = 6.903 \approx 7.5$ in *(Gambar 5.22)*

5.3.4 Sambungan Pertemuan Balok-Kolom-Brace

Besarnya gaya pada pertemuan balok-kolom-bracing dapat di lihat pada *gambar 5.23*



Gambar 5.23 Pertemuan sambungan

1. Kapasitas kolom

* Check disribusi tarik sayap balok terhadap badan kolom

a. Balok W_{18x192}

$$Fy_{b1} \cdot Af_{b1} = 50x(11.455x1.75) = 1002.312 \quad \surd$$

Balok W_{21x50}

$$Fy_{b2} \cdot Af_{b2} = 50x(6.53.x0.535) = 174.677$$

Pilih yang terbesar

b. Kolom W_{30x581}

$$Fy_k \cdot tw_k \cdot (tf_k + 5k) = 50 \cdot 1.97 \cdot (3.54 + 5 \cdot 4\,5/16) = 2472.59$$

chek : bila a.< b. ➔ Tidak perlu pengaku horizontal untuk badan kolom

a.> b. ➔ perlu pengaku horizontal untuk badan kolom

➔ Tidak perlu pengaku badan kolom

* Check disribusi tekan sayap balok terhadap sayap kolom

a. Balok W_{18x192}

$$0.4 \cdot \sqrt{Af_{b1} \cdot \frac{Fy_{b1}}{Fy_k}} = 0.4 \cdot \sqrt{20.046 \cdot \frac{50}{50}} = 1.791 \quad \surd$$

Balok W_{21x50}

$$0.4 \cdot \sqrt{Af_{b2} \cdot \frac{Fy_{b2}}{Fy_k}} = 0.4 \cdot \sqrt{3.493 \cdot \frac{50}{50}} = 0.747$$

Pilih yang terbesar

b. $tf_k = 3.54$ in

chek : bila a.< b. ➔ Tidak perlu pengaku horizontal untuk badan kolom

a.> b. ➔ perlu pengaku horizontal untuk badan kolom

➔ Tidak perlu pengaku sayap kolom

* Check disribusi geser – momen terhadap badan kolom

a.Balok W_{18x192}

momen yang diterima badan balok :

$$M_{bd} = \frac{I_b}{Ix} \cdot M = \frac{1\,12 \cdot tw \cdot (d - 2tf)^3}{Ix} \cdot M$$

$$= \frac{1/12 \cdot 0.96 \cdot (20.35 - 2 \cdot 1.75)^3}{3870} \cdot 19343.15 \quad = 1912.96 \text{ k-in}$$

Momen yang diterima sayap balok :

$M_{sy} = M - M_{bd}$ = 19343.15 – 1912.96 =17430.19 k-in

axial akibat momen pada sayap balok :

$$T_1 = \frac{M_{sy}}{d} = \frac{17430.19}{20.35} = 856.52 \text{ kips}$$

b. Balok W_{21x59}

momen yang diterima badan balok :

$$M_{bd} = \frac{I_b}{Ix} \cdot M = \frac{1/12 \cdot tw \cdot (d - 2tf)^3}{Ix}$$

$$= \frac{1/12 \cdot 0.38 \cdot (20.83 - 20.535)^3}{984} \cdot 2012.778 \quad = 499.763 \text{ k-in}$$

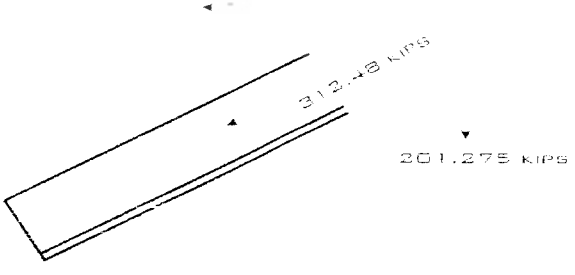
Momen yang diterima sayap balok :

$M_{sy} = M - M_{bd}$ = 2012.778 – 499.763 =1513.015 k-in

axial akibat momen pada sayap balok :

$$T_2 = \frac{M_{sy}}{d} = \frac{1513.015}{20.83} = 72.63 \text{ kips}$$

c. Brace



Gambar 5.24 Transfer gaya pada bracing

Transfer gaya pada bracing *(Gambar 5.24)* :

$V = Sin40.1^\circ \cdot P \quad = Sin40.1^\circ \cdot 312.48 \quad = 201.275$ kips

$H = Cos40.1^\circ \cdot P \quad = Cos40.1^\circ \cdot 312.48 \quad = 239.022$ kips

* Check badan terhadap geser *(Gambar 5.25)*

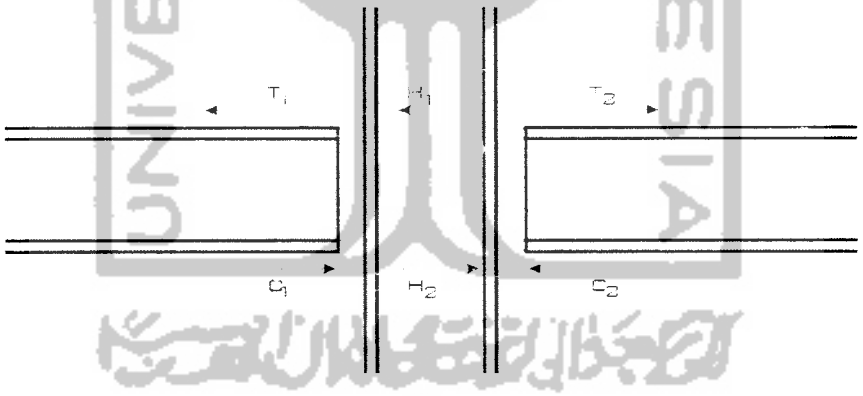
a. $v = T_1 - T_2 + H_1$ =856.52 -72.63 +120.195 =904.079 kips

b. $V = 0.55 \cdot Fy \cdot tw_k \cdot d_k$ = 0.55x50x1.97x35.39 =1917.23 kips

cek : bila a.< b. ➔ Tidak perlu pengaku vertikal untuk badan kolom

a.> b. ➔ perlu pengaku vertikal untuk badan kolom

➔ Tidak perlu pengaku badan kolom



Gambar 5.25 Distribusi geser pada pertemuan balok-kolom

catatan : bila diperlukan pengaku pada kolom :

* dimensi pengaku

a. Pengaku horizontal Terhadap Tekan sayap balok pada badan kolom

$$A_{ph} = \frac{Fy_b \cdot Af_b - Fy_k \cdot tw_k \cdot (tf_k + 5k)}{Fy_p}$$

Sambungan lasnya :

$$C = \frac{Fy_b \cdot Af_b - Fy_k \cdot tw_k \cdot (tf_k + 5k)}{2}$$

$$a_{las} = \frac{C}{1.7 \cdot 0.3 \cdot Fu \cdot 0.707 \cdot L_{las}}$$

b. Pengaku horizontal Terhadap tarik sayap balok pada badan kolom

$$T = (H_1 + T_1) - (0.55 \cdot Fy \cdot tw_k \cdot d_k)$$

$$A_{ph} = \frac{T}{Fy_p}$$

Sambungan lasnya :

$$a_{las} = \frac{T}{1.7 \cdot 0.3 \cdot Fu \cdot 0.707 \cdot L_{las}}$$

2. Sambungan 1 :Balok-kolom

* Sambungan sayap balok-sayap kolom

* Dipergunakan las *groove*

Panjang las =min (bf_{balok} ; bf_{kolom})

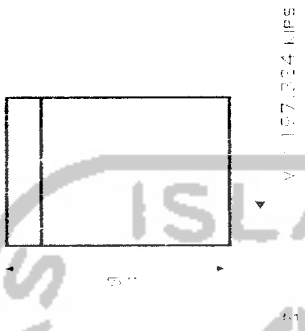
$$T = \frac{M_{sy}}{d} = 856.52 \text{ kips}$$

tebal las *groove* :

$$t_e = \text{a} = \frac{T}{bf_{\min} \cdot 1.7 \cdot Fv} = \frac{856.52}{11.455 \cdot 1.7 \cdot 0.3 \cdot 70} = 2.093 \text{ in}$$

dipakai $t_e = 2\,1/4$ in

* Samb.badan balok-sayap kolom



Gambar 5.26 Distribusi gaya pada sambungan

a. sambungan badan balok - conection

- Dicoba dipakai angel conection *2L5x5x1/2*

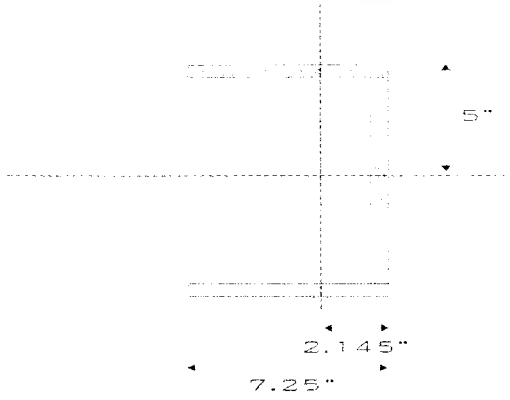
panjang = 15'' $< (T) = 15.5$ Ok

- Las fillet E70

Check sambungan geser *(Gambar 5.26)*

$V = 0.55 \cdot Fy \cdot Ab$ =0.55 x50x(2x15x0.5) =412.5 $> Pv$ = 197.334 kips ...Ok

* Sambungan las badan balok – connection *(Gambar 5.27)*



Gambar 5.27 Model las balok-connection

$Ip = Ix + Iy$

$Y = 1/2 \cdot L_2 = 1/2 \cdot 15 = 7.5$

$$X = \frac{1 \cdot L_2 \cdot x_1 + 1 \cdot L_1 \cdot x_2 + 1 \cdot L_3 \cdot x_2}{L_1 + L_2 + L_3}$$

$$= \frac{1 \cdot 15 \cdot 5 + 1 \cdot 5 \cdot 2.5 + 1 \cdot 5 \cdot 2.5}{1 \cdot (15 + 5 + 5)} = 4 \text{ in}$$

$$Ix = 1/12 \cdot 1 \cdot L_2^{\,3} + 1 \cdot L_2 \cdot y_1^{\,2} + 2 \cdot \left(1/12 \cdot L_1 \cdot 1^3 + L_1 \cdot 1 \cdot y_2^{\,2}\right)$$

$$= 1/12 \cdot 1 \cdot 15^3 + 1 \cdot 15 \cdot 0^2 + 2 \cdot \left(1/12 \cdot 5 \cdot 1^3 + 5 \cdot 1 \cdot 7.5^2\right) = 844.583 \text{ in}^4$$

$$Iy = 1/12 \cdot L_2 \cdot 1^3 + 1 \cdot L_2 \cdot x_1^{\,2} + 2 \cdot \left(1/12 \cdot 1 \cdot L_1^{\,3} + L_1 \cdot 1 \cdot x_2^{\,2}\right)$$

$$= 1/12 \cdot 15 \cdot 1^3 + 1 \cdot 15 \cdot (5-4)^2 + 2 \cdot \left(1/12 \cdot 1 \cdot 5^3 + 5 \cdot 1 \cdot (4 - 0.5 \cdot 5)^2\right) = 59.583 \text{ in}^4$$

$Ip = 2 \text{ x}(844.583 + 59.583) = 1808.326 \text{ in}^4$

* Gaya geser yang bekerja :

$$V_1 = \frac{V}{L_{las}} = \frac{197.334}{2 \cdot (15 + 5 + 5)} = 3.946 \text{ kips}$$

$$V_2 = \frac{M_{bd} \cdot X}{Ip} = \frac{1912.96 \cdot 4}{1808.326} = 4.184 \text{ kips}$$

$$H_1 = \frac{M_{bd} \cdot Y}{Ip} = \frac{1912.96 \cdot 7.5}{1808.326} = 7.933 \text{ kips}$$

Kombinasi geser :

$$fv = \sqrt{\left(V^2 + H^2\right)} = \sqrt{\left((3.946 + 4.184)^2 + 7.933^2\right)} = 11.359 \text{ kips}$$

tebal las :

$$a = \frac{fv}{1.7 \cdot 0.3 \cdot Fu \cdot 0.707} = \frac{11.359}{1.7 \cdot 0.3 \cdot 70 \cdot 0.707} = 0.45 \text{ in}$$

dipakai $a_{las} = \frac{1}{2}$ in

b. Sambungan baut conection - sayap kolom

- dicoba Baut $A_{325}x$ ➔ϕ -1'' $A_{baut} = 0.785$ in^2

$Ft = 44$ ksi

$Fv = 21$ ksi

- Baut mengalami geser dan tarik

$$Ft = 1.7 \cdot \sqrt{\left(44^2 - 2.15 \cdot fv^2\right)}$$

- jarak : tepi-baut =1.5ϕ s/d 3ϕ ➔1.5'' s/d 3''

baut – baut = 2.5ϕ s/d 7ϕ ➔2.5'' s/d 7''

$$fv = \frac{V}{2 \cdot n \cdot A_{baut}} = \frac{197.334}{2 \cdot 5 \cdot 0.785} = 25.138 \text{ k/in}^2$$

$$Ft = 1.7 \cdot \sqrt{\left(44^2 - 2.15 \cdot fv^2\right)} = 1.7 \cdot \sqrt{\left(44^2 - 2.15 \cdot 25.138^2\right)} = 40.848 \text{ kips}$$

$$T = \frac{M_{bd}}{L} = \frac{1912.96}{15} = 127.53 \text{ kpis}$$

$$ft = \frac{T}{n \cdot \phi_{baut}} = \frac{127.53}{5 \cdot 0.785} = 32.492 \text{kips} < Ft = 41.202 \text{ kips} \quad \text{.....Ok}$$

3. Sambungan 2 :Balok-kolom

* Sambungan sayap balok-sayap kolom

* Dipergunakan las groove

Panjang las =min (bf_{balok} ; bf_{kolom})

$$T = \frac{M_{sy}}{d} = \frac{1513.015}{20.83} = 72.636 \text{ kips}$$

tebal las *groove*

$$t_e = a = \frac{T'}{bf_{min} \cdot 1.7Fv} = \frac{72.636}{6.53 \cdot 1.7 \cdot 0.3 \cdot 70} = 0.311 \text{ in}$$

dipakai $t_e = \frac{1}{2}$ in

* Samb.badan balok-sayap kolom

a. samb badan balok - conection

- Dicoba dipakai *angel conection* 2L3x3x1/2

panjang = 10'' < T =18.25 ..... Ok

- Las *fillet* E70

Check geser conection :

$V = 0.55 \cdot Fy \cdot Ab$ = 0.55 x50x(2x10x0.5) =275 > Pv = 69 kips Ok

* Sambungan las badan balok – conection

$Ip = Ix + Iy$

$Y = 1/2 \cdot L_2 = 1/2 \cdot 10 = 5$

$$X = \frac{1 \cdot L_2 \cdot x_1 + 1 \cdot L_1 \cdot x_2 + 1 \cdot L_3 \cdot x_2}{L_1 + L_2 + L_3}$$

$$= \frac{1 \cdot 10 \cdot 3 + 1 \cdot 3 \cdot 1.5 + 1 \cdot 3 \cdot 1.5}{1 \cdot (10 + 3 + 3)} = 2.437 \text{ in}$$

$$Ix = 1/12 \cdot 1 \cdot L_2^3 + 1 \cdot L_2 \cdot y_1^2 + 2 \cdot \left(1/12 \cdot L_1 \cdot 1^3 + L_1 \cdot 1 \cdot y_2^2\right)$$

$$= 1/12 \cdot 1 \cdot 10^3 + 1 \cdot 10 \cdot 0^2 + 2 \cdot \left(1/12 \cdot 3 \cdot 1^3 + 3 \cdot 1 \cdot 5^2\right) = 106.33 \text{ in}^4$$

$$Iy = 1/12 \cdot L_2 \cdot 1^3 + 1 \cdot L_2 \cdot x_1^2 + 2 \cdot \left(1/12 \cdot 1 \cdot L_1^3 + L_1 \cdot 1 \cdot x_2^2\right)$$

$$= 1/12 \cdot 10 \cdot 1^3 + 1 \cdot 10 \cdot (3 - 2.437)^2 + 2 \cdot \left(1/12 \cdot 1 \cdot 3^3 + 3 \cdot 1 \cdot (2.437 - 0.5 \cdot 3)^2\right)$$

$$= 13.77 \text{ in}^4$$

Ip=2 x(106.33 +13.77) =240.2 in^4

* Gaya geser yang bekerja :

$$V_1 = \frac{V}{L_{las}} = \frac{69.18}{2 \cdot (10+3+3)} = 2.162 \text{ kips}$$

$$V_2 = \frac{M_{bd} \cdot X}{Ip} = \frac{499.763 \cdot 2.437}{240.2} = 5.07 \text{ kips}$$

$$H_1 = \frac{M_{bd} \cdot Y}{Ip} = \frac{499.763 \cdot 5}{240.2} = 10.403 \text{ kips}$$

Kombinasi geser :

$$fv = \sqrt{\left(V^2 + H^2\right)} = \sqrt{\left((2.162+5.07)^2 + 10.403^2\right)} = 12.669 \text{ kips}$$

tebal las :

$$a = \frac{fv}{1.7 \cdot 0.3 \cdot Fu \cdot 0.707} = \frac{12.669}{1.7 \cdot 0.3 \cdot 70 \cdot 0.707} = 0.502 \text{ in}$$

dipakai $a_{las} = 3/4$ in

b. Sambungan baut conection - sayap kolom

- dicoba Baut $A_{325}x$ ➔ϕ -1'' $A_{baut} = 0.785$ in^2

Ft = 44 ksi

Fv = 21 ksi

- Baut mengalami geser dan tarik

$$Ft = 1.7 \cdot \sqrt{\left(44^2 - 2.15 \cdot fv^2\right)}$$

- jarak : tepi-baut =1.5ϕ s/d 3ϕ ➔1.5'' s/d 3''

baut – baut = 2.5ϕ s/d 7ϕ ➔2.5'' s/d 7''

Dicoba 3 baut

$$fv = \frac{V}{2 \cdot n \cdot A_{baut}} = \frac{69.18}{2 \cdot 3 \cdot 0.785} = 14.687 \text{ k/in}^2$$

$$Ft = 1.7 \cdot \sqrt{(44^2 - 2.15 \cdot fv^2)} \quad = 1.7 \cdot \sqrt{(44^2 - 2.15 \cdot 14.687^2)} = 65.228 \text{ kips}$$

$$T = \frac{M_{bd}}{L} = \frac{499.763}{10} = 49.976 \text{ kips}$$

$$ft = \frac{T}{n \cdot \phi_{baut}} = \frac{49.976}{3 \cdot 0.785} = 21.221 \text{ kips} < Ft = 65.228 \text{ kips} \quad \ldots\ldots\text{Ok}$$

4. Sambungan Plat-Sayap balok/kolom

- dipakai tebal plat = 3/4 '' ➔ Fy=50 ksi

*. Sambungan plat -sayap balok/kolom

Transfer gaya :

$$X = P \cdot Cos\alpha = 312.48 \cdot Cos40.1 = 239.022 \text{ kips}$$

$$Y = P \cdot Sin\alpha = 310.518 \cdot Sin40.1 = 201.275 \text{ kips}$$

$$V_1 = \frac{X}{L_{las}} = \frac{239.022}{20 + 20} = 5.975 \text{ kips}$$

$$H_1 = \frac{y}{L_{las}} = \frac{201.275}{20 + 20} = 5.032 \text{ kips}$$

Kombinasi geser

$$fv = \sqrt{(V^2 + H^2)} = \sqrt{(5.975^2 + 5.032^2)} = 7.811 \text{ kips}$$

tebal las *Fillet* :

$$a = \frac{fv}{1.7 \cdot 0.3 \cdot Fu} = \frac{7.811}{1.7 \cdot 0.3 \cdot 70 \cdot 0.707} = 0.309 \text{ in}$$

dipakai a_{las} = 3/8 in

b. Sambungan plat –Brace (sambungan las sentris)

Dicoba $a_{las} = 3/8$'' las *Fillet*

Panjang kebutuhan las :

$$L_{las} = \frac{P}{1.7 \cdot 0.3 \cdot Fu \cdot 0.707 \cdot a_{las}} = \frac{312.48/2}{1.7 \cdot 0.3 \cdot 70 \cdot 0.707 \cdot 3/8} = 16.507 \text{ in}$$

$L_2 = 8$ in

$$L_1 \cdot y_1 + L_2 \cdot y_2 + L_3 \cdot y_3 = L_{las} \cdot Y$$

$$L_1 \cdot 0 + L_2 \cdot (1/2 \cdot 8) + L_3 \cdot 8 = 16.507 \cdot 2.41$$

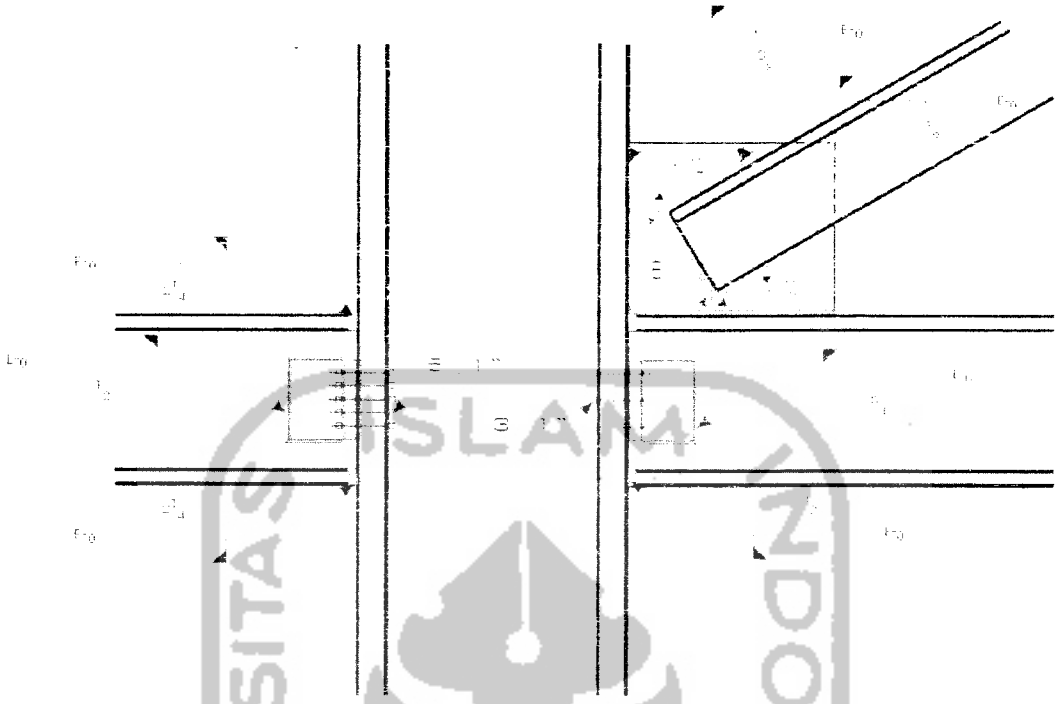
$L_3 = 0.972$ in ≈ 1.5 in

$L_1 + L_2 + L_3 = L_{las}$

$1.5 + 8 + L_3 = 16.507$

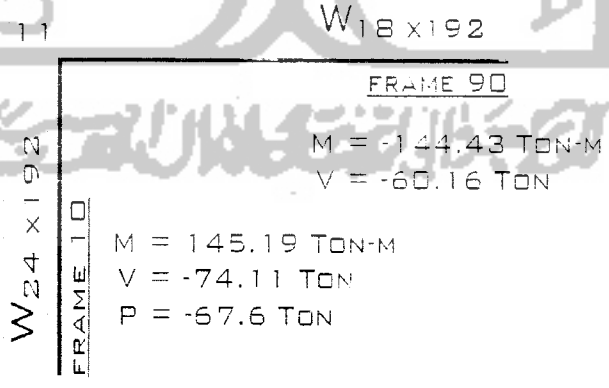
➔ $L_1 = 7.007 \approx 7.5$ in

Pemakaian las dan baut pada sambungan balok-kolom-bracing dapat dilihat pada *gambar 5.28*



Gambar 5.28 Sambungan Pertemuan Balok-Kolom-Brace

5.3.5 Sambungan Sudut - lurus *(Gambar 5.29)*



Gambar 5.29 Distribusi gaya pada joint 11

Balok W_{18x192}

A	= 56.4 in^2	Ix	= 3870 in^4	rx	= 8.28 in
d	= 20.35 in	Iy	= 440 in^4	ry	= 2.79 in
tw	= 0.96 in	Sx	= 380 in^3	Zx	= 442 in^3
bf	= 11.455 in	Sy	=76.8 in^3	Zy	= 119 in^3
tf	=1.75 in	K	= $2\frac{7}{16}$ in	K_1	=15/16 in
T	=15 $\frac{1}{2}$ in				

Kolom W_{24x192}

A	= 56.3 in^2	Ix	= 6260 in^4	rx	= 10.5 in
d	= 25.47 in	Iy	= 530 in^4	ry	= 3.07 in
tw	= 0.81 in	Sx	= 491 in^3	Zx	= 559 in^3
bf	= 12.95 in	Sy	=81.8 in^3	Zy	= 126 in^3
tf	=1.46 in	K	= $2\frac{1}{4}$ in	K_1	=1 in
T	=21 in				

Pada plat terdapat kuat geser sebesar :

$Tw = \tau y \cdot tw \cdot dk$ $\qquad \tau y = \frac{Fy}{\sqrt{3}} = 0.57\,Fy \approx 0.55\,Fy$

$= 0.55 \cdot 50 \cdot 0.81 \cdot 25.47 = 567.344$

Gaya geser yang bekerja (Gambar 5.28) :

$$T = \frac{M}{d_b} \frac{12535.816}{25.47} = 497.179 \text{ kips}$$

$Tw > T$ .....Tidak perlu pengaku diagonal

$$tw_{perlu} = \frac{M}{0.55 \cdot Fy \cdot d_b \cdot d_k} = \frac{12535.816}{0.55 \cdot 50 \cdot 20.35 \cdot 25.47} = 0.879 \text{ in} < tw_{kolom}$$

$tw_{perlu} < tw_{kolom}$ .....Tidak perlu pengaku diagonal

catatan :

Bila $tw_{perlu} > tw_{kolom}$ maka perlu pengaku diagonal badan kolom

$$\theta = tg^{1} \cdot \left(\frac{d_b}{d_k} \right)$$

$$As_{plat} = \frac{1}{Cos\,\theta} \cdot \left(\frac{M}{Fy \cdot d_b} - \frac{tw \cdot d_k}{0.55} \right)$$

5.3.6 Sambungan perpanjangan kolom.

Kolom atas = W_{24x192}

Kolom bawah = $W_{24x1370}$

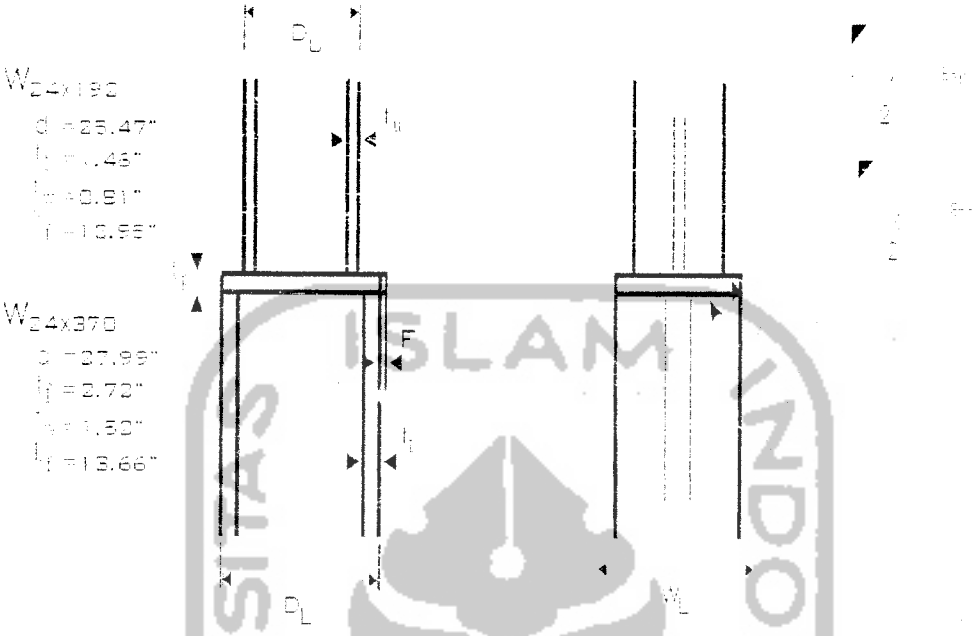
Tebal pelat t_p untuk profil W_8 s/d W_{10} adalah $1\frac{1}{2}$" dan selain profil tersebut , dipakai tebal pelat 2" dan dimensi pelat $\geq W_L$ dan D_L . Karena menggunakan profil W_{24} , maka dipakai $t_p = 2$" dan dimensi pelat 27.99" x 13.66" *(Gambar 5.30).*

Las pelat bagian atas, mengikuti t_f profil W_{24x192} atau tp.

Dipakai tebal las sesuai $tp = 2$"

Las pelat bagian bawah, mengikuti t_f profil W_{24x370} atau tp. Dan jika plat melebihi D_L, maka tambahkan pelat setebal F (lihat tabel D-7 AISC).

Dipakai tebal las sesuai $tp = 2$"



Gambar 5.30 Sambungan perpanjangan kolom I