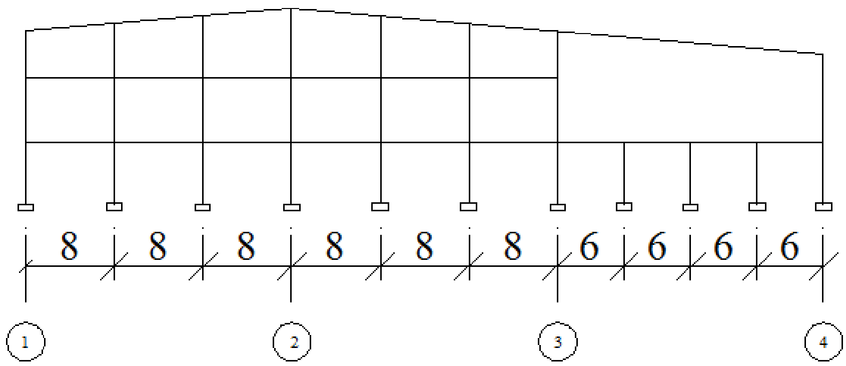
BAB IV

HASIL DAN PEMBAHASAN

A. Deskripsi Struktur

Tugas akhir ini yaitu perencanan struktur pada bangunan New Noodle Factory PT. Indofood CBP. Struktur dimodelkan dua dimensi dengan tinjaun portal terbesar dengan menggunakan *Struktur Analisis Program* SAP2000 V.14.



Gambar 4.1. Model portal

Perencanaan direncanakan dengan ketentuan-ketentuan sebagai berikut:

1. *Spesifikasi untuk Bangunan Gedung Baja Struktural* (SNI 1729:2015).
2. *Tata Cara Perencanaan Ketahanan Gempa untuk Struktur Bangunan Gedung dan Non Gedung* (SNI 1726:2012).
3. *Beban minimum untuk perencanaan bangunan gedung dan struktur lain* (SNI 1727:2013).
4. *Pedoman Perencanaan Pembebanan untuk Rumah dan Gedung* 1987.

B. Data Geomerti Strktur

Data yang digunakan dalam penyusunan tugas akhir ini yaitu sebagai berikut :

1. Baja
   a. Profil : ASTM A-36.
   b. Baut : ASTM A-325.

2. Material

Tabel 4.1 Data Meterial

NO	KODE	UKURAN	KETERANGAN
1	KB2	H 400X400X13X21	KOLOM BAJA
2	KB3	WF 350X350X12X19	
3	BB1	WF 500X200X10X16	BALOK BAJA
4	BB2	WF 450X200X9X14	
18	BR4	PIPA 3"	BRACING
19	BR5	WF 300X150X6,5X9	
21	R1	WF 500X200X10X15	RAFTER
23	R3	WF 300X150X6,5X9	

Sumber : BITA

C. Analisis Pembebanan

Pada perencanaan struktur ini beban-beban yang bekerja sesuai dengan *Beban minimum untuk perencanaan bangunan gedung dan struktur lain* (SNI 1727:2013) dan *Pedoman Perencanaan Pembebanan untuk Rumah dan Gedung* 1987.

1. Beban mati pada plat lantai

Beban mati yang direncanakan pada plat lantai yaitu sebagai berikut :

a. Tebal polyurethane (3 mm) = 0,003 meter

b. Berat polyurethane = 36 kg/m3

Beban polyurethane = 0,003 × 36 = 0,108 kg/m2

c. Plat beton (120 mm) = 0,12 meter

d. Berat beton bertulang = 2400 kg/m2

Beban plat beton = 0,12 × 2400 = 288 kg/m2

Beban mati plat lantai = (0,108 + 288) × 6 × 0,5

= 864,324 kg/m

e. Beban tambahan (SDL)

Berat dinding (hebel 20) = 200 kg/m^2

Tinggi dinding = 4 m

SDL = 200 × 4 = 800 kg/m

2. Beban mati atap

a. Berat gording (C 150×50×20×2,3) = 4,96 kg/m

b. Penutup atap metal gelombang = 10 kg/m^2

c. Jarak antar gording = 1,2 m

d. Berat atap = 10 × 1,2 = 12 kg/m

e. Beban mati atap = 4,96 + 12 = 16,96 kg/m

3. Beban angin

a. Sudut kuda-kuda (α) = 5^o

b. Q angin = 40 kg/m^2

c. Jarak antar kuda-kuda = 6 m

d. Jarak antar gording = 1,2 m

e. Koefisien angin tekan (c) = (0,02α – 0,4)

= (0,02(5) – 0,4) = – 0,3

f. Koefisien angin hisap = – 0,4

g. Beban angin pada kuda-kuda

Angin tekan = – 0,3 × 6 × 40 = 72 kg/m

Angin hisap = – 0,4 × 6 × 40 = 96 kg/m

4. Beban hidup

a. Beban hidup plat lantai = 6 kN/m^2

b. Beban hidup atap = 100 kg

5. Beban hujan

40 − 0,8 α

40 − 0,8 (5) = 36 kg/m

6. Beban gempa

a. Klasifikasi situs

Dalam melakukan analisis struktur khususnya dalam mengetahui klasifikasi suatu situs tanah respon spekrum gempa terlebih dahulu kita harus mengetahui situs tanah yang akan di dirikan sebagai bangunan nantinya. Pada perencanaan tersebut perlu dilakukan penyelidikan tanah di area pembangunan yang dipersiapkan agar mengetahui jenis tanah berdasarkan hasil penyelidikan tanah yang telah dilakukan berdasarkan tabel 4.2. dan tabel 4.3.

Tabel 4.2. Hasil Penujian SPT

DB 5			
KEDALAMAN (m)	TEBAL (m)	N-SPT	Ti/Ni
0 - 3,1	3,1	11	0,282
3,1 - 4,8	1,7	9	0,189
4,8 - 7,3	2,5	5	0,500
7,3 - 9,4	2,1	6	0,350
9,4 - 11,3	1,9	7	0,271
11,3 - 13,5	2,2	5	0,440
13,5 - 18,7	5,2	22,667	0,229
18,7 - 23,5	4,8	22,5	0,213
23,5 – 30	6,5	50	0,130
JUMLAH	30		2,605

Sumber : BITA ENARCON ENGINEERING, 2014

Tabel 4.3. Hasil Pengujian SPT

DB 9			
KEDALAMAN (m)	TEBAL (m)	N-SPT	Ti/Ni
0 - 2,7	2,7	6	0,45
2,7 - 5,3	2,6	5	0,52
5,3 - 7,4	2,1	10	0,21
7,4 - 13,20	5,8	6,333	0,916
13,20 - 17,60	4,4	12,5	0,352
17,60 - 23,30	5,7	25,333	0,225
23,30 - 28,70 28,70 - 30,45	5,4 1,75	40,333 23	0,134 0,076
JUMLAH	30,45		2,883

Sumber : BITA ENARCON ENGINEERING, 2014

Nilai N rata-rata ditentukan dengan rumus :

$$N=\frac{\sum_{i=1}^{n} di}{\sum_{i=1}^{n} \frac{di}{Ni}} \tag{4.1}$$

$$N = \frac{35}{2,774} = 11,512$$

$$N = \frac{30,45}{2,883} = 10,562$$

Jadi N rata-rata = $\frac{11,512 + 10,562}{2}$ =11,590

Berdasarkan SNI 1726:2012 pasal 5.3 untuk nilai N = 11,590 klasifikasi tanah situs termasuk jenis **Tanah Lunak.**

a. Respon spektrum

Analisis respon spektrum mengacu pada SNI 1726:2012 Tata cara perencanaan ketahanan gempa untuk struktur bangunan gedung dan non gedung. Pada gambar 9 dan 10 SNI 1726:2012 diperoleh nilai SS dan S1.

SS = 0,715 dan S1 = 0,291

Koefisien situs Fa dan Fv diperoleh pada tabel 4.4. dan 4.5. berdasarkan SNI 1726:2012.

Tabel 4.4. Hasil perhitungan koefisien situs Fa

Kelas Situs	Parameter Respon Spektrum Percepatan Gempa Terpetakan pada Periode Pendek T=0,2s Ss							
	Ss ≤ 0,25	-	Ss = 0,5	Ss=0,715	Ss = 0,75	-	Ss = 1,00	-	Ss ≥ 1,25
SA	0,8	-	0,8	0,8	0,8	-	0,8	-	0,8
SB	1,0	-	1,0	1	1,0	-	1,0	-	1
SC	1,2	-	1,2	1,114	1,1	-	1,0	-	1
SD	1,6	-	1,4	1,228	1,2	-	1,1	-	1
SE	2,5	-	1,7	1,270	1,2	-	0,9	-	0,9
SF	SS								

Tabel 4.5. Hasil perhitungan koefisien situs Fv

Kelas Situs	Parameter Respons Spektral Percepatan Gempa Terpetakan pada Periode 1 detik , S1								
	S1 ≤ 0,1	-	S1 = 0,2	S1=0,291	S1 = 0,3	-	S1 = 0,4	-	S1 ≥ 0,5
SA	0,8	-	0,8	0,8	0,8	-	0,8	-	0,8
SB	1,0	-	1	1	1	-	1	-	1
SC	1,7	-	1,6	1,509	1,5	-	1,4	-	1,3
SD	2,4	-	2	1,818	1,8	-	1,6	-	1,5
SE	3,5	-	3,2	2,836	2,8	-	2,4	-	2,4
SF	SS								

Untuk menentukan respons spektral percepatan gempa di permukaan tanah, diperlukan suatu faktor amplifikasi seismik pada periode 0,2 detik dan periode 1 detik. Faktor amplifikasi getaran terkait percepatan pada periode getaran pendek (*Fa*) dan faktor amplifikasi terkait percepatan yang mewakili getaran periode 1 detik (*Fv*). Parameter spektrum respon periode pendek (S_{MS}) dan periode 1 detik (S_{M1}) yang diperoleh seperti pada tabel 4.6. berdasarkan SNI 1726:2012.

Tabel 4.6. Hasil perhitungan S_{MS} dan S_{M1}

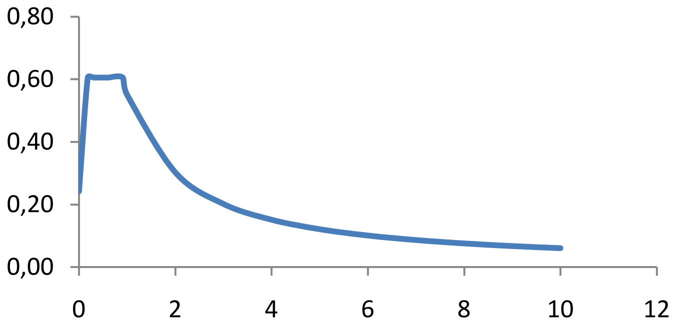
Kelas Situs	SMS	SM1
SA	0,572	0,233
SB	0,715	0,291
SC	0,797	0,439
SD	0,878	0,529
SE	0,908	0,825

Parameter percepatan spektral desain untuk periode pendek (S_{DS}) dan pada periode 1 detik (S_{D1}) berdasarkan hasil perhitungan seperti pada tabel 4.7.

Tabel 4.7. Hasil perhitungan S_{DS} dan S_{D1}

Kelas Situs	SDS	SD1
SA	0,381	0,155
SB	0,477	0,194
SC	0,531	0,293
SD	0,585	0,353
SE	0,605	0,550

Untuk menentukan pengaruh gempa rencana pada struktur gedung maka wilayah gempa ditetapkan spektrum respon rencana seperti pada gambar 4.2.



Gambar 4.2. Spektrum respons

Gambar diatas diperoleh berdasarkan hasil hitungan seperti pada tabel 4.8.

Tabel 4.8. Respons spektrum gempa

TANAH KERAS (SC)		TANAH SEANG (SD)		TANAH LUNAK (SE)	
T (s)	**Sa (g)**	**T (s)**	**Sa (g)**	**T (s)**	**Sa (g)**
0	0,21	0	0,23	0	0,24
0,11	0,53	0,12	0,59	0,18	0,61
0,20	0,53	0,2	0,59	0,30	0,61
0,30	0,53	0,3	0,59	0,40	0,61
0,40	0,53	0,4	0,59	0,50	0,61
0,50	0,53	0,5	0,59	0,60	0,61
0,55	0,53	0,60	0,59	0,91	0,61
0,90	0,33	1	0,35	1,00	0,55
1,00	0,29	2	0,18	2,00	0,30
2,00	0,15	3	0,12	3,00	0,20
3,00	0,10	4	0,09	4,00	0,15
4,00	0,07	5	0,07	5,00	0,12
5,00	0,06	6	0,06	6,00	0,10
6,00	0,05	7	0,05	7,00	0,09
7,00	0,04	8	0,04	8,00	0,08
8,00	0,04	9	0,04	9,0	0,07
9,00	0,03	10	0,04	10,0	0,06

Berdasarkan hasil nilai yang diperoleh parameter percepatan spektral desain untuk periode pendek (S_{DS}) sebesar 0,605 serta pada periode 1 detik (S_{D1}) sebesar 0,550 dengan spesifikasi 0,50 $\leq S_{DS}$ dan 0,20 $\leq S_{D1}$ bedasarkan tabel yang telah dijalaskan pada pembahasan sebelumnya yaitu memenuhi spesifikasi dengan kategori resiko IV dengan tingkat resiko kegempaan sistem rangka pemikul momen khusus (SRPMK) dengan nilai koefisien modifikasi respon (R) 8. Sistem rangka pemikul momen dimana rangka memikul 100% gaya gempa yang disyaratkan dan tidak melingkupi atau dihubungkan dengan komponen yang lebih kaku dan akan mencegah rangka dari defleksi dengan nilai Ct 0,0724, nilai x 0,8 dan nilai koefisien Cu 1,4.

b. Geser dasar seismik

$$Cs = \frac{S_{Ds}}{\left(\frac{R}{Ie}\right)}$$

$$Cs = \frac{0,605}{\left(\frac{8}{1}\right)}$$

Cs = 0,076

V = Cs × W

V = 0,076 × 4194,246

V = 318,763 kN

c. Periode fundamental

$Ta = Ct \times hn^{x}$

$Ta = 0,0724 \times 17,66^{0,8}$

Ta = 0,72 detik maka k = 2

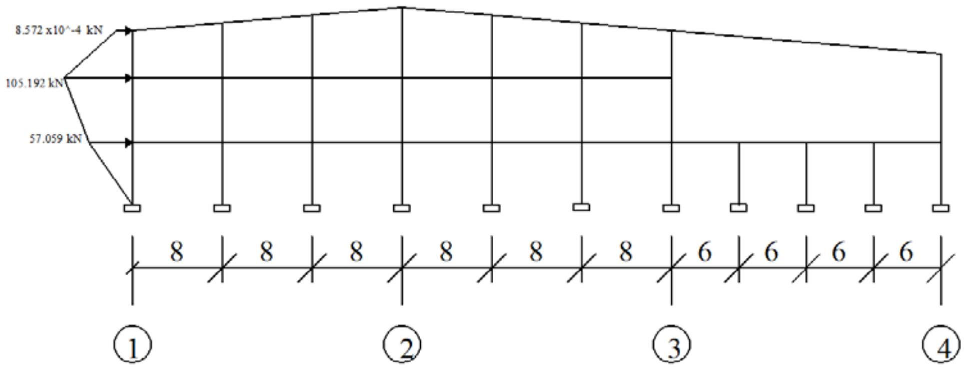
d. Distribusi vertikal gaya gempa

Fx = Cvx × V dan

$$Cvx = \frac{w_x h_x^k}{\sum_{i=1}^{n} wi\ h_i^k}$$

Tabel 4.9. Hasil perhitungan distribusi vertikal gaya gempa

Lantai ke	Hi (m)	Wi (kN)	Hi x Wi (kg m)	$\frac{w_x h_x^k}{\sum_{i=1}^{n} wi\ h_i^k}$	Fi (kN)
atap	16,11	3,374	54,35514	2,690E-06	8,575E-04
lantai 2	11,34	1679,978	19050,95052	0,330	105,333
lantai 1	5,59	2510,894	14035,89746	0,179	57,176
∑		4194,246	33141,20312		



Gambar 4.3. Analisis portal akibat beban gempa

D. Desain Balok

1. Data profil rencana BB1 IWF 500×200×10×16

   Dari hasil analisis struktur dengan menggunakan SAP 2000 V.14 diperoleh gaya dalam balok terbesar yaitu sebagai berikut :

   Mu = 124,908 kN m

   Vu = 168,323 kN

   d = 500 mm

   bf = 200 mm

   tw = 10 mm

   tf = 16 mm

   ix = 205 mm

   iy = 43,3 mm

   As = 11420 mm^2

   Sx = 1910 cm^3

   r = 20 mm

   fr = 70 Mpa

   Jx = 47800 cm^4

   Jy = 2140 cm^4

   h = (d – (2 × tf)) – (2 × r)

   = (500 – (2 × 16)) – (2 × 20)

   = 428 mm

   Zxb $= (bf \times tf) \times (d - tf) + tw \left(\frac{d}{2} - tf\right)^2$

   $= (200 \times 16) \times (500 - 16) + 10 \left(\frac{500}{2} - 16\right)^2$

   $= 2{,}096 \times 10^6\ mm^3$

   Zyb $= \left(\frac{bf}{2} tf\right) \times bf + \frac{tw^2}{4} \times (d - (2 \times tf))$

   $= \left(\frac{200}{2} 16\right) \times 200 + \frac{10^2}{4} \times (500 - (2 \times 16)$

   $= 3{,}317 \times 10^5$ mm

   Es = 200000 Mpa

   fy = 240 Mpa

a. Pemeriksaan kelangsingan penampang balok

$$\frac{bf}{2\times tf} \leq \lambda = 0{,}38\sqrt{\frac{Es}{fy}}$$

6,250 ≤ 10,97 ... (OK)

$$\frac{d}{tw} \leq \lambda = 2{,}45\sqrt{\frac{Es}{fy}}$$

50 ≤ 70,725 ... (OK)

Jadi, penampang balok memenuhi syarat kekompakan.

b. Pemeriksaan pengaruh tekuk lateral dan kuat lentur

Balok diberi penopang lateral pada setiap jarak 2 meter.

$$Lb = \frac{6000mm}{3} = 2\times10^{3}mm$$

Cek :

$$Lbmax = 0{,}086 \times iy \times \frac{Es}{fy}$$

$Lbmax = 3{,}103 \times 10^{3}$ mm

Cek kekuatan :

Lb < Lbmax ... (OK)

$$Lp = 1{,}76 \times iy \times \sqrt{\frac{Es}{fy}}$$

$Lp = 2{,}2 \times 10^{3}$ mm

Untuk Lb ≤ Lp

maka momen nominal Mn = Mp = Zxb × fy

Mn = Mp = 524 kN m

Dengan nilai reduksi lentur Φb = 0,9 maka rasio kapasitas lentur balok:

$$\text{Rasio momen} = \frac{Mu}{\Phi b\times Mn} = 0{,}265 < 1 \ldots(OK)$$

c. Pemeriksaan kuat geser balok

$$\lambda w = \frac{d}{tw}$$

$$\lambda w = \frac{500}{10} = 50$$

$$kn = 5 + \frac{5}{\left(\frac{Lb}{d}\right)^2}$$

$$kn = 5 + \frac{5}{\left(\frac{2 \times 10^3}{500}\right)^2} = 5{,}313 \text{ sehingga } 1{,}1\sqrt{\frac{kn \times Es}{fy}} = 73{,}193$$

Karena $\lambda w \leq 1{,}1\sqrt{\frac{kn \times Es}{fy}}$ maka leleh terjadi pada plat badan.

Kuat geser nominal ditentukan sebagai berikut :

$Vn = 0{,}6 \times fy \times (d \times tw)$

$Vn = 0{,}6 \times 0{,}24 \times (500 \times 10)$

Vn = 720 kN

Dengan nilai reduksi geser $\Phi s = 0{,}9$ maka rasio kapasitas geser balok :

Rasio shear = $\frac{Vu}{\Phi s \times Vn}$ = 0,260 <1…(OK)

d. Pemeriksaan interaksi Lentur dan Geser

Persamaan interaksi :

$$\frac{Mu}{\Phi b \times Mn} + 0{,}625 \times \frac{Vu}{\Phi s \times Vn} = 0{,}428 < 1{,}375 \ldots OK$$

2. Data profil rencana BB2 IWF 450×200×9×14

Dari hasil analisis struktur dengan menggunakan SAP 2000 V.14 diperoleh gaya dalam balok terbesar yaitu sebagai berikut :

Mu = 126,028 kN m

Vu = 119,357 kN

d = 450 mm

bf = 200 mm

tw = 9 mm

tf = 14 mm

ix = 186 mm

iy = 44,0 mm

As = 9676 mm^2

Sx = 1490 cm^3

r = 18 mm

fr = 70 Mpa

Jx = 33500 cm^4

Jy = 1870 cm^4

h = (d – (2 × tf)) – (2 × r)

= (450 – (2 × 14)) – (2 × 18)

= 386 mm

Zxb $= (bf \times tf) \times (d - tf) + tw\left(\frac{d}{2} - tf\right)^2$

$= (200 \times 14) \times (450 - 14) + 9\left(\frac{500}{2} - 14\right)^2$

$= 1{,}621 \times 10^6\ mm^3$

Zyb $= \left(\frac{bf}{2} tf\right) \times bf + \frac{tw^2}{4} \times (d - (2 \times tf))$

$= \left(\frac{200}{2} 14\right) \times 200 + \frac{9^2}{4} \times (450 - (2 \times 14)$

$= 2{,}885 \times 10^5\ mm$

Es = 200000 Mpa

fy = 240 Mpa

a. Pemeriksaan kelangsingan penampang balok

$$\frac{bf}{2 \times tf} \leq \lambda = 0{,}38 \sqrt{\frac{Es}{fy}}$$

$7{,}143 \leq 10{,}97$ ... (OK)

$$\frac{d}{tw} \leq \lambda = 2{,}45 \sqrt{\frac{Es}{fy}}$$

$50 \leq 70{,}725$ ... (OK)

Jadi, penampang balok memenuhi syarat kekompakan.

b. Pemeriksaan pengaruh tekuk lateral dan kuat lentur

Balok diberi penopang lateral pada setiap jarak 2 meter.

$$Lb = \frac{8000\ mm}{4} = 2 \times 10^3 m$$

Cek :

$$Lbmax = 0{,}086 \times iy \times \frac{Es}{fy}$$

$$Lbmax = 3{,}153 \times 10^3 \ mm$$

Cek kekuatan :

Lb < Lbmax ... (OK)

$$Lp = 1{,}76 \times iy \times \sqrt{\frac{Es}{fy}}$$

$$Lp = 2{,}236 \times 10^3 \ mm$$

Untuk Lb ≤ Lp

maka momen nominal Mn = Mp = Zxb × fy

Mn = Mp = 389,04 kN m

Dengan nilai reduksi lentur Φb = 0,9 maka rasio kapasitas lentur balok:

$$\text{Rasio momen} = \frac{Mu}{\Phi b \times Mn} = 0{,}360 < 1 \ldots \text{(OK)}$$

c. Pemeriksaan kuat geser balok

$$\lambda w = \frac{d}{tw}$$

$$\lambda w = \frac{450}{9} = 50$$

$$kn = 5 + \frac{5}{\left(\frac{Lb}{d}\right)^2}$$

$$kn = 5 + \frac{5}{\left(\frac{2 \times 10^3}{450}\right)^2} = 5{,}253 \text{ sehingga } 1{,}1\sqrt{\frac{kn \times Es}{fy}} = 72{,}779$$

Karena $\lambda w \leq 1{,}1\sqrt{\frac{kn \times Es}{fy}}$ maka leleh terjadi pada plat badan.

Kuat geser nominal ditentukan sebagai berikut :

$$Vn = 0{,}6 \times fy \times (d \times tw)$$

$$Vn = 0{,}6 \times 0{,}24 \times (450 \times 9)$$

$$Vn = 583{,}2 \ kN$$

Dengan nilai reduksi geser Φs = 0,9 maka rasio kapasitas geser balok :

$$\text{Rasio shear} = \frac{Vu}{\Phi s \times Vn} = 0{,}227 < 1 \ldots (OK)$$

d. Pemeriksaan interaksi Lentur dan Geser

Persamaan interaksi :

$$\frac{Mu}{\Phi b \times Mn} + 0{,}625 \times \frac{Vu}{\Phi s \times Vn} = 0{,}502 < 1{,}375 \ldots OK$$

3. Data profil rencana R1 IWF 500×200×10×16

Dari hasil analisis struktur dengan menggunakan SAP 2000 V.14 diperoleh gaya dalam rafter terbesar yaitu sebagai berikut :

Mu = 30,31 kN m

Vu = 16,68 kN

d = 500 mm

bf = 200 mm

tw = 10 mm

tf = 16 mm

ix = 205 mm

iy = 43,3 mm

As = 11420 mm^2

Sx = 1910 cm^3

r = 20 mm

fr = 70 Mpa

Jx = 47800 cm^4

Jy = 2140 cm^4

h = (d – (2 × tf)) – (2 × r)

= (500 – (2 × 16)) – (2 × 20)

= 428 mm

$$Zxb = (bf \times tf) \times (d - tf) + tw\left(\frac{d}{2} - tf\right)^2$$

$$= (200 \times 16) \times (500 - 16) + 10\left(\frac{500}{2} - 16\right)^2$$

$$= 2{,}096 \times 10^6 \text{ mm}^3$$

Zyb $= \left(\frac{bf}{2} tf\right) \times bf + \frac{tw^2}{4} \times (d - (2 \times tf))$

$= \left(\frac{200}{2} 16\right) \times 200 + \frac{10^2}{4} \times (500 - (2 \times 16)$

$= 3{,}317 \times 10^5$ mm

Es = 200000 Mpa

fy = 240 Mpa

a. Pemeriksaan kelangsingan penampang rafter

$$\frac{bf}{2\times tf} \leq \lambda = 0{,}38 \sqrt{\frac{Es}{fy}}$$

$6{,}250 \leq 10{,}97$ ... (OK)

$$\frac{d}{tw} \leq \lambda = 2{,}45 \sqrt{\frac{Es}{fy}}$$

$50 \leq 70{,}725$ ... (OK)

Jadi, penampang balok memenuhi syarat kekompakan.

b. Pemeriksaan pengaruh tekuk lateral dan kuat lentur

Rafter diberi penopang lateral pada setiap jarak 2 meter.

$$Lb = \frac{8029{,}42 \text{ mm}}{4} = 2\times10^3 \text{mm}$$

Cek :

$$Lbmax = 0{,}086 \times iy \times \frac{Es}{fy}$$

Lbmax = $3{,}103 \times 10^3$ mm

Cek kekuatan :

Lb < Lbmax ... (OK)

$$Lp = 1{,}76 \times iy \times \sqrt{\frac{Es}{fy}}$$

Lp = $2{,}2 \times 10^3$ mm

Untuk Lb $\leq$ Lp

maka momen nominal Mn = Mp = Zxb × fy

Mn = Mp = 524 kN m

Dengan nilai reduksi lentur Φb = 0,9 maka rasio kapasitas lentur balok:

Rasio momen = $\frac{Mu}{\Phi b \times Mn}$ = 0,064 < 1…(OK)

c. Pemeriksaan kuat geser balok

$\lambda w = \frac{d}{tw}$

$\lambda w = \frac{500}{10} = 50$

$kn = 5 + \frac{5}{\left(\frac{Lb}{d}\right)^2}$

$kn = 5 + \frac{5}{\left(\frac{2 \times 10^3}{500}\right)^2}$ = 5,313 sehingga $1,1\sqrt{\frac{kn \times Es}{fy}}$ = 73,193

Karena $\lambda w \leq 1,1\sqrt{\frac{kn \times Es}{fy}}$ maka leleh terjadi pada plat badan.

Kuat geser nominal ditentukan sebagai berikut :

$Vn = 0,6 \times fy \times (d \times tw)$

$Vn = 0,6 \times 0,24 \times (500 \times 10)$

Vn = 720 kN

Dengan nilai reduksi geser Φs = 0,9 maka rasio kapasitas geser balok :

Rasio shear = $\frac{Vu}{\Phi s \times Vn}$ = 0,039 <1…(OK)

d. Pemeriksaan interaksi Lentur dan Geser

Persamaan interaksi :

$\frac{Mu}{\Phi b \times Mn} + 0,625 \times \frac{Vu}{\Phi s \times Vn}$ = 0,088 < 1,375…OK

E. Desain Kolom

1. Data profil rencana KB2 IWF 400×400×13×21

   Dari hasil analisis struktur dengan menggunakan SAP 2000 V.14 diperoleh gaya dalam kolom terbesar yaitu sebagai berikut :

   Pu = 26,794 kN

d = 400 mm

bf = 400 mm

tw = 13 mm

tf = 21 mm

ix = 175 mm

iy = 101 mm

As = 21870 mm

Sx = 3330 cm^3

r = 22 mm

fr = 70 Mpa

Jx = 66600 cm^4

Jy = 22400 cm^4

a. Pemeriksaan kelangsingan penampang kolom

Untuk sayap :

$$\frac{bf}{2 \times tf} \leq \lambda = 0{,}38 \sqrt{\frac{Es}{fy}}$$

$9{,}524 \leq 10{,}97$ ... (OK)

Untuk badan :

$Py = As \times fy$

$Py = 21870 \times 240 = 5{,}249 \times 10^3$ kN dan $\Phi c = 0{,}9$

$$Ca = \frac{pu}{\Phi c \times Py}$$

$$Ca = \frac{26{,}794}{0{,}9 \times 5{,}249 \times 10^3} = 5{,}672 \times 10^{-3} \leq 0{,}125$$

sehingga $\frac{d}{tw} \leq \lambda = 2{,}45 \sqrt{\frac{Es}{fy}}\ (1 - 0{,}93 \times Ca)$

$30{,}769 \leq 70{,}354$ ... (OK)

Jadi, penampang kolom tidak kompakan.

b. Pemeriksaan kelangsingan elemen kolom

Lb < Lbmax

$$Lbmax = 0{,}086 \times iy \times \frac{Es}{fy}$$

$$Lbmax = 0{,}086 \times 101 \times \frac{200000}{240}$$

Lbmax = $7{,}238 \times 10^3$ mm

Lb = 5590 mm

Lb < Lbmax ... (OK)

c. Pemeriksaan kapasitas aksial kolom

1) Menentukan panjang efektif kolom

Dengan menggunakan Direct Analysis Method (DAM) maka kx = ky = 1

$$\lambda x = \frac{kx \times Lb}{ix}$$

$$\lambda x = \frac{1 \times 5590}{175} = 31{,}943$$

$$\lambda y = \frac{ky \times Lb}{iy}$$

$$\lambda y = \frac{1 \times 5590}{101} = 55{,}347$$

2) Pemeriksa tegangan lentur tekuk

$$Fey = \frac{\pi^2 \times Es}{\lambda y^2}$$

$$Fey = \frac{\pi^2 \times 200000}{55{,}347^2} = 644{,}379 \text{ Mpa}$$

$$Fcr = 0{,}658^{\frac{fy}{Fey}} \times fy$$

$$Fcr = 0{,}658^{\frac{240}{644{,}379}} \times 240 = 205{,}357 \text{ Mpa}$$

Maka kapasitas aksial kolom

$\Phi Pn = \Phi c \times Fcr \times As = 4{,}042 \times 10^3$ kN

$$\text{Rasio aksial} = \frac{Pu}{\Phi Pn} = 6{,}629 \times 10^{-3} < 1 \text{ … (OK)}$$

2. Data profil rencana KB3 IWF 350×350×12×19

   Dari hasil analisis struktur dengan menggunakan SAP 2000 V.14 diperoleh gaya dalam kolom terbesar yaitu sebagai berikut :

   Pu = 251,7 kN

   d = 350 mm

   bf = 350 mm

   tw = 12 mm

   tf = 19 mm

   ix = 152 mm

   iy = 88,4 mm

   As = 17390 mm

   Sx = 2300 cm^3

   r = 20 mm

   fr = 70 Mpa

   Jx = 40300 cm^4

   Jy = 13600 cm^4

   a. Pemeriksaan kelangsingan penampang kolom

      Untuk sayap :

      $$\frac{bf}{2 \times tf} \leq \lambda = 0{,}38 \sqrt{\frac{Es}{fy}}$$

      9,211 ≤ 10,97 ... (OK)

      Untuk badan :

      Py = As × fy

      Py = 17390 × 240 = 4,174 × 10^3 kN dan Φc = 0,9

      $$Ca = \frac{pu}{\Phi c \times Py}$$

      $$Ca = \frac{251{,}7}{0{,}9 \times 4{,}174 \times 10^3} = 0{,}067 \leq 0{,}125$$

      sehingga $\frac{d}{tw} \leq \lambda = 2{,}45 \sqrt{\frac{Es}{fy}}\ (1 - 0{,}93 \times Ca)$

$29{,}167 \leq 66{,}340$ ... (OK)

Jadi, penampang kolom tidak kompakan.

b. Pemeriksaan kelangsingan elemen kolom

Lb < Lbmax

$$Lbmax = 0{,}086 \times iy \times \frac{Es}{fy}$$

$$Lbmax = 0{,}086 \times 88{,}4 \times \frac{200000}{240}$$

$Lbmax = 6{,}335 \times 10^3$ mm

Lb = 5590 mm

Lb < Lbmax ... (OK)

c. Pemeriksaan kapasitas aksial kolom

1) Menentukan panjang efektif kolom

Dengan menggunakan Direct Analysis Method (DAM) maka kx = ky = 1

$$\lambda x = \frac{kx \times Lb}{ix}$$

$$\lambda x = \frac{1 \times 5590}{152} = 36{,}776$$

$$\lambda y = \frac{ky \times Lb}{iy}$$

$$\lambda y = \frac{1 \times 5590}{88{,}4} = 63{,}235$$

2) Pemeriksa tegangan lentur tekuk

$$Fey = \frac{\pi^2 \times Es}{\lambda y^2}$$

$$Fey = \frac{\pi^2 \times 200000}{63{,}235^2} = 493{,}645 \text{ Mpa}$$

$$Fcr = 0{,}658^{\frac{fy}{Fey}} \times fy$$

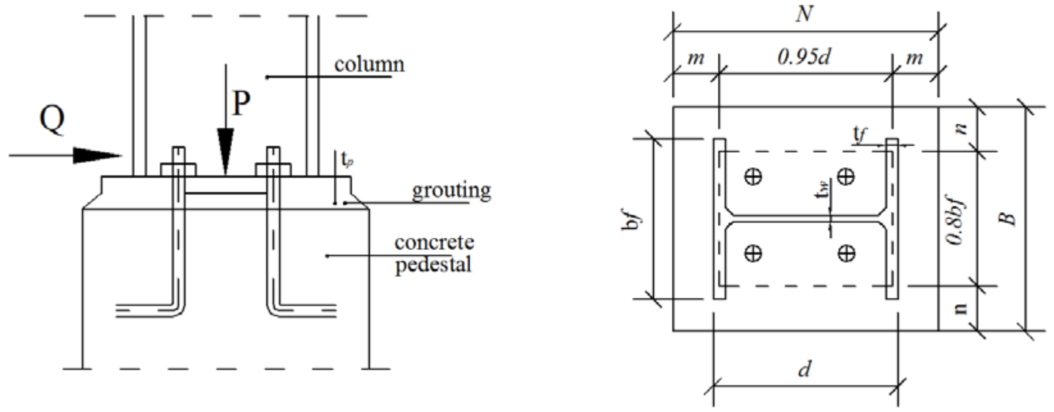
$$Fcr = 0{,}658^{\frac{240}{493{,}645}} \times 240 = 195{,}811 \text{ Mpa}$$

Maka kapasitas aksial kolom adalah

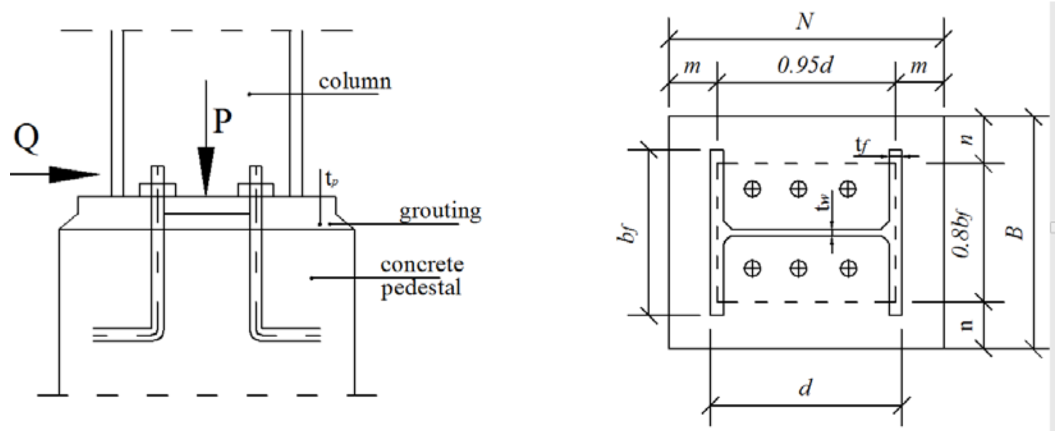
$\Phi Pn = \Phi c \times Fcr \times As = 3{,}065 \times 10^3$ kN

$$\text{Rasio aksial} = \frac{Pu}{\Phi Pn} = 0{,}082 < 1 \ldots \text{(OK)}$$

F. Perhitungan angkur base plat



Gambar 4.4. Detail Angkur



Gamabar 4.5. Detail Angkur

1. Base plat (PD2A) 400×400×13×21
   a. Data profil :

      B = 550 mm

      N = 595 mm

      b_f = 400 mm

      d = 400 mm

      t_w = 13 mm

      t_f = 21 mm

   b. Karakteristik baut A-307

      fy = 240 N/mm^2

fc’ = 25 N/mm^2

c. Beban-beban ketika gaya aksial maksimum dan gaya lateral maksimum terjadi.

1) Gaya aksial maksimum

Actual axial load (P) = 24546,77 kg

Actual lateral Fx = 744,72 kg

Actual lateral Fy = 0 kg

Actual lateral load (Q)

$Q = \sqrt{Fx^2 + Fy^2}$

$Q = \sqrt{744{,}72^2 + 0^2}$

Q = 744,72 kg

Tension load :

Actual tension load (T) = 24546,77 kg

2) Gaya lateral maksimum

Actual axial load (P) = 24546,77 kg

Actual lateral Fx = 744,72 kg

Actual lateral Fy = 0 kg

Actual lateral load (Q)

$Q = \sqrt{Fx^2 + Fy^2}$

$Q = \sqrt{744{,}72^2 + 0^2}$

Q = 744,72 kg

d. Tahanan ijin

Fp = 0,35×fc’×10

Fp = 0,35×25×10

Fp = 87,5 kg/mm^2

e. Luasan plat :

$A_1 = \frac{P}{Fp}$

$$A_1 = \frac{24546,77}{87,5}$$

A_1 = 280,535 mm^2

$A_2 = B \times N$

A_2 = 550 × 595 = 327250 mm^2

f. Cek

$\Delta = 0,5 \times (0,95 \times d \times 0,8 \times bf)$

$\Delta = 0,5 \times (0,95 \times 400 - 0,8 \times 400)$

Δ = 30 mm

$$A_1 \geq \frac{1}{A_2}\left[\frac{P}{0,35 \times f'c}\right]$$

$$A_1 \geq \frac{1}{327250}\left[\frac{24546,77}{\frac{0,35 \times 25}{10}}\right]$$

$A_1 \geq$ 2404,877 mm^2

$$A_1 \geq \frac{P}{0,7 \times f'c}$$

$$A_1 \geq \frac{24546,77}{\left(\frac{0,7 \times 25}{10}\right)}$$

$A_1 \geq$ 14026,73 mm

Diisyaratkan area A1 = 14026,73 mm

$$N = \sqrt{A_1} + \Delta$$

$$N = \sqrt{14026,73} + 30$$

N = 148,43 mm < d = 400 mm

$$B = \frac{A_1}{N}$$

$$B = \frac{14026,73}{148,43}$$

B = 94,50 mm < bf = 400 mm

g. Tahan tekanan aktual

$$fp = \frac{P}{B \times N}$$

$$fp = \frac{24072,158}{550 \times 595}$$

fp = 0,075 kg/mm^2 = 0,109 kip/in^2

0,25 × Fy = 0,25 × 240 × 10 = 600 kg/cm^2 = 8,702 kip/in^2

$$m = \frac{N - 0,95 \times d}{2}$$

$$m = \frac{595 - 0,95 \times 400}{2}$$

m = 107,5 mm

m = 10,75 cm = 4,232 in

$$n = \frac{B - 0,8 \times bf}{2}$$

$$n = \frac{550 - 0,8 \times 400}{2}$$

n = 115 mm

n = 11,5 cm = 4,528 in

$$tp = (\max m \text{ or } n) \times \sqrt{\frac{fp}{0,25 \times fy}}$$

$$tp = (4,528) \times \sqrt{\frac{0,109}{8,702}}$$

tp = 0,506 in

tp = 0,506 × 25,4

tp = 12,858 mm

Tebal plat yang disyaratkan adalah = 12,858 mm

Tebal base plat yang direkomendasikan adalah = 25 mm

h. Karakteristik baut A-307

F_u = 360 N/mm^2 (tegangan tarik minimum, $360 \times \frac{100}{9,8067}$ = 3671 kg/cm^2)

F_y = 240 N/mm^2 (tegangan leleh minimum, $240 \times \frac{100}{9,8067}$ = 2447 kg/cm^2)

F_t = 310 N/mm^2 (tegangan tarik, $310 \times \frac{100}{9,8067}$ = 3161 kg/cm^2)

F_v = 165 N/mm^2 (tegangan geser, $165 \times \frac{100}{9,8067}$ = 1683 kg/cm^2)

$F_b = 0,9 \times 240 = 216$ N/mm^2 (tahanan ijin, $216 \times \frac{100}{9,8067}$ = 2203 kg/cm^2)

i. Cek gaya geser

Diameter baut angkur = M 25

Jumlah baut (n) = 4

$A_g = 0,25 \times \pi \times (25^2)$

A_g = 491 mm^2 (cross section area of bolt)

$$f_v = \frac{Q}{n \times A_g}$$

$$f_v = \frac{744,72 \times 9,8067}{4 \times 491}$$

f_v = 3,720 N/mm^2 < F_v allowable OK

j. cek tahanan pada plat

t = 25 mm (tebal base plat direkomdasikan)

$A_{tu} = 25 \times 25 = 625$ mm^2 (shear section area of bolt)

$$F_{btu} = \frac{Q}{n \times A_{tu}}$$

$$F_{btu} = \frac{744,72}{4 \times 625}$$

F_{btu} = 2,92 N/mm^2 < F_b allowable OK

k. Cek kekuatan tarik dari batang angkur

$$T_{rod} = \frac{T}{n}$$

$$T_{rod} = \frac{24546,77}{4}$$

T_{rod} = 6137 kg

$F_t \times A_g$ = 15517 kg > T_{rod} Ok

Tension and Shear in Bearing-type Connections (AISC'89 Sect. J3.5)

F_t (ksi) = $26 - (1,8 \times f_v) \leq 20$ ksi

F_t = 179 – (1,8 × 3,720)

F_t = 173 N/mm^2 < 310 N/mm^2

$\frac{T_{rod}}{A_g}$ = 122,599 N/mm^2 < 173 N/mm^2

l. Panjang angkur

L_a = 400 mm

d = 25 mm

fc’ = 25 Mpa

fy = 240 Mpa

Panjang angkur minimum yang diperlukan :

$$L_{min} = \frac{fy}{\left(4 \times \sqrt{fc'}\right)} \times d$$

$$L_{min} = \frac{240}{\left(4 \times \sqrt{25}\right)} \times 25$$

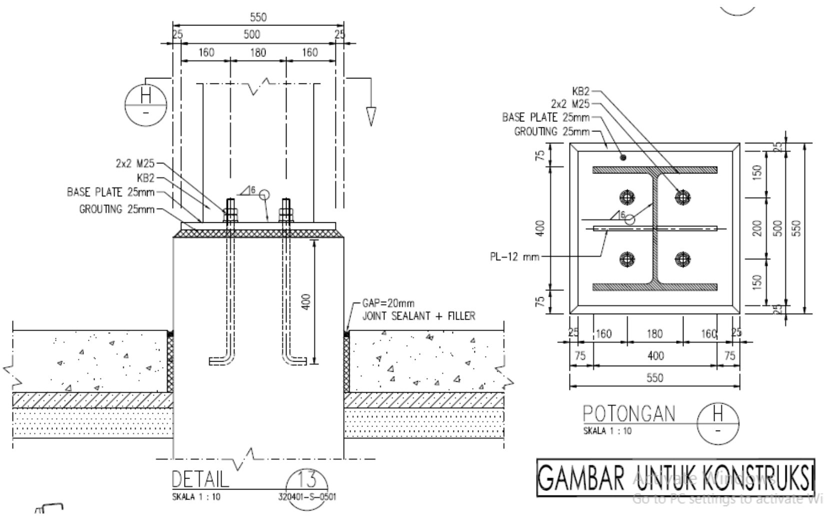
L_{min} = 300 mm

Syarat yang harus dipenuhi adalah :

$L_{min} \leq La$

$300 \leq 400$

Maka digunakan angkur 4 M 25 dengan panjang angkur 400 mm



Gambar 4.6. Hasil perencanaan angkur

2. Base plat (PD2) 400×400×13×21
   a. Data profil

      B = 550 mm

      N = 550 mm

      b_f = 400 mm

      d = 400 mm

      t_w = 13 mm

      t_f = 21 mm
   b. Karakteristik baut A-307

      fy = 240 N/mm^2

      fc' = 25 N/mm^2
   c. Beban-beban ketika gaya aksial maksimum dan gaya lateral maksimum terjadi.
      1) Gaya aksial maksimum

         Actual axial load (P) = 48520,85 kg

         Actual lateral Fx = 12,42 kg

         Actual lateral Fy = 0 kg

         Actual lateral load (Q)

         $Q = \sqrt{Fx^2+Fy^2}$

         $Q = \sqrt{12{,}42^2+0^2}$

         Q = 12,420 kg

         Tension load :

         Actual tension load (T) = 48520,85 kg
      2) Gaya lateral maksimum

         Actual axial load (P) = 18522,57 kg

         Actual lateral Fx = 22,02 kg

         Actual lateral Fz = 0 kg

Actual lateral load (Q)

$$Q = \sqrt{Fx^2+Fy^2}$$

$$Q = \sqrt{22{,}02^2+0^2}$$

Q = 22,02 kg

d. Tahanan ijin

F_p = 0,35×fc'×10

F_p = 0,35×25×10

F_p = 87,5 kg/mm^2

e. Luasan plat

$$A_1 = \frac{P}{F_p}$$

$$A_1 = \frac{18522{,}57}{87{,}5}$$

A_1 = 554,524 mm^2

A_2 = B × N

A_2 = 550 × 550 = 302500 mm^2

f. Cek

Δ = 0,5 × (0,95 × d × 0,8 × b_f)

Δ = 0,5 × (0,95 × 400 − 0,8 × 400)

Δ = 30 mm

$$A_1 \geq \frac{1}{A_2}\left[\frac{P}{0{,}35 \times f'c}\right]$$

$$A_1 \geq \frac{1}{302500}\left[\frac{48520{,}85}{\frac{0{,}35 \times 25}{10}}\right]^2$$

A_1 ≥ 10165,186 mm^2

$$A_1 \geq \frac{P}{0{,}7 \times f'c}$$

$$A_1 \geq \frac{48520{,}85}{\left(\frac{0{,}7 \times 25}{10}\right)}$$

$A_1 \geq 27726,20$ mm

Diisyaratkan area A1 = 27726,20 mm

$N = \sqrt{A_1} + \Delta$

$N = \sqrt{27726,20} + 30$

N = 196,51 mm < d = 400 mm

$B = \frac{A_1}{N}$

$B = \frac{27726,20}{196,51}$

B = 141,09 mm < bf = 400 mm

g. Tahan tekanan aktual

$fp = \frac{P}{B \times N}$

$fp = \frac{48520,85}{550 \times 550}$

fp = 0,160 kg/mm^2 = 0,233 kip/in^2

0,25 × Fy = 0,25 × 240 × 10 = 600 kg/cm^2 = 8,7 kip/in^2

$m = \frac{N - 0,95 \times d}{2}$

$m = \frac{550 - 0,95 \times 400}{2}$

m = 85 mm

m = 8,5 cm = 3,346 in

$n = \frac{B - 0,8 \times b_f}{2}$

$n = \frac{550 - 0,8 \times 400}{2}$

n = 115 mm

n = 11,5 cm = 4,528 in

$tp = (\max m \text{ or } n) \times \sqrt{\frac{fp}{0,25 \times fy}}$

$$tp = (4{,}528) \times \sqrt{\frac{0{,}233}{8{,}7}}$$

tp = 0,740 in

tp = 0,740 × 25,4

tp = 18,803 mm

Tebal plat yang disyaratkan adalah = 18,803mm

Tebal base plat yang direkomendasikan adalah = 25 mm

h. Karakteristik baut A-307

$F_u = 360\ N/mm^2$ (tegangan tarik minimum, $360 \times \frac{100}{9{,}8067} = 3671\ kg/cm^2$)

$F_y = 240\ N/mm^2$ (tegangan leleh minimum, $240 \times \frac{100}{9{,}8067} = 2447\ kg/cm^2$)

$F_t = 310\ N/mm^2$ (tegangan tarik, $310 \times \frac{100}{9{,}8067} = 3161\ kg/cm^2$)

$F_v = 165\ N/mm^2$ (tegangan geser, $165 \times \frac{100}{9{,}8067} = 1683\ kg/cm^2$)

$F_b = 0{,}9 \times 240 = 216\ N/mm^2$ (tahanan ijin, $216 \times \frac{100}{9{,}8067} = 2203\ kg/cm^2$)

i. Cek gaya geser

Diameter baut angkur = M 25

Jumlah baut (n) = 6

$A_g = 0{,}25 \times \pi \times (25^2)$

$A_g = 491\ mm^2$ (cross section area of bolt)

$$f_v = \frac{Q}{n \times A_g}$$

$$f_v = \frac{22{,}02 \times 9{,}8067}{4 \times 491}$$

$f_v = 0{,}073 N/mm^2 < F_v$ allowable OK

j. cek tahanan pada plat

t = 25 mm (tebal base plat direkomdasikan)

$A_{tu} = 25 \times 25 = 625\ mm^2$ (shear section area of bolt)

$$F_{btu} = \frac{Q}{n \times A_{tu}}$$

$$F_{btu} = \frac{22{,}02 \times 9{,}8067}{4 \times 625}$$

$F_{btu} = 0{,}06\ N/mm^2 < F_b$ allowable OK

k. Cek kekuatan tarik dari batang angkur

$$T_{rod} = \frac{T}{n}$$

$$T_{rod} = \frac{48520{,}85}{6}$$

$T_{rod} = 8087$ kg

$F_t \times A_g = 15517$ kg > Trod Ok

Tension and Shear in Bearing-type Connections (AISC'89 Sect. J3.5)

F_t (ksi) $= 26 - (1{,}8 \times f_v) \leq 20$ ksi

$F_t = 179 - (1{,}8 \times 0{,}110)$

$F_t = 179\ N/mm^2 < 310\ N/mm^2$

$\frac{Trod}{Ag} = 161{,}559\ N/mm^2 < 179\ N/mm^2$ OK

l. Panjang angkur

$L_a = 400$ mm

$d = 25$ mm

$fc' = 25$ Mpa

$fy = 240$ Mpa

Panjang angkur minimum yang diperlukan

$$L_{min} = \frac{fy}{\left(4 \times \sqrt{fc'}\right)} \times d$$

$$L_{min} = \frac{240}{\left(4 \times \sqrt{25}\right)} \times 25$$

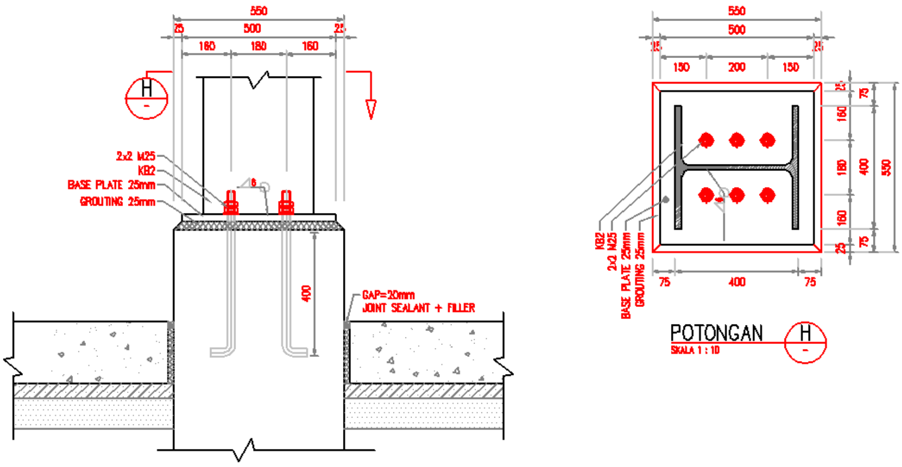
$L_{min} = 300$ mm

Syarat yang harus dipenuhi adalah :

$L_{min} \leq L_a$

$300 \leq 400$

Maka digunakan angkur 6 M 25 dengan panjang angkur 400 mm



Gambar 4.7. Hasil perencanaan angkur

3. Base plat (PD3) 350×350×12×19

   a. Data profil

      B = 500 mm

      N = 500 mm

      b_f = 350 mm

      d = 350 mm

      t_w = 12 mm

      t_f = 19 mm

   b. Karakteristik baut A-307

      fy = 240 N/mm^2

      fc' = 25 N/mm^2

   c. Beban-beban ketika gaya aksial maksimum dan gaya lateral maksimum

      1) Gaya aksial maksimum

         Actual axial load (P) = 17617,84 kg

         Actual lateral Fx = 50,19 kg

         Actual lateral Fy = 0 kg

Actual lateral load (Q)

$Q = \sqrt{Fx^2+Fy^2}$

$Q = \sqrt{50{,}19^2+0^2}$

Q = 50,19 kg

Tension load :

Actual tension load (T) = 17617,84 kg

2) Gaya lateral maksimum

Actual axial load (P) = 17617,84 kg

Actual lateral Fx = 50,19 kg

Actual lateral Fy = 0 kg

Actual lateral load (Q)

$Q = \sqrt{Fx^2+Fy^2}$

$Q = \sqrt{50{,}19^2+0^2}$

Q = 50,19 kg

d. Tahanan ijin

$Fp = 0{,}35 \times fc' \times 10$

$Fp = 0{,}35 \times 25 \times 10$

$Fp = 87{,}5\ kg/mm^2$

e. Luasan plat :

$A_1 = \frac{P}{Fp}$

$A_1 = \frac{17617{,}84}{87{,}5}$

$A_1 = 201{,}347\ mm^2$

$A_2 = B \times N$

$A_2 = 500 \times 500 = 250000\ mm^2$

f. Cek

$\Delta = 0{,}5 \times (0{,}95 \times d \times 0{,}8 \times bf)$

$\Delta = 0{,}5 \times (0{,}95 \times 350 - 0{,}8 \times 350)$

$\Delta = 26{,}25$ mm

$$A_1 \geq \frac{1}{A2}\left[\frac{P}{0{,}35 \times f'c}\right]$$

$$A_1 \geq \frac{1}{302500}\left[\frac{17617{,}84}{\frac{0{,}35 \times 25}{10}}\right]^2$$

$A_1 \geq 1621{,}620$ mm^2

$$A_1 \geq \frac{P}{0{,}7 \times f'c}$$

$$A_1 \geq \frac{17617{,}84}{\left(\frac{0{,}7 \times 25}{10}\right)}$$

$A_1 \geq 10067{,}34$ mm

Diisyaratkan area $A_1 = 10067{,}34$ mm

$N = \sqrt{A_1} + \Delta$

$N = \sqrt{10067{,}34} + 26{,}25$

$N = 126{,}59$ mm < $d = 350$ mm

$$B = \frac{A_1}{N}$$

$$B = \frac{10067{,}34}{126{,}59}$$

$B = 79{,}53$ mm < $bf = 350$ mm

g. Tahan tekanan aktual

$$f_p = \frac{P}{B \times N}$$

$$f_p = \frac{17617{,}84}{350 \times 350}$$

$f_p = 0{,}07 kg/mm^2 = 0{,}102 kip/in^2$

$0{,}25 \times Fy = 0{,}25 \times 240 \times 10 = 600 kg/cm^2 = 8{,}702 kip/in^2$

$$m = \frac{N - 0{,}95 \times d}{2}$$

$$m = \frac{500 - 0{,}95 \times 350}{2}$$

m = 83,75 mm

m = 8,375 cm = 3,297 in

$$n = \frac{B - 0{,}8 \times b_f}{2}$$

$$n = \frac{500 - 0{,}8 \times 350}{2}$$

n = 110 mm

n = 11 cm = 4,331 in

$$tp = (\text{max m or n}) \times \sqrt{\frac{fp}{0{,}25 \times fy}}$$

$$tp = (4{,}331) \times \sqrt{\frac{0{,}102}{8{,}702}}$$

tp = 0,469 in

tp = 0,469 × 25,4

tp = 11,921 mm

Tebal plat yang disyaratkan adalah = 11,921 mm

Tebal base plat yang direkomendasikan adalah = 25 mm

h. Karakteristik baut A-307

F_u = 360 N/mm^2 (tegangan tarik minimum, $360 \times \frac{100}{9{,}8067}$ = 3671 kg/cm^2)

F_y = 240 N/mm^2 (tegangan leleh minimum, $240 \times \frac{100}{9{,}8067}$ = 2447 kg/cm^2)

F_t = 310 N/mm^2 (tegangan tarik, $310 \times \frac{100}{9{,}8067}$ = 3161 kg/cm^2)

F_v = 165 N/mm^2 (tegangan geser, $165 \times \frac{100}{9{,}8067}$ = 1683 kg/cm^2)

F_b = 0,9 × 240 = 216 N/mm^2 (tahanan ijin, $216 \times \frac{100}{9{,}8067}$ = 2203 kg/cm^2)

i. Cek gaya geser

Diameter baut angkur = M 25

Jumlah baut (n) = 4

$A_g = 0{,}25 \times \pi \times (25^2)$

A_g = 491 mm^2 (cross section area of bolt)

$$f_v = \frac{Q}{n \times A_g}$$

$$f_v = \frac{50,19}{4 \times 491}$$

f_v = 0,251 N/mm^2 < F_v allowable OK

j. cek tahanan pada plat

t = 25 mm (tebal base plat direkomdasikan)

A_{tu} = 25 × 25 = 625 mm^2 (shear section area of bolt)

$$F_{btu} = \frac{Q}{n \times A_{tu}}$$

$$F_{btu} = \frac{50,19 \times 9,8067}{4 \times 625}$$

F_{btu} = 0,20 N/mm^2 < F_b allowable OK

k. Cek kekuatan tarik dari batang angkur

$$T_{rod} = \frac{T}{n}$$

$$T_{rod} = \frac{17617,84}{4}$$

T_{rod} = 4404 kg

$F_t \times A_g$ = 15517 kg > T_{rod} Ok

Tension and Shear in Bearing-type Connections (AISC'89 Sect. J3.5)

F_t (ksi) = 26 – (1,8 × f_v) ≤ 20 ksi

F_t = 179 – (1,8 × 0,251)

Ft = 179 N/mm^2 < 310 N/mm^2

$\frac{Trod}{Ag}$ = 87,993 N/mm^2 < 179 N/mm^2 OK

l. Panjang angkur

L_a = 400 mm

d = 25 mm

fc' = 25 Mpa

fy = 240 Mpa

Panjang angkur minimum yang diperlukan :

$$L_{min} = \frac{fy}{\left(4 \times \sqrt{fc'}\right)} \times d$$

$$L_{min} = \frac{240}{\left(4 \times \sqrt{25}\right)} \times 25$$

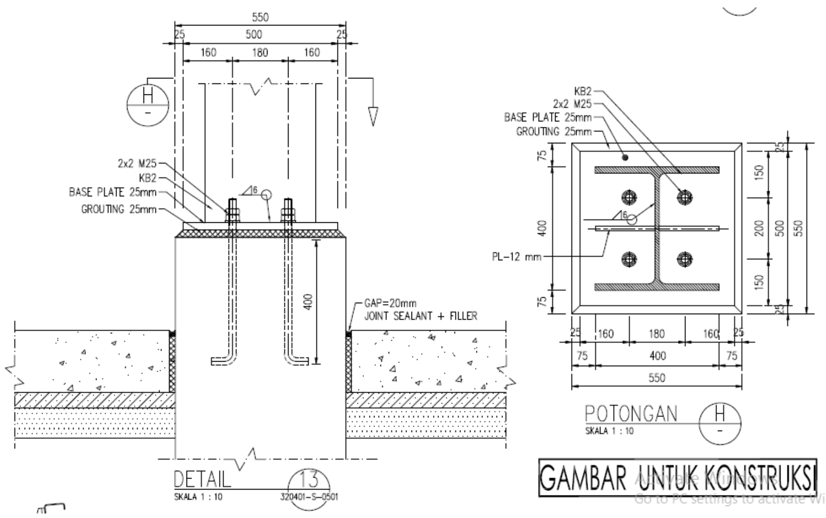
L_{min} = 300 mm

Syarat yang harus dipenuhi adalah :

$L_{min} \leq L_a$

$300 \leq 400$

Maka digunakan angkur 4 M 25 dengan panjang angkur 400 mm



Gambar 4.8. Hasi perencanaan angkur

4. Base plat (PD3A) 350×350×12×19
   a. Data profil

      B = 500 mm

      N = 570 mm

      b_f = 350 mm

      d = 350 mm

      t_w = 12 mm

      t_f = 19 mm
   b. Karakteristik baut A-307

      fy = 240 N/mm^2

      fc' = 25 N/mm^2

c. Beban-beban ketika gaya aksial maksimum dan gaya lateral maksimum

1) Gaya aksial maksimum

Actual axial load (P) = 11315,62 kg

Actual lateral Fx = 460,03 kg

Actual lateral Fy = 0 kg

Actual lateral load (Q)

$$Q = \sqrt{Fx^2 + Fy^2}$$

$$Q = \sqrt{460{,}03^2 + 0^2}$$

Q = 460,03 kg

Tension load :

Actual tension load (T) = 11315,62 kg

2) Gaya lateral maksimum

Actual axial load (P) = -10567,8 kg

Actual lateral Fx = 460,03 kg

Actual lateral Fy = 0 kg

Actual lateral load (Q)

$$Q = \sqrt{Fx^2 + Fy^2}$$

$$Q = \sqrt{460{,}030^2 + 0^2}$$

Q = 460,030 kg

d. Tegangan ijin

Fp = 0,35×fc'×10

Fp = 0,35×25×10

Fp = 87,5 kg/mm^2

e. Luasan plat :

$$A_1 = \frac{P}{Fp}$$

$$A_1 = \frac{11315,62}{87,5}$$

A_1 = 129,321 mm^2

A_2 = B × N

A_2 = 500 × 570 = 285000 mm^2

f. Cek

$\Delta = 0,5 \times (0,95 \times d \times 0,8 \times b_f)$

$\Delta = 0,5 \times (0,95 \times 350 - 0,8 \times 350)$

Δ = 26,25 mm

$$A_1 \geq \frac{1}{A2}\left[\frac{P}{0,35 \times f'c}\right]$$

$$A_1 \geq \frac{1}{285000}\left[\frac{11315,62}{\frac{0,35 \times 25}{10}}\right]^2$$

$A_1 \geq$ 586,808 mm^2

$$A_1 \geq \frac{P}{0,7 \times f'c}$$

$$A_1 \geq \frac{11315,62}{\left(\frac{0,7 \times 25}{10}\right)}$$

$A_1 \geq$ 6466,07 mm

Diisyaratkan area A_1 = 6466,07 mm

$N = \sqrt{A1} + \Delta$

$N = \sqrt{6466,07} + 26,25$

N = 106,66 mm < d = 350 mm

$$B = \frac{A_1}{N}$$

$$B = \frac{6466,07}{106,66}$$

B = 60,62 mm < b_f = 350 mm

g. Tahan tekanan aktual :

$$f_p = \frac{P}{B \times N}$$

$$f_p = \frac{11315{,}62}{500 \times 570}$$

f_p = 0,0397kg/mm^2 = 0,058 kip/in^2

0,25 × Fy = 0,25 × 240 × 10 = 600 kg/cm^2 = 8,702 kip/in^2

$$m = \frac{N - 0{,}95 \times d}{2}$$

$$m = \frac{570 - 0{,}95 \times 350}{2}$$

m = 118,75 mm

m = 11,875 cm = 4,675 in

$$n = \frac{B - 0{,}8 \times b_f}{2}$$

$$n = \frac{500 - 0{,}8 \times 350}{2}$$

n = 110 mm

n = 11 cm = 4,331 in

$$tp = (\text{max m or n}) \times \sqrt{\frac{fp}{0{,}25 \times fy}}$$

$$tp = (4{,}675) \times \sqrt{\frac{0{,}058}{8{,}702}}$$

tp = 0,380 in

tp = 0,380 × 25,4

tp = 9,66 mm

Tebal plat yang disyaratkan adalah = 9,66 mm

Tebal base plat yang direkomendasikan adalah = 25 mm

h. Karakteristik baut A-307

F_u = 360 N/mm^2 (tegangan tarik minimum, $360 \times \frac{100}{9{,}8067}$ = 3671 kg/cm^2)

F_y = 240 N/mm^2 (tegangan leleh minimum, $240 \times \frac{100}{9{,}8067}$ = 2447 kg/cm^2)

F_t = 310 N/mm^2 (tegangan tarik, $310 \times \frac{100}{9{,}8067}$ = 3161 kg/cm^2)

F_v = 165 N/mm^2 (tegangan geser, $165 \times \frac{100}{9{,}8067}$ = 1683 kg/cm^2)

$F_b = 0{,}9 \times 240 = 216\ N/mm^2$ (tahanan ijin, $240 \times \frac{100}{9{,}8067} = 2203\ kg/cm^2$)

i. Cek gaya geser

Diameter baut angkur = M 25

Jumlah baut (n) = 4

$A_g = 0{,}25 \times \pi \times (25^2)$

$A_g = 491\ mm^2$ (cross section area of bolt)

$$f_v = \frac{Q}{n \times A_g}$$

$$f_v = \frac{460{,}030 \times 9{,}8067}{4 \times 491}$$

$f_v = 2{,}298\ N/mm^2 <$ Fv allowable OK

j. Cek tahanan pada plat

t = 25 mm (tebal base plat direkomdasikan)

$A_{tu} = 25 \times 25 = 625\ mm^2$ (shear section area of bolt)

$$F_{btu} = \frac{Q}{n \times A_{tu}}$$

$$F_{btu} = \frac{460{,}030 \times 9{,}8067}{4 \times 625}$$

$F_{btu} = 1{,}80\ N/mm^2 < F_b$ allowable OK

k. Cek kekuatan tarik dari batang angkur

$$T_{rod} = \frac{T}{n}$$

$$T_{rod} = \frac{11315{,}62}{4}$$

$T_{rod} = 2829$ kg

$F_t \times A_g = 15517\ kg > T_{rod}$ Ok

Tension and Shear in Bearing-type Connections (AISC'89 Sect. J3.5)

F_t (ksi) $= 26 - (1{,}8 \times f_v) \leq 20$ ksi

$F_t = 179 - (1{,}8 \times 2{,}298)$

$F_t = 175\ N/mm^2 < 310\ N/mm^2$

$\frac{Trod}{Ag} = 56{,}516\ N/mm^2 < 175\ N/mm^2$ OK

l. Panjang angkur

L_a = 400 mm

d = 25 mm

fc' = 25 Mpa

fy = 240 Mpa

Panjang angkur minimum yang diperlukan :

$$L_{min} = \frac{fy}{\left(4 \times \sqrt{fc'}\right)} \times d$$

$$L_{min} = \frac{240}{\left(4 \times \sqrt{25}\right)} \times 25$$

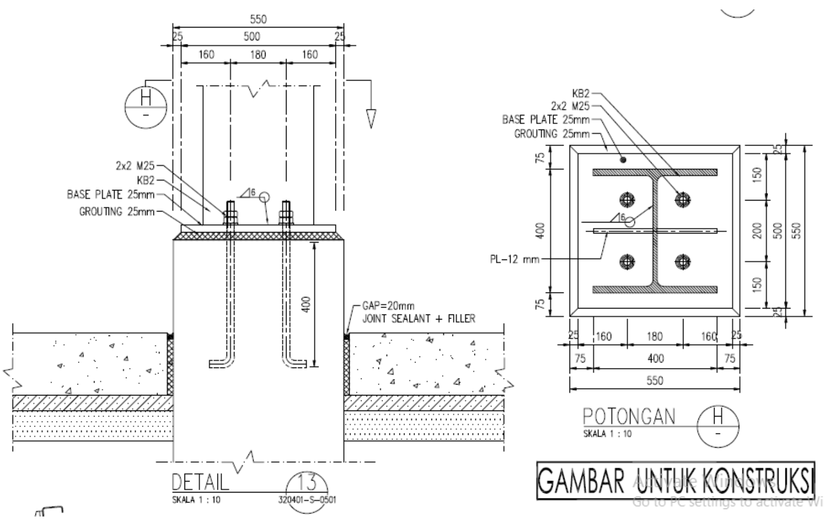
L_{min} = 300 mm

Syarat yang harus dipenuhi adalah :

$L_{min} \leq L_a$

$300 \leq 400$

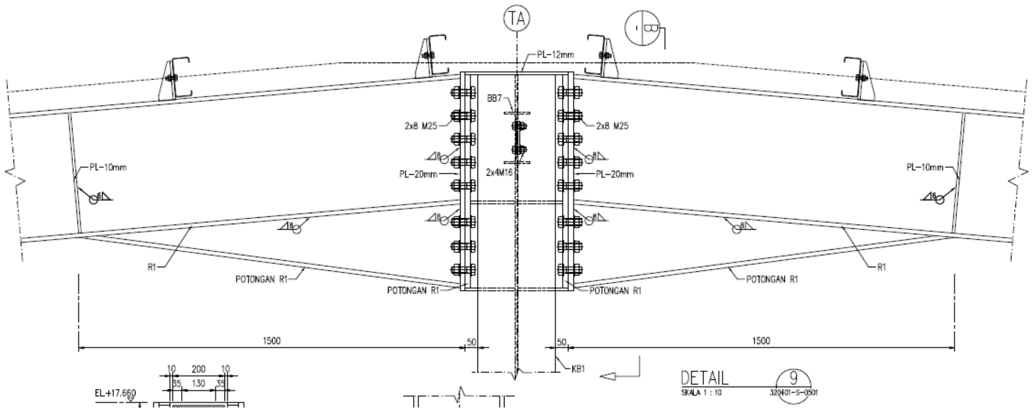
Maka digunakan angkur 4 M 25 dengan panjang angkur 400 mm



Gambar 4.9. Hasil perencanaan angkur

G. Perhitungan sambungan

1. R1 dengan KB3



Gambar 4.10. Detail sambungan rafter

(Sumber : PT Bita Enarco Engineering)

R1 WF 500×200×10×16

KB3 WF 350×350×12×19

a. Baut A 325

$\sigma|$ = 585 Mpa (Tegangan leleh)

$$\bar{\sigma} = \frac{\sigma l}{1,5}$$

$$\bar{\sigma} = \frac{585}{1,5}$$

$\bar{\sigma}$ = 390 Mpa (Tegangan dasar)

$\bar{\tau} = 0,6 \times \bar{\sigma}$

$\bar{\tau} = 0,6 \times 390$

$\bar{\tau}$ = 234 Mpa (Tegangan geser ijin)

$\bar{\sigma}\ ta = 0,7 \times \bar{\sigma}$

$\bar{\sigma}\ ta = 0,7 \times 390$

$\bar{\sigma}\ ta$ = 273 Mpa (Tegangan tarik ijin)

$\bar{\sigma}\ tu = 1,5 \times \bar{\sigma}$

$\bar{\sigma}\ tu = 1,5 \times 390$

$\bar{\sigma}\ tu$ = 585 Mpa (Tegangan tumpu ijin)

b. Actual loads

Q_0 = 7,93 kN (Gaya geser aktual)

N_0 = 0,78 kN (Gaya aksial aktual)

M_0 = 13,84 kNm (Momen aktual)

c. Dicoba diameter baut M 25

nx = 2 (jumlah baut diatas)

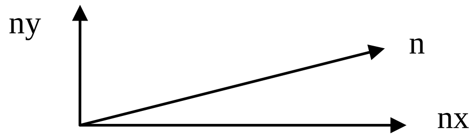
ny = 8

n = 16 (jumlah baut total)

e = 450 mm (eksentrisitas)

$\alpha = 5^o$

$\alpha = \frac{5\times\pi}{180} = 0{,}09$ rad

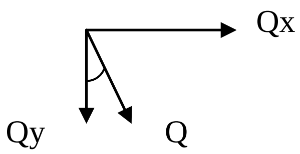


Ny = N × Sin α

Ny = 0,07 kN

Nx = N × Cos α

Nx = 0,78 kN



Qx = Q × Sin α

Qx = 0,69 kN

Qy = Q × Cos α

Qy = 7,90 kN

d. Gaya tahanan yang disebabkan oleh eksentrisitas :

Q_1 = Ny + Qy

= 0,07 + 7,90

= 7,97 kN

$N_1 = Nx + Qx$

$= 0{,}78 + 0{,}69$

$= 1{,}47$ kN

$M_1 = M_0 + (Qx \times e) + (Nx \times e)$

$= 13{,}84 + (0{,}69 \times 450) + (0{,}78 \times 450)$

$= 14{,}50$ kNm

e. Cek gaya geser

$$A_g = \frac{1}{4} \times \pi \times D^2$$

$$A_g = \frac{1}{4} \times \pi \times 25^2$$

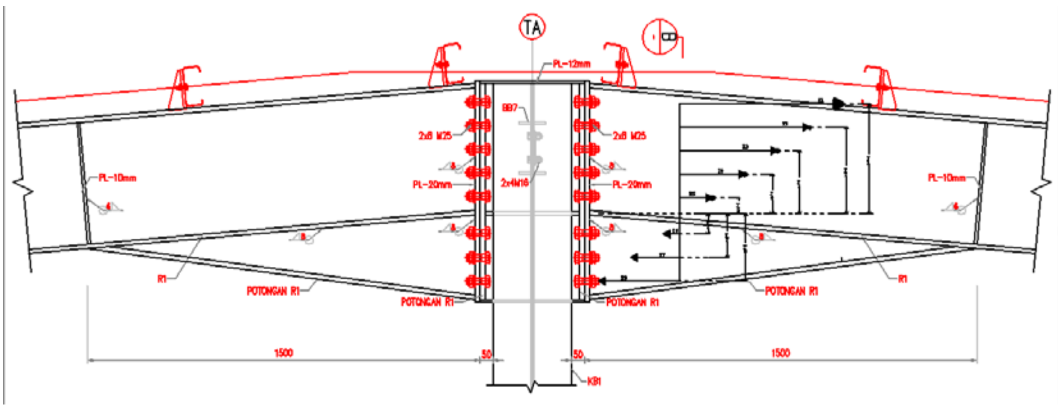
$A_g = 490{,}86\ mm^2$ (cross section area of bolt)

$$\tau = \frac{Q_1}{\left(n \times A_g\right)}$$

$$\tau = \frac{7{,}97 \times 1000}{(16 \times 490{,}86)}$$

$\tau = 1{,}01$ Mpa $< \bar{\tau} = 234$ Mpa OK

f. Cek gaya tarik



Gambar 4.11. Skema sambungan baut

$y_1 = 385$ mm | $y_9 = 385$ mm

$y_2 = 305$ mm | $y_{10} = 305$ mm

$y_3 = 225$ mm | $y_{11} = 225$ mm

$y_4 = 145$ mm | $y_{12} = 145$ mm

$y_5 = 65$ mm | $y_{13} = 65$ mm

y_6 = -60 mm y_{14} = -60 mm

y_7 = -140 mm y_{15} = -140 mm

y_8 = -220 mm y_{16} = -220 mm

$\sum y^2$ = 728425 mm^2

g. Tension for one bolt by axial (T_{an})

$$T_{an} = \frac{N_1}{n}$$

$$T_{an} = \frac{1,47}{16}$$

T_{an} = 0,09 kN

h. Tension for one bolt by moment (T_{am})

$$T_{am} = \frac{M_1 \times Yi}{\sum y^2}$$

T_{am1} = 7,18 kN T_{am9} = 7,18 kN

T_{am2} = 5,69 kN T_{am10} = 5,69 kN

T_{am3} = 4,20 kN T_{am11} = 4,20 kN

T_{am4} = 2,70 kN T_{am12} = 2,70 kN

T_{am5} = 1,21 kN T_{am13} = 1,21 kN

T_{am6} = -1,12 kN T_{am14} = -1,12 kN

T_{am7} = -2,61 kN T_{am15} = -2,61 kN

T_{am8} = -4,10 kN T_{am16} = -4,10 kN

T_a = T_{an} + T_{am}

T_{a1} = 7,27 kN T_{a9} = 7,27 kN

T_{a2} = 5,78 kN T_{a10} = 5,78 kN

T_{a3} = 4,80 kN T_{a11} = 4,80 kN

T_{a4} = 2,80 kN T_{a12} = 2,80 kN

T_{a5} = 1,30 kN T_{a13} = 1,30 kN

T_{a6} = -1,03 kN T_{a14} = -1,03 kN

T_{a7} = -2,52 kN T_{a15} = -2,52 kN

T_{a8} = -4,01 kN T_{a16} = -4,01 kN

i. Cross section area of bolt

$A_{ta} = \frac{1}{4}\pi\ (0{,}85 \times D)^2$

$A_{ta} = \frac{1}{4}\pi\ (0{,}85 \times 25)^2$

$A_{ta} = 354{,}65\ mm^2$

$\sigma ta = \frac{T_{a1}}{Ata}$

$\sigma ta = \frac{7{,}27 \times 1000}{354{,}65}$

$\sigma ta = 20{,}58$ Mpa < $\bar{\sigma}ta = 273$ Mpa OK

j. Kombinasi gaya geser dan gaya tarik

$\sigma i = \sqrt{\sigma ta^2 + 3\ \tau^2}$

$\sigma i = \sqrt{20{,}51^2 + 3 \times 1{,}01^2}$

$\sigma i = 20{,}58$ Mpa < $\bar{\sigma} = 390$ Mpa OK

k. Bearing plate thickness (t)

Cek tebal plat yang mengalami tarik

Dari pemodelan menggunakan program SAP :

Mtension = 2250,30 kgmm

$\frac{M}{Z} \leq \sigma ta$

$\frac{M}{\frac{bt^2}{6}} \leq \sigma ta$

$\frac{6M}{t^2} \leq \sigma ta$

$t^2 \geq \frac{6M}{\sigma ta}$

$\bar{\sigma}\ ta = 0{,}7 \times 390 \times 10$

$\bar{\sigma}\ ta = 2730\ kg/cm^2$

$\bar{\sigma}\ ta = 27{,}3\ kg/mm^2$

$$t \geq \sqrt{\frac{6 \times M}{\sigma ta}}$$

t ≥ 22,239 mm take plat t = 20 mm

l. Check for bearing plate

t = 20 mm (plat thickness)

$A_{tu} = t \times D$

$= 20 \times 25$

$= 500\ mm^2$

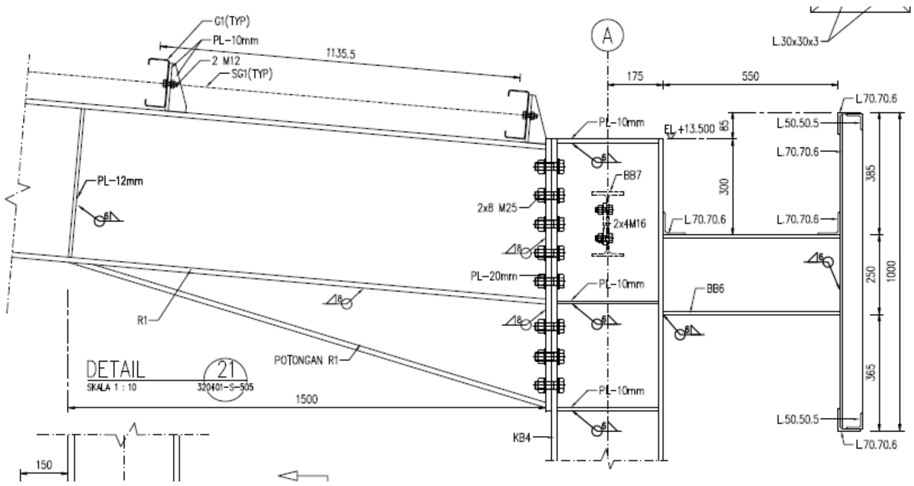
$$\sigma tu = \frac{Q}{n \times A_{tu}}$$

$$\sigma tu = \frac{7{,}93 \times 1000}{16 \times 25 \times 20}$$

$\sigma tu = 0{,}99$ Mpa $< \bar{\sigma} tu$ OK

Use bolt 16 M 25

2. R1 dengan KB3



Gambar 4.12. Detail sambungan rafter dengan kolom

(Sumber : PT Bita Enarco Engineering)

R1 WF 500×200×10×16

KB3 WF 350×350×12×19

a. Baut A 325

σ| = 585 Mpa (Tegangan leleh)

$\bar{\sigma} = \dfrac{\sigma l}{1{,}5}$

$\bar{\sigma} = \dfrac{585}{1{,}5}$

$\bar{\sigma}$ = 390 Mpa (Tegangan dasar)

$\bar{\tau}$ = 0,6 × $\bar{\sigma}$

$\bar{\tau}$ = 0,6 × 390

$\bar{\tau}$ = 234 Mpa (Tegangan geser ijin)

$\bar{\sigma}$ ta = 0,7 × $\bar{\sigma}$

$\bar{\sigma}$ ta = 0,7 × 390

$\bar{\sigma}$ ta = 273 Mpa (Tegangan tarik ijin)

$\bar{\sigma}$ tu = 1,5 × $\bar{\sigma}$

$\bar{\sigma}$ tu = 1,5 × 390

$\bar{\sigma}$ tu = 585 Mpa (Tegangan tumpu ijin)

b. Actual loads

Q_0 = 16,68 kN (Gaya geser aktual)

N_0 = 16,86 kN (Gaya aksial aktual)

M_0 = 47,20 kNm (Momen aktual)

c. Dicoba diameter baut M 25

nx = 2 (jumlah baut diatas)

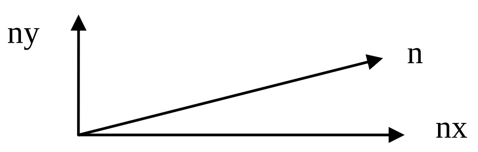
ny = 8

n = 16 (jumlah baut total)

e = 450 mm (eksentrisitas)

α = 5^o

α = $\frac{5\times\pi}{180}$ =0,09 rad

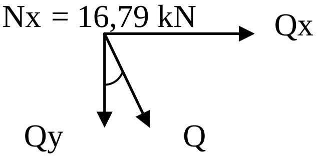


$Ny = N \times \sin \alpha$

$Ny = 1{,}47$ kN

$Nx = N \times \cos \alpha$

$Nx = 16{,}79$ kN



$Qx = Q \times \sin \alpha$

$Qx = 1{,}45$ kN

$Qy = Q \times \cos \alpha$

$Qy = 16{,}62$ kN

d. Gaya tahanan yang disebabkan oleh eksentrisitas

$Q_1 = Ny + Qy$

$= 1{,}47 + 16{,}62$

$= 18{,}09$ kN

$N_1 = Nx + Qx$

$= 16{,}79 + 1{,}45$

$= 18{,}25$ kN

$$M_1 = M_0 + \left(\frac{Qx \times e}{1000}\right) + \left(\frac{Nx \times e}{1000}\right)$$

$$= 47{,}20 + \left(\frac{1{,}45 \times 450}{1000}\right) + \left(\frac{16{,}79 \times 450}{1000}\right)$$

$= 55{,}41$ kNm

e. Cek gaya geser

$$A_g = \frac{1}{4} \times \pi \times D^2$$

$$A_g = \frac{1}{4} \times \pi \times 25^2$$

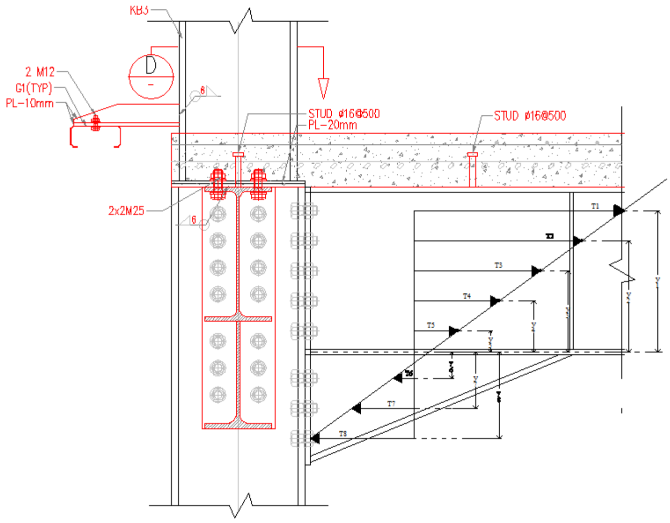
$A_g = 490{,}86\ mm^2$ (cross section area of bolt)

$$\tau = \frac{Q_1}{(n \times Ag)}$$

$$\tau = \frac{18{,}09 \times 1000}{(16 \times 490{,}86)}$$

τ = 2,30 Mpa < $\bar{\tau}$ = 234 Mpa O

f. Cek gaya tarik :



Gambar 4.13. Skema sambungan baut

y_1	= 385 mm	y_9	= 385 mm
y_2	= 305 mm	y_{10}	= 305 mm
y_3	= 225 mm	y_{11}	= 225 mm
y_4	= 145 mm	y_{12}	= 145 mm
y_5	= 65 mm	y_{13}	= 65 mm
y_6	= -60 mm	y_{14}	= -60 mm
y_7	= -140 mm	y_{15}	= -140 mm
y_8	= -220 mm	y_{16}	= -220 mm

$\sum y^2$ = 777450 mm^2

g. Tension for one bolt by axial (T_{an})

$$T_{an} = \frac{N_1}{n}$$

$$T_{an} = \frac{18{,}25}{16}$$

T_{an} = 1,14 kN

h. Tension for one bolt by moment (T_{am})

$$T_{am} = \frac{M_1 \times Yi}{\sum y^2}$$

T_{am1}	= 27,44 kN	T_{am9}	= 27,44 kN
T_{am2}	= 21,74 kN	T_{am10}	= 21,74 kN
T_{am3}	= 16,04 kN	T_{am11}	= 16,04 kN
T_{am4}	= 10,33 kN	T_{am12}	= 10,33 kN
T_{am5}	= 4,63 kN	T_{am13}	= 4,63 kN
T_{am6}	= -4,28 kN	T_{am14}	= -4,28 kN
T_{am7}	= -9,98 kN	T_{am15}	= -9,98 kN
T_{am8}	= -15,68 kN	T_{am16}	= -15,68 kN

Ta = Tan + Tam

T_{a1}	= 28,58 kN	T_{a9}	= 28,58 kN
T_{a2}	= 22,88 kN	T_{a10}	= 22,88 kN
T_{a3}	= 17,18 kN	T_{a11}	= 17,18 kN
T_{a4}	= 11,48 kN	T_{a12}	= 11,48 kN
T_{a5}	= 5,77 kN	T_{a13}	= 5,77 kN
T_{a6}	= -3,14 kN	T_{a14}	= -3,14 kN
T_{a7}	= -8,84 kN	T_{a15}	= -8,84 kN
T_{a8}	= -14,54 kN	T_{a16}	= -14,54 kN

i. Cross section area of bolt

$$A_{ta} = \frac{1}{4}\pi\ (0{,}85 \times D)^2$$

$$A_{ta} = \frac{1}{4}\pi\ (0{,}85 \times 25)^2$$

A_{ta} = 354,65 mm^2

$$\sigma ta = \frac{T_{a1}}{Ata}$$

$$\sigma ta = \frac{28{,}58 \times 1000}{354{,}65}$$

$\sigma ta = 80{,}59$ Mpa < $\bar{\sigma}ta = 273$ Mpa OK

j. Kombinasi gaya geser dan gaya tarik

$\sigma i = \sqrt{\sigma ta^2 + 3\ \tau^2}$

$\sigma i = \sqrt{80{,}59^2 + 3 \times 2{,}30^2}$

σi = 80,69 Mpa < $\bar{\sigma}$ = 390 Mpa OK

k. Bearing plate thickness (t)

Cek tebal plat yang mengalami tarik

Dari pemodelan menggunakan program SAP :

Mtension = 2250,30 kgmm

$\frac{M}{Z} \leq \sigma ta$

$\frac{M}{\frac{bt^2}{6}} \leq \sigma ta$

$\frac{6M}{t^2} \leq \sigma ta$

$t^2 \geq \frac{6M}{\sigma ta}$

$\bar{\sigma}$ ta = 0,7 × 390 × 10

$\bar{\sigma}$ ta = 2730 kg/cm^2

$\bar{\sigma}$ ta = 27,3 kg/mm^2

$t \geq \sqrt{\frac{6 \times M}{\sigma ta}}$

t ≥ 22,239 mm take plat t = 20 mm

l. Check for bearing plate

t = 20 mm (plat thickness)

A_{tu} = t × D

= 20 × 25

= 500 mm^2

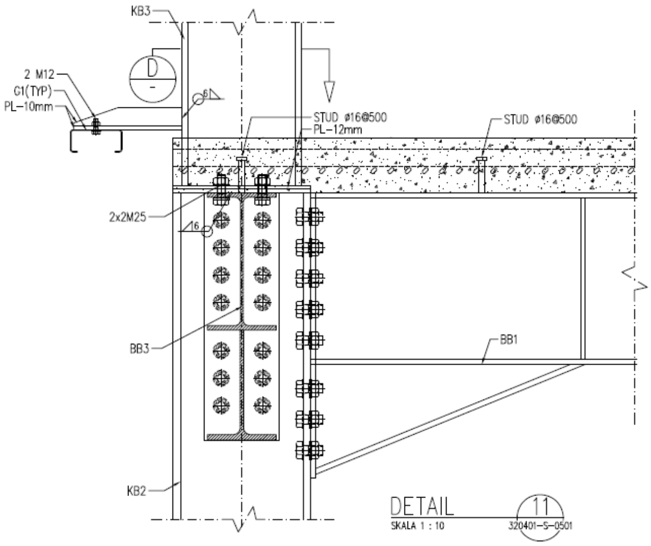
$\sigma tu = \frac{Q}{n \times Atu}$

$\sigma tu = \frac{7{,}93 \times 1000}{16 \times 25 \times 20}$

σtu = 0,99 Mpa < $\bar{\sigma}tu$ OK

Use bolt 16 M 25

3. BB1 dengan KB2



Gambar 4.14. Detail sambungan balok dengan kolom

(Sumber : PT Bita Enarco Engineering)

BB1 WF 500×200×10×16

KB2 WF 400×400×13×21

a. Baut A 325

$\sigma|$ = 585 Mpa (Tegangan leleh)

$$\bar{\sigma} = \frac{\sigma l}{1,5}$$

$$\bar{\sigma} = \frac{585}{1,5}$$

$\bar{\sigma}$ = 390 Mpa (Tegangan dasar)

$\bar{\tau}$ = 0,6 × $\bar{\sigma}$

$\bar{\tau}$ = 0,6 × 390

$\bar{\tau}$ = 234 Mpa (Tegangan geser ijin)

$\bar{\sigma}$ ta = 0,7 × $\bar{\sigma}$

$\bar{\sigma}$ ta = 0,7 × 390

$\bar{\sigma}$ ta = 273 Mpa (Tegangan tarik ijin)

$\bar{\sigma}$ tu = 1,5 × $\bar{\sigma}$

$\bar{\sigma}$ tu = 1,5 × 390

$\bar{\sigma}$ tu = 585 Mpa (Tegangan tumpu ijin)

b. Actual loads

Q_0 = 115,22 kN (Gaya geser aktual)

N_0 = 0 kN (Gaya aksial aktual)

M_0 = 158,23 kNm (Momen aktual)

c. Dicoba diameter baut M 25

nx = 2 (jumlah baut diatas)

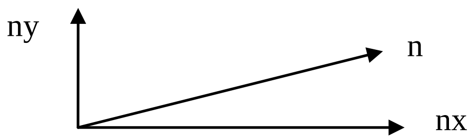
ny = 8

n = 16 (jumlah baut total)

e = 450 mm (eksentrisitas)

α = 5^o

$\alpha = \frac{5 \times \pi}{180} = 0{,}09$ rad

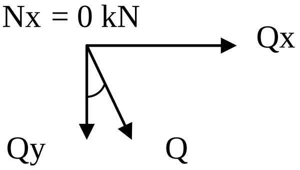


Ny = N × Sin α

Ny = 0 kN

Nx = N × Cos α

Nx = 0 kN



Qx = Q × Sin α

Qx = 10,04 kN

Qy = Q × Cos α

Qy = 114,78 kN

d. Gaya tahanan yang disebabkan oleh eksentrisitas :

Q_1 = Ny + Qy

= 0 + 114,78

= 114,78 kN

$N_1 = Nx + Qx$

$= 0 + 10{,}04$

$= 10{,}04 \text{ kN}$

$M_1 = M_0 + (Qx \times e) + (Nx \times e)$

$= 158{,}23 + (10{,}04 \times 450) + (0 \times 450)$

$= 162{,}75 \text{ kNm}$

e. Cek gaya geser

$$A_g = \frac{1}{4} \times \pi \times D^2$$

$$A_g = \frac{1}{4} \times \pi \times 25^2$$

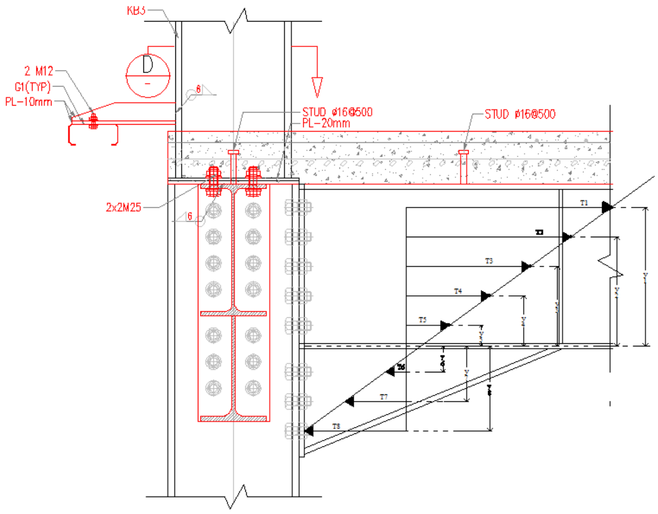
$A_g = 490{,}86 \text{ mm}^2$ (cross section area of bolt)

$$\tau = \frac{Q_1}{(n \times Ag)}$$

$$\tau = \frac{114{,}78 \times 1000}{(16 \times 490{,}86)}$$

$\tau = 14{,}61$ Mpa $< \bar{\tau} = 234$ Mpa OK

f. Cek gaya tarik



Gambar 4.15. Skema sambungan baut

y_1 = 385 mm	y_9 = 385 mm
y_2 = 305 mm	y_{10} = 305 mm
y_3 = 225 mm	y_{11} = 225 mm
y_4 = 145 mm	y_{12} = 145 mm
y_5 = 65 mm	y_{13} = 65 mm
y_6 = -60 mm	y_{14} = -60 mm
y_7 = -140 mm	y_{15} = -140 mm
y_8 = -220 mm	y_{16} = -220 mm

$\sum y^2$ = 777450 mm^2

g. Tension for one bolt by axial (T_{an})

$$T_{an} = \frac{N_1}{n}$$

$$T_{an} = \frac{10{,}04}{16}$$

T_{an} = 0,63 kN

h. Tension for one bolt by moment (T_{am})

$$T_{am} = \frac{M_1 \times Yi}{\sum y^2}$$

T_{am1} = 80,59 kN	T_{am9} = 80,59 kN
T_{am2} = 63,85 kN	T_{am10} = 63,85 kN
T_{am3} = 47,10 kN	T_{am11} = 47,10 kN
T_{am4} = 30,35 kN	T_{am12} = 30,35 kN
T_{am5} = 13,61 kN	T_{am13} = 13,61 kN
T_{am6} = -12,56 kN	T_{am14} = -12,56 kN
T_{am7} = -29,31 kN	T_{am15} = -29,31 kN
T_{am8} = -46,05 kN	T_{am16} = -46,05 kN

Ta = Tan + Tam

T_{a1} = 81,22 kN	T_{a9} = 81,22 kN
T_{a2} = 64,47 kN	T_{a10} = 64,47 kN
T_{a3} = 47,73 kN	T_{a11} = 47,73 kN
T_{a4} = 30,98 kN	T_{a12} = 30,98 kN

T_{a5} = 14,23 kN　　T_{a13} = 14,23 kN

T_{a6} = -11,93 kN　　T_{a14} = -11,93 kN

T_{a7} = -28,68 kN　　T_{a15} = -28,68 kN

T_{a8} = -45,43 kN　　T_{a16} = -45,43 kN

i. Cross section area of bolt

$$A_{ta} = \frac{1}{4}\pi\,(0{,}85 \times D)^2$$

$$A_{ta} = \frac{1}{4}\pi\,(0{,}85 \times 25)^2$$

$$A_{ta} = 354{,}65\ \text{mm}^2$$

$$\sigma ta = \frac{T_{a1}}{A_{ta}}$$

$$\sigma ta = \frac{81{,}22 \times 1000}{354{,}65}$$

σta = 229,02 Mpa < $\bar{\sigma}$ta = 273 Mpa OK

j. Kombinasi gaya geser dan gaya tarik

$$\sigma i = \sqrt{\sigma ta^2 + 3\,\tau^2}$$

$$\sigma i = \sqrt{81{,}22^2 + 3 \times 14{,}61^2}$$

σi = 230,41 Mpa < $\bar{\sigma}$ = 390 Mpa OK

k. Bearing plate thickness (t)

Cek tebal plat yang mengalami tarik

Dari pemodelan menggunakan program SAP :

Mtension = 2250,30 kgmm

$$\frac{M}{Z} \leq \sigma ta$$

$$\frac{M}{\frac{bt^2}{6}} \leq \sigma ta$$

$$\frac{6M}{t^2} \leq \sigma ta$$

$$t^2 \geq \frac{6M}{\sigma ta}$$

$\bar{\sigma}$ ta = 0,7 × 390 × 10

$\bar{\sigma}$ ta = 2730 kg/cm^2

$\bar{\sigma}$ ta = 27,3 kg/mm^2

$$t \geq \sqrt{\frac{6 \times M}{\sigma ta}}$$

t ≥ 22,239 mm take plat t = 20 mm

l. Check for bearing plate

t = 20 mm (plat thickness)

A_{tu} = t × D

= 20 × 25

= 500 mm^2

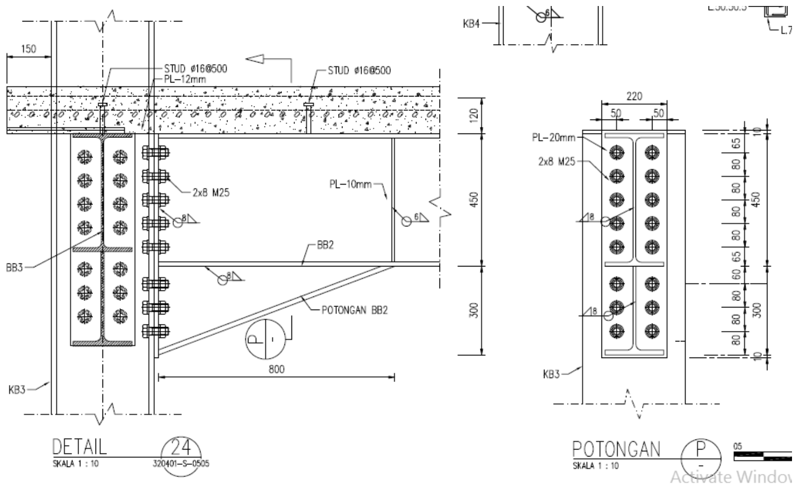
$$\sigma tu = \frac{Q}{n \times Atu}$$

$$\sigma tu = \frac{115{,}22 \times 1000}{16 \times 25 \times 20}$$

σtu = 14,40 Mpa < $\bar{\sigma}$tu OK

Use bolt 16 M 25

4. BB2 dengan KB2



Gambar 4.16. Detail sambungan balok dengan kolom

(Sumber : PT Bita Enarco Engineering)

BB2 WF 450×200×9×14

KB2 WF 400×400×13×21

a. Baut A 325

$\sigma|$ = 585 Mpa (Tegangan leleh)

$$\bar{\sigma} = \frac{\sigma l}{1,5}$$

$$\bar{\sigma} = \frac{585}{1,5}$$

$\bar{\sigma}$ = 390 Mpa (Tegangan dasar)

$\bar{\tau}$ = 0,6 × $\bar{\sigma}$

$\bar{\tau}$ = 0,6 × 390

$\bar{\tau}$ = 234 Mpa (Tegangan geser ijin)

$\bar{\sigma}$ ta = 0,7 × $\bar{\sigma}$

$\bar{\sigma}$ ta = 0,7 × 390

$\bar{\sigma}$ ta = 273 Mpa (Tegangan tarik ijin)

$\bar{\sigma}$ tu = 1,5 × $\bar{\sigma}$

$\bar{\sigma}$ tu = 1,5 × 390

$\bar{\sigma}$ tu = 585 Mpa (Tegangan tumpu ijin)

b. Actual loads

Q_0 = 81,36 kN (Gaya geser aktual)

N_0 = 0 kN (Gaya aksial aktual)

M_0 = 83,56 kNm (Momen aktual)

c. Dicoba diameter baut M 25

nx = 2 (jumlah baut diatas)

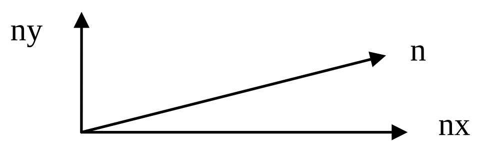
ny = 8

n = 16 (jumlah baut total)

e = 450 mm (eksentrisitas)

α = 5^o

$\alpha = \frac{5\times\pi}{180} = 0,09$ rad

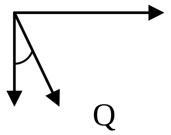


$Ny = N \times \sin \alpha$

$Ny = 0$ kN

$Nx = N \times \cos \alpha$

$Nx = 0$ kN



$Qx = Q \times \sin \alpha$

$Qx = 7{,}09$ kN

$Qy = Q \times \cos \alpha$

$Qy = 81{,}05$ kN

d. Gaya tahanan yang disebabkan oleh eksentrisitas :

$Q_1 = Ny + Qy$

$= 0 + 81{,}05$

$= 81{,}05$ kN

$N_1 = Nx + Qx$

$= 0 + 7{,}09$

$= 7{,}09$ kN

$M_1 = M_0 + (Qx \times e) + (Nx \times e)$

$= 83{,}56 + (7{,}09 \times 450) + (0 \times 450)$

$= 86{,}75$ kNm

e. Cek gaya geser :

$$A_g = \frac{1}{4} \times \pi \times D^2$$

$$A_g = \frac{1}{4} \times \pi \times 25^2$$

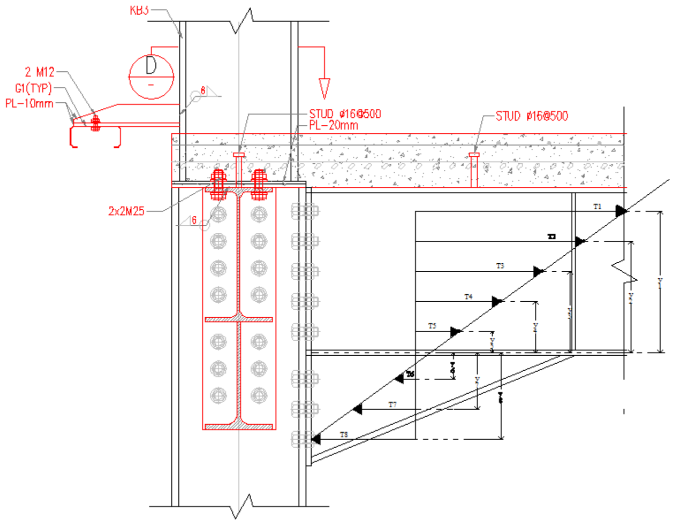
$A_g = 490{,}86\ mm^2$ (cross section area of bolt)

$$\tau = \frac{Q_1}{(n \times Ag)}$$

$$\tau = \frac{81{,}05 \times 1000}{(16 \times 490{,}86)}$$

τ = 10,32 Mpa < $\bar{\tau}$ = 234 Mpa OK

f. Cek gaya tarik



Gambar 4.17. Skema sambungan baut

y_1	= 385 mm	y_9	= 385 mm
y_2	= 305 mm	y_{10}	= 305 mm
y_3	= 225 mm	y_{11}	= 225 mm
y_4	= 145 mm	y_{12}	= 145 mm
y_5	= 65 mm	y_{13}	= 65 mm
y_6	= -60 mm	y_{14}	= -60 mm
y_7	= -140 mm	y_{15}	= -140 mm
y_8	= -220 mm	y_{16}	= -220 mm

$\sum y^2$ = 777450 mm^2

g. Tension for one bolt by axial (T_{an})

$$T_{an} = \frac{N_1}{n}$$

$$T_{an} = \frac{7{,}09}{16}$$

T_{an} = 0,44 kN

h. Tension for one bolt by moment (T_{am})

$$T_{am} = \frac{M_1 \times Yi}{\sum y^2}$$

T_{am1}	= 42,96 kN	T_{am9}	= 42,96 kN
T_{am2}	= 34,03 kN	T_{am10}	= 34,03 kN
T_{am3}	= 25,11 kN	T_{am11}	= 25,11 kN
T_{am4}	= 16,18 kN	T_{am12}	= 16,18 kN
T_{am5}	= 7,25 kN	T_{am13}	= 7,25 kN
T_{am6}	= -6,70 kN	T_{am14}	= -6,70 kN
T_{am7}	= -15,62 kN	T_{am15}	= -15,62 kN
T_{am8}	= -24,55 kN	T_{am16}	= -24,55 kN

Ta = Tan + Tam

T_{a1}	= 43,40 kN	T_{a9}	= 43,40 kN
T_{a2}	= 34,48 kN	T_{a10}	= 34,48 kN
T_{a3}	= 25,55 kN	T_{a11}	= 25,55 kN
T_{a4}	= 16,62 kN	T_{a12}	= 16,62 kN
T_{a5}	= 7,70 kN	T_{a13}	= 7,70 kN
T_{a6}	= -6,25 kN	T_{a14}	= -6,25 kN
T_{a7}	= -15,18 kN	T_{a15}	= -15,18 kN
T_{a8}	= -24,11 kN	T_{a16}	= -24,11 kN

i. Cross section area of bolt

$$A_{ta} = \frac{1}{4}\pi\,(0{,}85 \times D)^2$$

$$A_{ta} = \frac{1}{4}\pi\,(0{,}85 \times 25)^2$$

$$A_{ta} = 354{,}65 \text{ mm}^2$$

$$\sigma ta = \frac{T_{a1}}{Ata}$$

$$\sigma ta = \frac{43{,}40 \times 1000}{354{,}65}$$

$\sigma ta = 122{,}38$ Mpa < $\bar{\sigma} ta = 273$ Mpa OK

j. Kombinasi gaya geser dan gaya tarik

$\sigma i = \sqrt{\sigma ta^2 + 3\ \tau^2}$

$\sigma i = \sqrt{122{,}38^2 + 3 \times 10{,}32^2}$

$\sigma i = 123{,}68$ Mpa < $\bar{\sigma} = 390$ Mpa OK

k. Bearing plate thickness (t)

Cek tebal plat yang mengalami tarik

Dari pemodelan menggunakan program SAP :

Mtension = 2250,30 kgmm

$\frac{M}{Z} \leq \sigma ta$

$\frac{M}{\frac{bt^2}{6}} \leq \sigma ta$

$\frac{6M}{t^2} \leq \sigma ta$

$t^2 \geq \frac{6M}{\sigma ta}$

$\bar{\sigma}\ ta = 0{,}7 \times 390 \times 10$

$\bar{\sigma}\ ta = 2730\ kg/cm^2$

$\bar{\sigma}\ ta = 27{,}3\ kg/mm^2$

$t \geq \sqrt{\frac{6 \times M}{\sigma ta}}$

$t \geq 22{,}239$ mm take plat t = 20 mm

l. Check for bearing plate

t = 20 mm (plat thickness)

$A_{tu} = t \times D$

$= 20 \times 25$

$= 500\ mm^2$

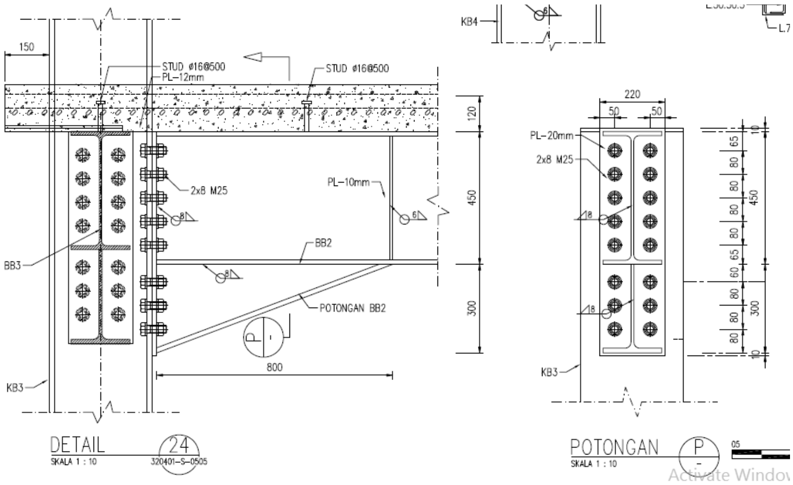
$\sigma tu = \frac{Q}{n \times A_{tu}}$

$\sigma tu = \frac{81{,}36 \times 1000}{16 \times 25 \times 20}$

σtu = 10,17 Mpa < $\bar{\sigma}tu$ OK

Use bolt 16 M 25

5. BB2 dengan KB3



Gambar 4.18. Detail sambungan balok dengan kolom

(Sumber : PT Bita Enarco Engineering)

BB2 WF 450×200×9×14

KB3 WF 350×350×13×21

a. Baut A 325

$\sigma|$ = 585 Mpa (Tegangan leleh)

$$\bar{\sigma} = \frac{\sigma l}{1,5}$$

$$\bar{\sigma} = \frac{585}{1,5}$$

$\bar{\sigma}$ = 390 Mpa (Tegangan dasar)

$\bar{\tau}$ = 0,6 × $\bar{\sigma}$

$\bar{\tau}$ = 0,6 × 390

$\bar{\tau}$ = 234 Mpa (Tegangan geser ijin)

$\bar{\sigma}$ ta = 0,7 × $\bar{\sigma}$

$\bar{\sigma}$ ta = 0,7 × 390

$\bar{\sigma}$ ta = 273 Mpa (Tegangan tarik ijin)

$\bar{\sigma}$ tu = 1,5 × $\bar{\sigma}$

$\bar{\sigma}$ tu = 1,5 × 390

$\bar{\sigma}$ tu = 585 Mpa (Tegangan tumpu ijin)

b. Actual loads

Q_0 = 84,09 kN (Gaya geser aktual)

N_0 = 0 kN (Gaya aksial aktual)

M_0 = 85,71 kNm (Momen aktual)

c. Dicoba diameter baut M 25

nx = 2 (jumlah baut diatas)

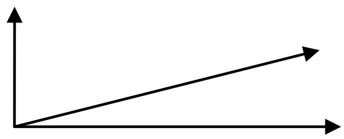
ny = 8

n = 16 (jumlah baut total)

e = 450 mm (eksentrisitas)

$\alpha = 5^o$

$\alpha = \frac{5 \times \pi}{180} = 0,09$ rad

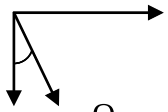


Ny = N × Sin α

Ny = 0 kN

Nx = N × Cos α

Nx = 0 kN



Qx = Q × Sin α

Qx = 7,33 kN

Qy = Q × Cos α

Qy = 83,77 kN

d. Gaya tahanan yang disebabkan oleh eksentrisitas

$Q_1 = Ny + Qy$

$= 0 + 83{,}77$

$= 83{,}77$ kN

$N_1 = Nx + Qx$

$= 0 + 7{,}33$

$= 7{,}33$ kN

$M_1 = M_0 + (Qx \times e) + (Nx \times e)$

$= 85{,}71 + (7{,}33 \times 450) + (0 \times 450)$

$= 89{,}01$ kN

e. Cek gaya geser

$$A_g = \frac{1}{4} \times \pi \times D^2$$

$$A_g = \frac{1}{4} \times \pi \times 25^2$$

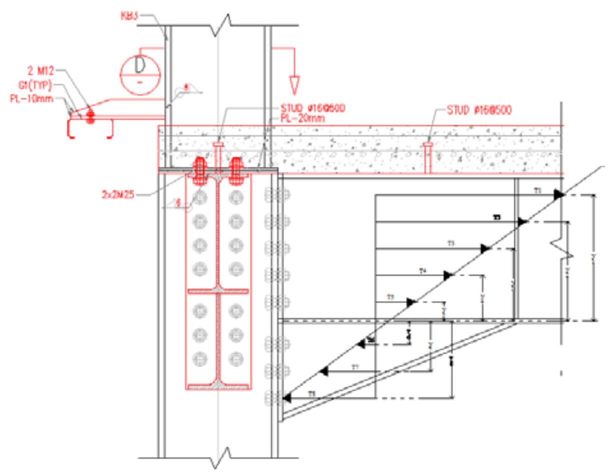
$A_g = 490{,}86\ mm^2$ (cross section area of bolt)

$$\tau = \frac{Q_1}{(n \times Ag)}$$

$$\tau = \frac{83{,}77 \quad \times 1000}{(16 \times 490{,}86)}$$

$\tau = 10{,}67$ Mpa $< \bar{\tau} = 234$ Mpa OK

f. Cek gaya tarik



Gambar 4.19. Skema sambungan baut

y_1	= 385 mm	y_9	= 385 mm
y_2	= 305 mm	y_{10}	= 305 mm
y_3	= 225 mm	y_{11}	= 225 mm
y_4	= 145 mm	y_{12}	= 145 mm
y_5	= 65 mm	y_{13}	= 65 mm
y_6	= -60 mm	y_{14}	= -60 mm
y_7	= -140 mm	y_{15}	= -140 mm
y_8	= -220 mm	y_{16}	= -220 mm

$\sum y^2 = 777450\ mm^2$

g. Tension for one bolt by axial (T_{an})

$$T_{an} = \frac{N_1}{n}$$

$$T_{an} = \frac{7{,}33}{16}$$

T_{an} = 0,46 kN

h. Tension for one bolt by moment (T_{am})

$$T_{am} = \frac{M_1 \times Yi}{\sum y^2}$$

T_{am1}	= 44,08 kN	T_{am9}	= 44,08 kN
T_{am2}	= 34,92 kN	T_{am10}	= 34,92 kN
T_{am3}	= 25,76 kN	T_{am11}	= 25,76 kN
T_{am4}	= 16,60 kN	T_{am12}	= 16,60 kN
T_{am5}	= 7,44 kN	T_{am13}	= 7,44 kN
T_{am6}	= -6,87 kN	T_{am14}	= -6,87 kN
T_{am7}	= -16,03 kN	T_{am15}	= -16,03 kN
T_{am8}	= -25,19 kN	T_{am16}	= -25,19 kN

Ta = Tan + Tam

T_{a1}	= 44,54 kN	T_{a9}	= 44,54 kN
T_{a2}	= 35,38 kN	T_{a10}	= 35,38 kN
T_{a3}	= 26,22 kN	T_{a11}	= 26,22 kN
T_{a4}	= 17,06 kN	T_{a12}	= 17,06 kN
T_{a5}	= 7,90 kN	T_{a13}	= 7,90 kN

T_{a6} = -6,41 kN T_{a14} = -6,41 kN

T_{a7} = -15,57 kN T_{a15} = -15,57 kN

T_{a8} = -24,73 kN T_{a16} = -24,73 kN

i. Cross section area of bolt

$$A_{ta} = \frac{1}{4}\pi\,(0{,}85 \times D)^2$$

$$A_{ta} = \frac{1}{4}\pi\,(0{,}85 \times 25)^2$$

A_{ta} = 354,65 mm^2

$$\sigma ta = \frac{T_{a1}}{Ata}$$

$$\sigma ta = \frac{44{,}54 \times 1000}{354{,}65}$$

$\sigma ta = 125{,}58$ Mpa < $\bar{\sigma} ta = 273$ Mpa OK

j. Kombinasi gaya geser dan gaya tarik

$$\sigma i = \sqrt{\sigma ta^2 + 3\,\tau^2}$$

$$\sigma i = \sqrt{125{,}58^2 + 3 \times 10{,}67^2}$$

$\sigma i = 126{,}93$ Mpa < $\bar{\sigma} = 390$ Mpa OK

k. Bearing plate thickness (t)

Cek tebal plat yang mengalami tarik

Dari pemodelan menggunakan program SAP :

Mtension = 2250,30 kgmm

$$\frac{M}{Z} \leq \sigma ta$$

$$\frac{M}{\frac{bt^2}{6}} \leq \sigma ta$$

$$\frac{6M}{t^2} \leq \sigma ta$$

$$t^2 \geq \frac{6M}{\sigma ta}$$

$\bar{\sigma}$ ta = 0,7 × 390 × 10

$\bar{\sigma}$ ta = 2730 kg/cm^2

$\bar{\sigma}$ ta = 27,3 kg/mm^2

$$t \geq \sqrt{\frac{6 \times M}{\sigma ta}}$$

t ≥ 22,239 mm take plat t = 20 mm

l. Check for bearing plate

t = 20 mm (plat thickness)

A_{tu} = t × D

= 20 × 25

= 500 mm^2

$$\sigma tu = \frac{Q}{n \times A_{tu}}$$

$$\sigma tu = \frac{84{,}09 \times 1000}{16 \times 25 \times 20}$$

σtu = 10,51 Mpa < $\bar{\sigma}$tu OK

Use bolt 16 M 25