BAB V

PERHITUNGAN STRUKTUR BAJA ASD BERDASARKAN PPPJJR DAN BMS

5.1 DATA TEKNIS PERENCANAAN

Fungsi jembatan = jembatan jalan raya

Lalu lintas jembatan = lalu lintas bawah

Kelas jembatan = kelas B

Beban jembatan = BM 70

Bentang jembatan = 2 * 50 = 100 m

Lebar perkerasan jembatan = 6 m

Lebar trotoar jembatan = 0,5 m

Lebar total jembatan = ± 7 m

Struktur atas jembatan

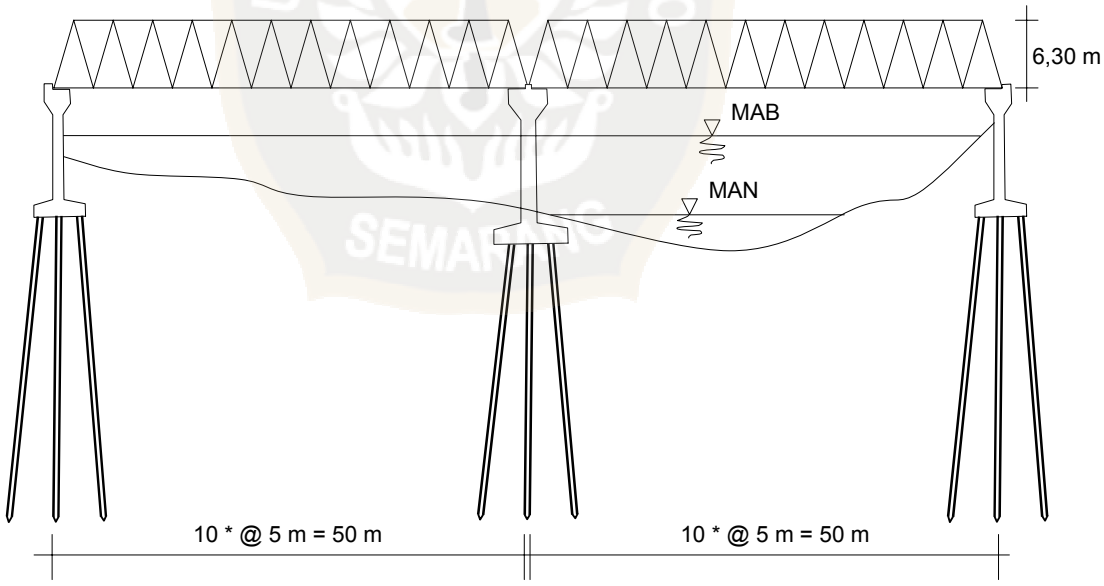
1. Struktur utama = rangka baja tipe *"Wagner Biro Indonesia"*
2. Mutu baja = BJ 50 (SNI 03-1729 2002)
   - σ_y = 2900 kg/cm^2
   - $\overline{\sigma}$ = 1900 kg/cm^2
   - σ_u = 5000 kg/cm^2
   - E = 2*10^6 kg/cm^2
3. Lantai trotoar = beton bertulang
   - fc = 30 Mpa
   - fy = 400 Mpa
4. Lantai kendaraan = beton bertulang komposit dengan dek baja
   - fc = 30 Mpa
   - fy = 400 Mpa
5. Ikatan angin = tertutup tipe *"Wagner Biro Indonesia"*

Struktur bawah jembatan

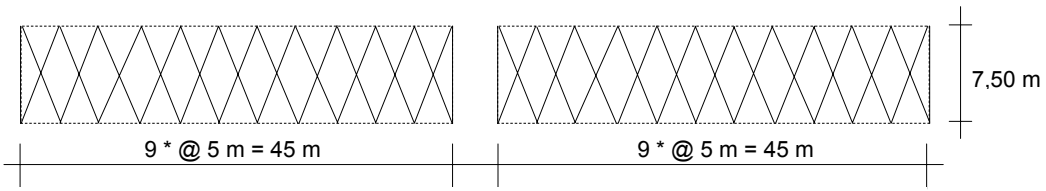
1. Pilar, *abutment*

dan pondasi	= beton bertulang
fc	= 35 Mpa
fy	= 400 Mpa
Tebal trotoar	= variasi 30-32 cm
Tebal lantai kendaraan	= variasi 20-27 cm
Tebal perkerasan	= 5 cm
Tebal air hujan	= 5 cm
γ_b	= 2500 kg/cm^3
γ_{asp}	= 2200 kg/cm^3
γ_w	= 1000 kg/cm^3
Perencanaan ASD	= Struktur atas jembatan (beton dan baja)

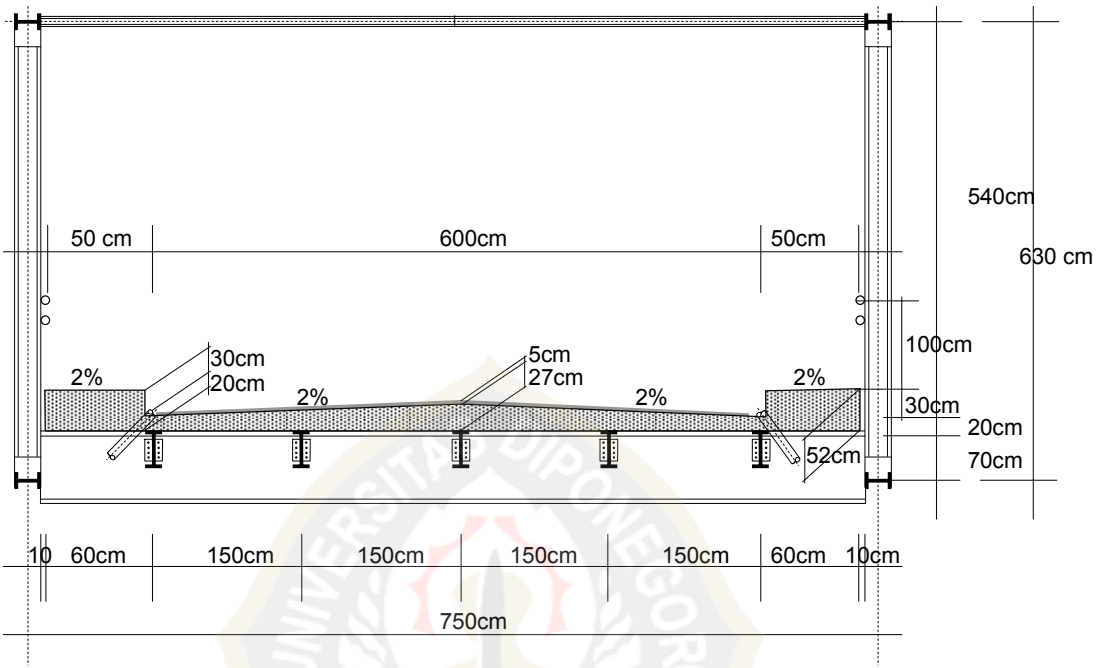
5.2 GAMBAR RENCANA STRUKTUR



Gambar 5.1 Potongan Memanjang Jembatan



Gambar 5.2 Ikatan Angin Atas



Gambar 5.3 Potongan Melintang Jembatan

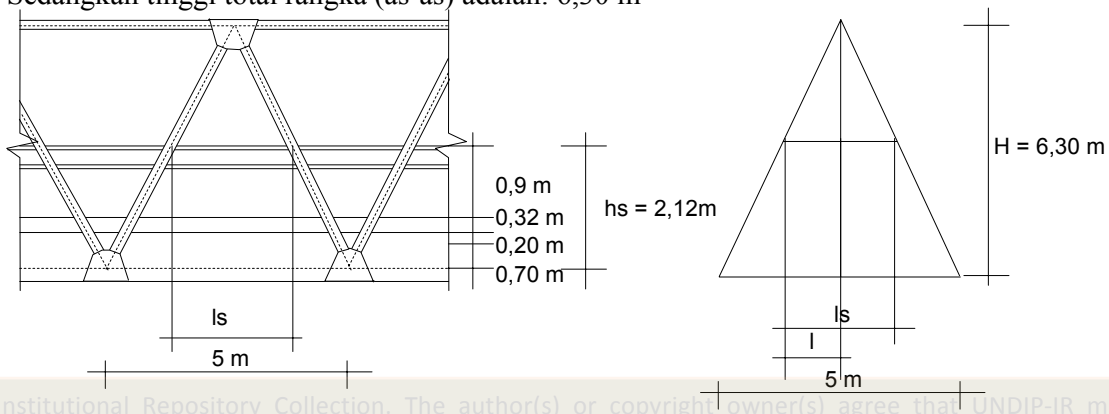
5.3 PERHITUNGAN STRUKTUR METODE ASD BERDASAR PPPJJR

5.3.1 Sandaran

Menurut PPPJJR 1987 bahwa tiang sandaran berfungsi menahan beban horisontal sebesar 100 kg/m yang bekerja pada tinggi 90 cm di atas lantai trotoar. Maka tinggi sandaran dari as rangka induk terbawah adalah:

hs = 0,70m +0,20m +0,32m +0,9m = 2,12 m

Sedangkan tinggi total rangka (as-as) adalah: 6,30 m



Gambar 5.4 Sandaran Pada Jembatan

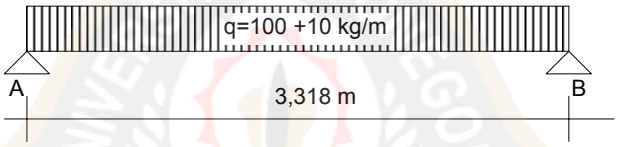
Sandaran diasumsikan menumpu sendi pada rangka induk dengan panjang sandaran yang menumpu pada rangka induk sebesar (pada tengah bentang) seperti yang ditunjukkan pada gambar 3.4 di atas adalah:

Dengan perbandingan segitiga

$$\frac{l}{2{,}5m} = \frac{6{,}30m - 2{,}12m}{6{,}30m} = 1{,}659\,\text{m} \qquad \text{ls} = 2*1{,}659\text{m} = 3{,}318\ \text{m}$$

Berat sendiri pipa (taksir): 10 kg/m

Gaya yang terjadi akibat beban 100 kg/m:



Gambar 5.5 Skema Pembebanan Sandaran

$$R_A = R_B = \frac{q*l_s}{2} = \frac{110kg/m*3{,}318m}{2} = 182{,}49\ \text{kg}$$

$$M_{max} = \frac{1}{8}*q*l_s^{\,2} = \frac{1}{8}*110kg/m*3{,}318^2\,m = 151{,}375\,\text{kgm}$$

Sandaran direncanakan menggunakan pipa Ø 89,1 mm

5.3.1.1 Data Teknis Perencanaan

Mutu baja = BJ37

σ ijin = 1600 kg/cm^2

E baja = 2,0x10^6 kg/cm^2

5.3.1.2 Data Teknis Profil

D = 8,91 cm

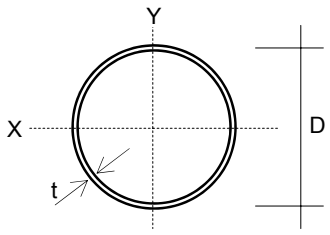
t = 0,4 cm

A = 10,69 cm^2

G = 8,39 kg/m

I = 97 cm^4

i = 3,01 cm^6



Gambar 5.6 Penampang Pipa Sandaran

W = 21,8 cm^3

5.3.1.3 Kontrol Terhadap Bahan dan Tegangan

a. Terhadap lendutan/ kekakuan

$$\Delta = \frac{5 * q * l^4}{384 * E * I} < \Delta = \frac{5 * q * l^4}{384 * E * I}$$

$$\Delta = \frac{5 * 1{,}1 kg/cm * 331{,}8^4 cm}{384 * 2{,}0 * 10^6 kg/cm^2 * 97 cm^4} = 0{,}895 \text{ cm} < \frac{331{,}8 cm}{360} = 0{,}922 \text{ cm}.....\text{ok}$$

b. Terhadap momen

$$\sigma = \frac{M_{max}}{W} < \bar{\sigma}$$

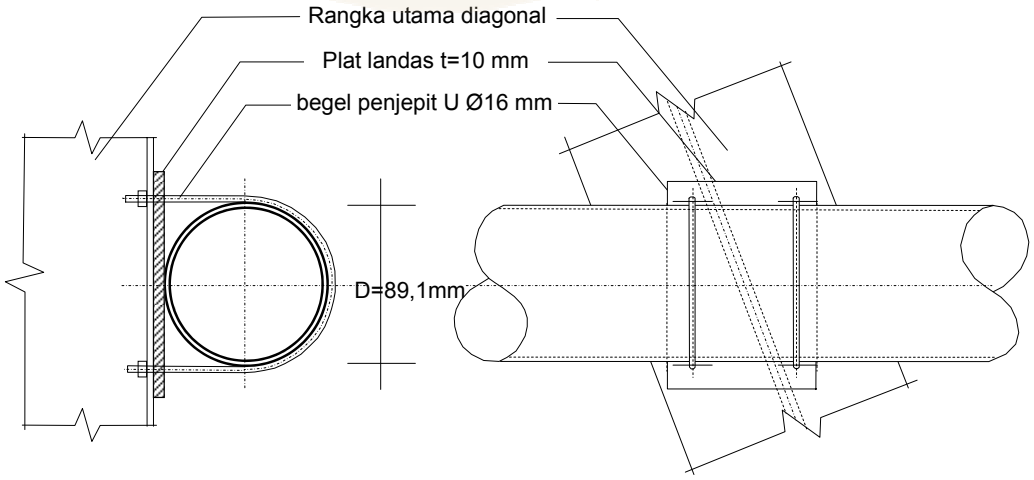
$$\sigma = \frac{15137{,}5 kg/cm}{21{,}8 cm^3} = 694{,}4 \text{ kg/cm}^2 < 1600 \text{ kg/cm}^2 .....\text{ok}$$

c. Terhadap geser

$$\tau = \frac{D}{A} < \bar{\tau} = 0{,}58 * \bar{\sigma}$$

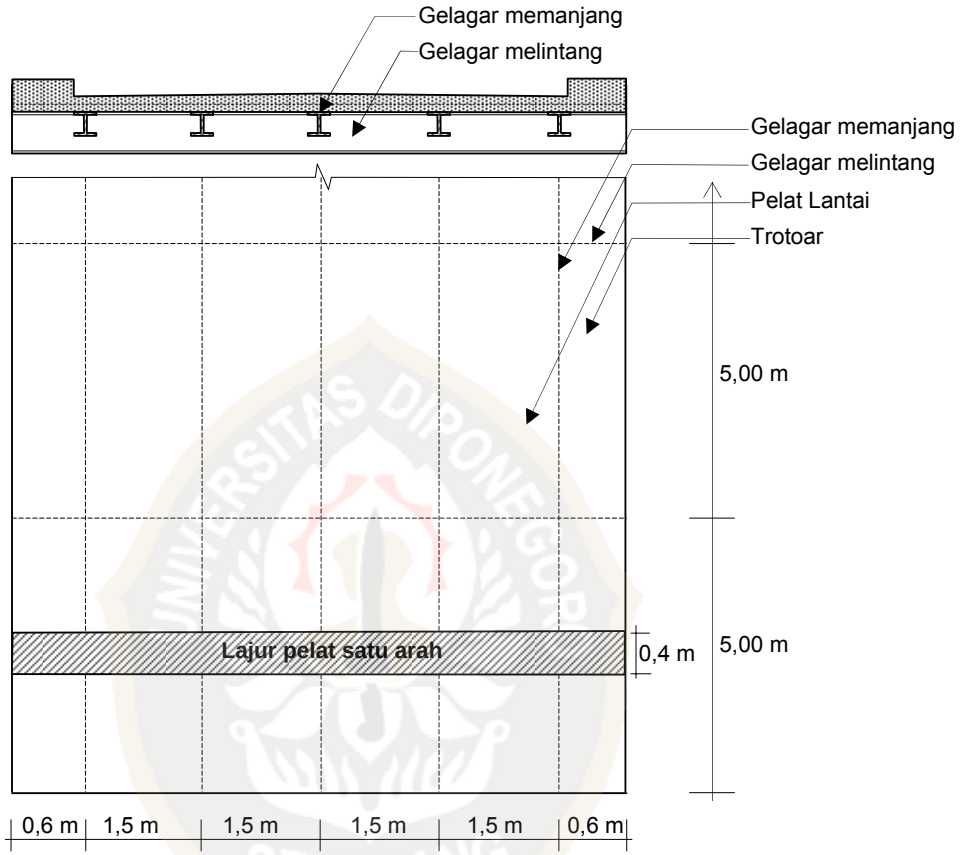
$$\tau = \frac{182{,}49 kg}{10{,}69 cm^2} = 17{,}07 \text{ kg/cm}^2 < 0{,}58 * 1600 = 928 \text{ kg/cm}^2 .....\text{ok}$$

Jadi pipa Ø 89,1 mm dapat dipakai untuk sandaran.



Gambar 5.7 Pemasangan Pipa Sandaran

5.3.2 Lantai Kendaraan Dan Trotoar



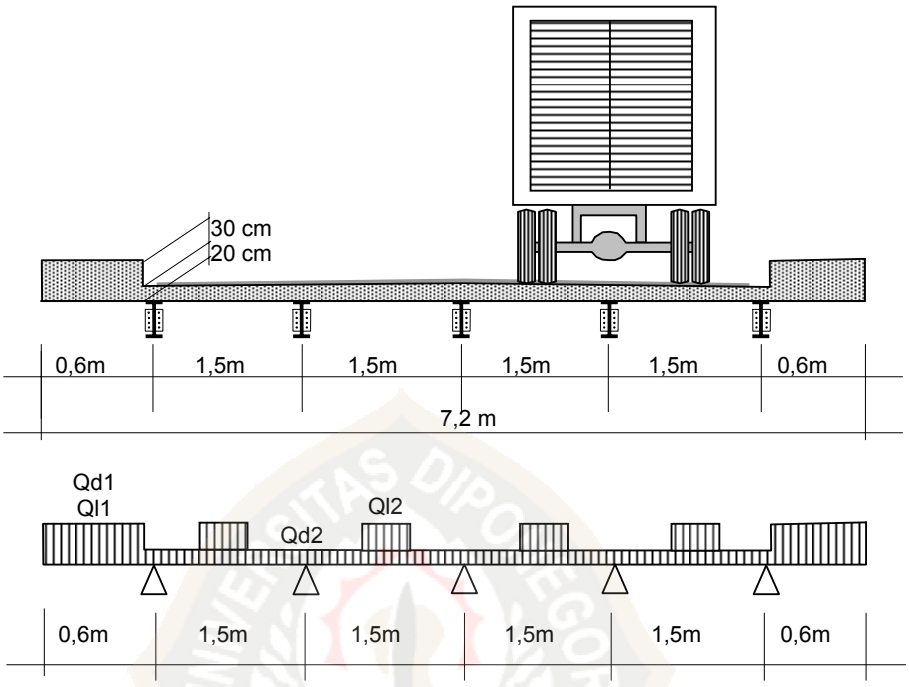
Gambar 5.8 Denah Pelat Lantai dan Gelagar

Karena menggunakan *metal deck* maka beban diarahkan kesatu arah sehingga termasuk dalam sistem pelat satu arah,sehingga bisa diasumsikan sebafai konstruksi yang terletak menerus diatas beberapa tumpuan.

5.3.2.1 Pembebanan

Dengan menempatkan menempatkan roda ditengah-tengah pelat diharapkan mendpatkan momen yang maksimal,daripada menempatkan 2 roda pada pelat dengan jarak minimal 1 m.

Untuk tinjauan pertimbangan penampang pelat lantai diambil selebar per segmen *metal deck* yaitu selebar 400 mm dan sudah dianggap mewakili.



Gambar 5.9 Pembebanan Lantai Jembatan

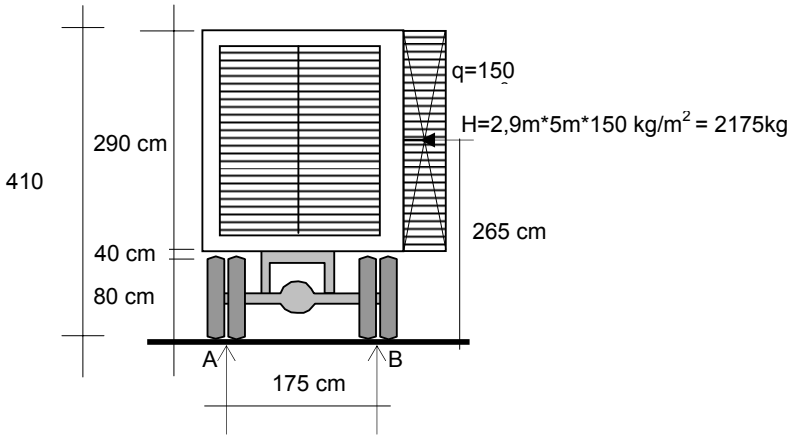
a. Beban mati

- beban sendiri = 0,2m*0,4m*25kN/m^3 = 2,0 kN/m
- tebal perkerasan =0,05m*0,4m*22kN/m =0,44kN/m
- beban air hujan = 0,05m*0,4m*9,8kN/m^3 = 0,196kN/m

Qd2=2,636kN/m

=2636 N/m

b. Beban hidup lantai



Gambar 5.10 Beban Angin pada Kendaraan Truk Semi Trailer

- Σ Ma=0

  (H*265)+(2*Rb*1,75) =0

  Rb= $\frac{2175*2,65KN}{2m*1,75m} = 16,47kN$

  (Rb=karena untuk beban hidup diambil sebesar 100% luas bidang sisi yang langsung terkena angin)

  - beban roda = 100 kN+16,47kN =116,47kN

    $= \frac{116,47KN}{0,2m*0,5m} = 1164,7kN/m^2$

    Beban Ql2 =1164,7kN/m²*0,2m*1,3=302 822,2N/m

c. Beban mati trotoar

- berat sendiri = 0,5m*0,4m*25kN/m^3 = 5,0 kN/m

  Qd1= 5000 N/m

d. Beban hidup trotoar

-beban hidup =500 kg/m^{2*} $\frac{5m2}{5m} = 5kN/m$

Ql1=5000N/m

- Dari perhitungan menggunakan SAP didapat

  M max = 27009959 Nmm

5.3.2.2 Perhitungan tulangan

a. Lantai dan trotoar

fc = 30 Mpa Ø = 12 mm

fy = 400 Mpa p = 40 mm (struktur tak terlindung Ø < 16mm)

d = H-Ø-1/2 Ø = 40cm-1,2cm-0,6cm = 38,2 cm

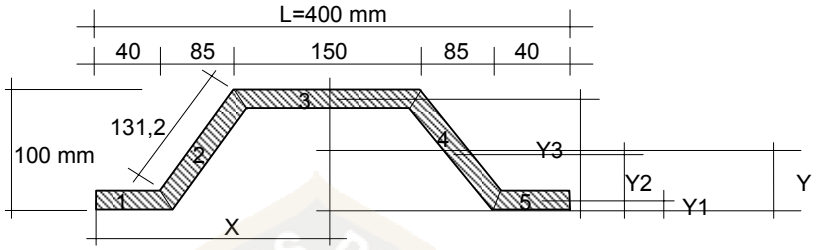
$\frac{M_u}{b*d^2} = \frac{27,009959KNm}{0,5m*0,382^2m} = 370,192$ KN/m^2.....dari Buku Grafik dan Tabel Beton Bertulang Ir.Gideon dkk tabel 5.1.h didapat ρ = 0,00158

ρ min = 0,0018 (tabel 7 Buku Dasar-Dasar Perencanaan Peton Bertulang Ir.Gideon dkk), karena ρ< ρ min maka dipakai ρ min = 0,0018

As = ρ *b*d = 0,0018*500mm*382mm = 343.8 mm^2

Data *Metal Deck* = bentukan dingin dari baja *grade* memiliki tinggi 100 mm dan tebal 4,5 mm,serta lebar gelombang pada potongan melintang adalah 400 mm.

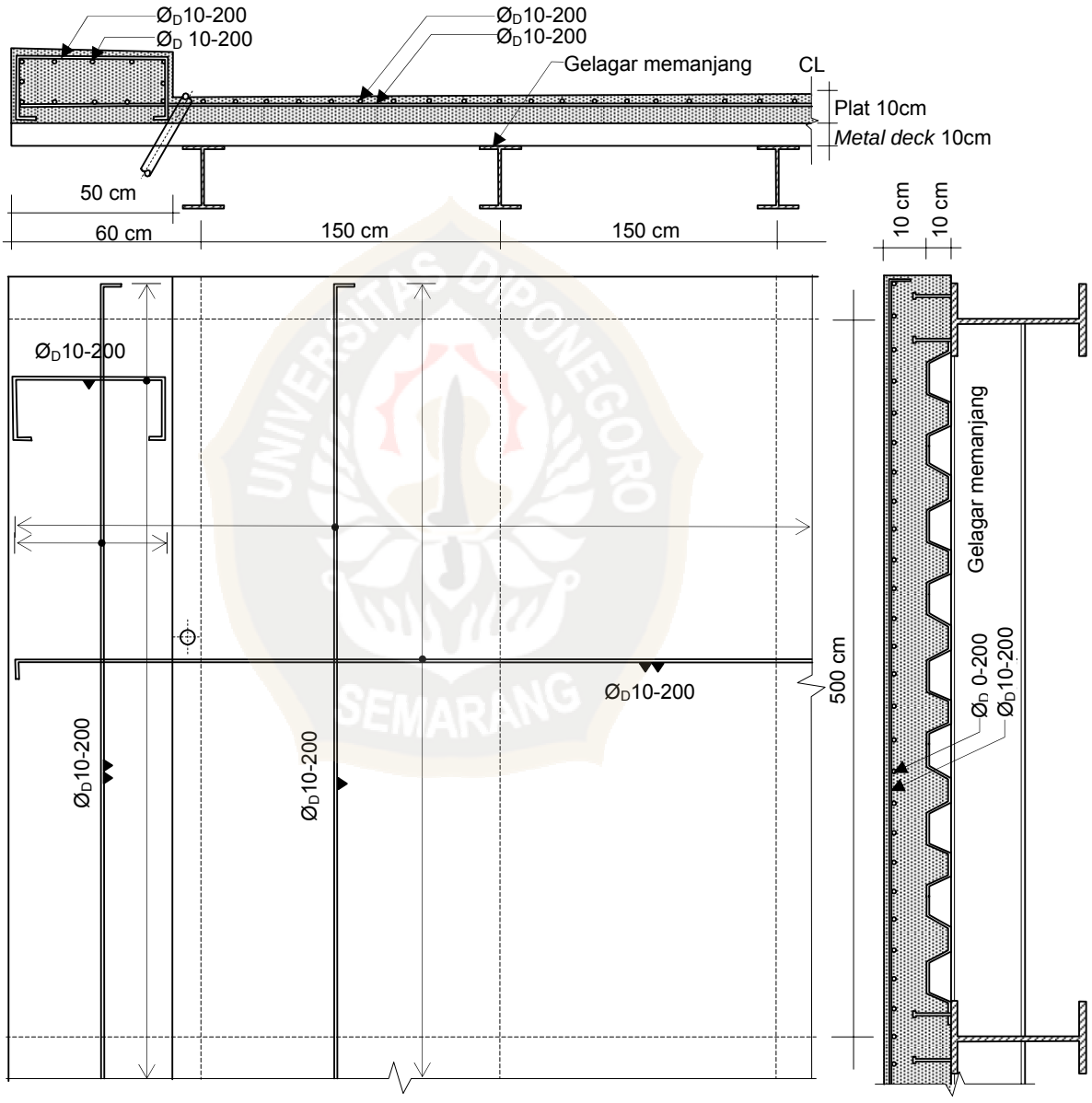
*Ametal deck =(4,5*40)+(4,5*131,2)+(4,5*150)+(4,5*131,2)+(4,5*40)
=2215,8 mm²



Gambar 5.11 Penampang *Metal deck* Per Segmen

Karena As tulangan rencana =343,8 mm² < A *metal deck* =2215,8 mm² maka dianggap penggunaan *metal deck* aman terhadap momen yang terjadi.

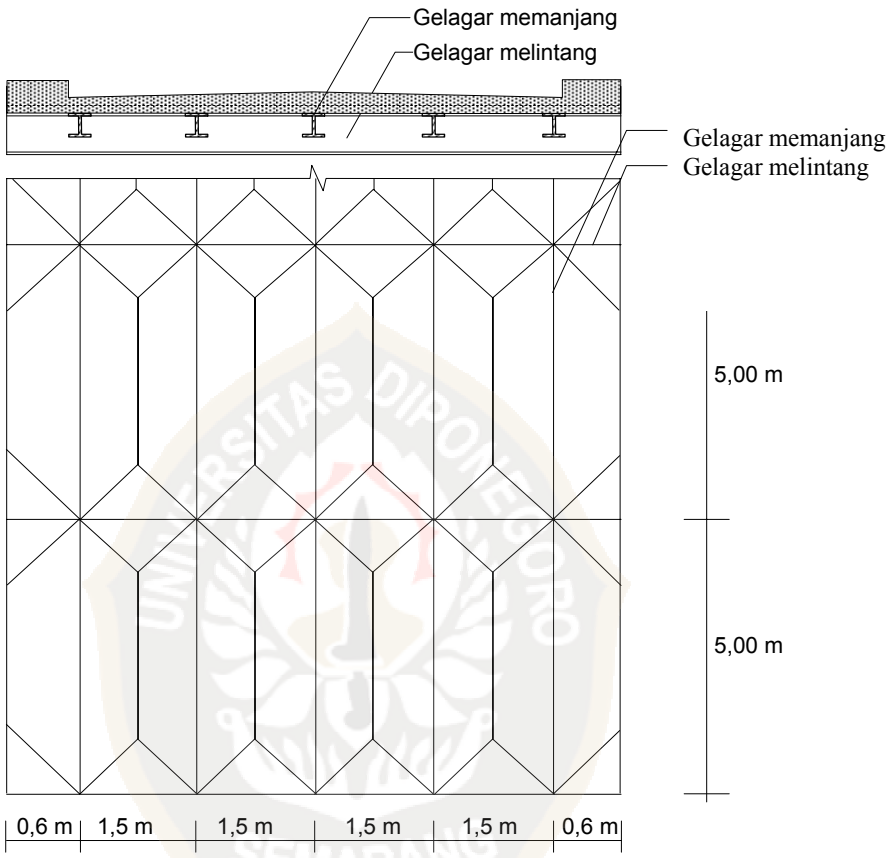
Tulangan pada serat atas plat lantai dan trotoar digunakan tulangan susut dipakai tulangan Ø10-200.



Gambar 5.12 Penulangan Plat Lantai Kendaraan

5.3.3 Gelagar Memanjang (*Non Komposit*)

5.3.3.1 Pembebanan



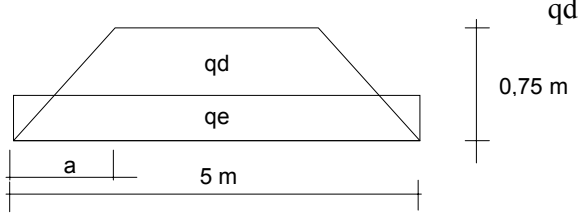
Gambar 5.13 Pembagian Beban Untuk Gelagar

a. Perataan beban

➢ Gelagar memanjang tengah:

- Beban lantai = 0,2m*0,75m*25kN/m^3 = 3,75 kN/m
- Beban perkerasan = 0,05m*0,75m*22kN/m^3= 0,825 kN/m
- Beban air hujan = 0,05m*0,75m*1kN/m^3 =0,3675 kN/m
- beban metal dek (15 kg/m^2) = 0,15kN/m^2*0,75m = 0,125 t/m +

qd = 5,0625 t/m



Gambar 5.14 Perataan Beban Gelagar Memanjang Tengah

$\frac{1}{8}$*qe*l^2 $= \frac{qd*(3*l^2-4*a^2)}{24}$

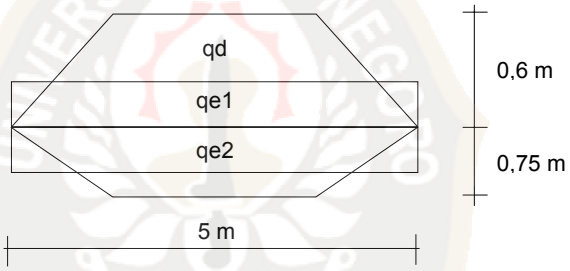
$\frac{1}{8}$*qe*5^2 $= \frac{qd*(3*5^2-4*0{,}75^2)}{24}$

qe $= 2*0{,}9616*qd = 1{,}0256$ t/m

➢ Gelagar memanjang tepi:

- Beban lantai $= 0{,}2m*0{,}6m*25kN/m^3 = 3$ kN/m
- Beban trotoar $= 0{,}31m*0{,}5m*25kN/m^3 = 3{,}875$ kN/m
- beban metal dek (15 kg/m^2) $= 0{,}15kN/m^2*0{,}6m = 0{,}09$ kN/m +

qd = 6,965 kN/m



Gambar 5.15 Perataan Beban Gelagar Memanjang Tepi

Dengan perhitungan seperti di atas didapat: qe1 = 6,831272 kN/m

qe2 = 4,910625 kN/m +

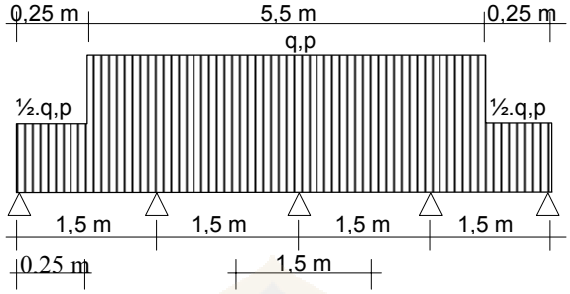
qt = 11,742 kN/m

5.3.3.2 Perhitungan Momen dan Reaksi

1. Beban perataan (terbesar) qe = 1174,2 kg/m
2. Beban sendiri profil (taksir) G = 70 kg/m
3. Beban D

- Beban merata

Sesuai buku PPPJJR 1987 untuk L = 60 m, maka:



Gambar 3.16 Pengaruh Beban D pada Gelagar Memanjang

➢ Gelagar memanjang tengah:

$$q = 2{,}2 - \frac{1{,}1}{60} * (L-30) = 2{,}2 - \frac{1{,}1}{60} * (50m-30) = 1{,}833 \text{ t/m} = 18{,}33 \text{ kN/m}$$

$$q = \frac{q}{2{,}75} * s = \frac{18{,}33 kN/m}{2{,}75m} * 1{,}5m = 9{,}998 kN/m$$

➢ Gelagar memanjang tepi:

$$q = \frac{q}{2{,}75} * s = \frac{9{,}165 kN/m}{2{,}75m} * 0{,}75m = 2{,}499 kN/m$$

- Koefisien kejut

Menurut PPPJJR 1987 $K = 1 + \frac{20}{50 + L} = 1 + \frac{20}{50 + 50m} = 1{,}2$

- Beban garis

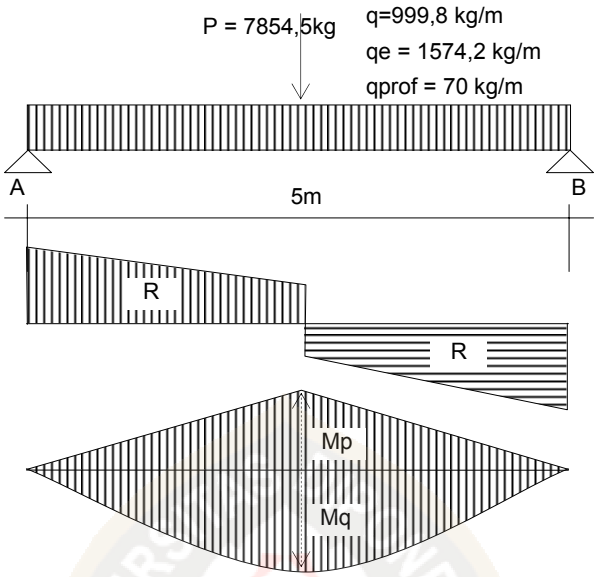
Menurut PPPJJR 1987

➢ Gelagar memanjang tengah:

$$P = \frac{P}{2{,}75} * k * s = \frac{12t}{2{,}75m} * 1{,}2 * 1{,}5m = 78{,}545 kN$$

➢ Gelagar memanjang tepi:

$$P = \frac{P}{2{,}75} * k * s = \frac{6t}{2{,}75m} * 1{,}2 * 0{,}75m = 19{,}636 kN$$



Gambar 5.17 Pembebanan, Reaksi dan Momen Gelagar Memanjang

$$RA = \frac{P + (qu * l)}{2} = \frac{7854{,}5kg + (2644kg/m * 5m)}{2} = 10537{,}25\,\text{kg}$$

$$Mmax = \frac{1}{8} * qu * l^2 + \frac{1}{4} * P * l = \frac{1}{8} * 2644kg/m * 5^2 m + \frac{1}{4} * 7854{,}5kg * 5m$$

Mmax = 18080,625 kgm

5.3.3.3 Menentukan profil gelagar memanjang

$$Wx = \frac{M\,\max}{\sigma} = \frac{1808062{,}5kgcm}{1900kg/cm^2} = 951{,}611\,\text{cm}^3$$

Pilih profil IWF 400*200*8*13 dengan data profil sebagai berikut:

Wx = 1190 cm^3.....> 1025,7 cm^3

A = 84,12 cm^2

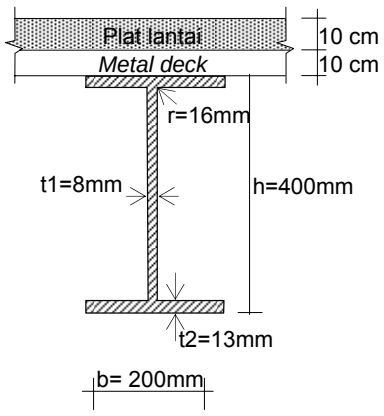
G = 66 kg/m.....< 70 kg/m (taksir)

Ix = 23700 cm^4

h = 400 mm

b = 200 mm

r = 16 mm



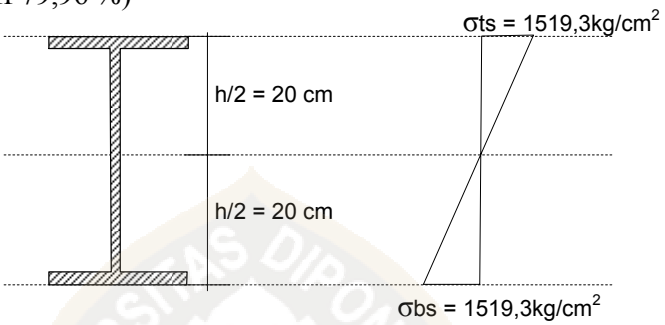
Gambar 5.18 Penampang Profil Gelagar Memanjang

5.3.3.4 Cek Kekuatan

a. Tegangan lentur

$$\sigma bs = \sigma ts = \frac{M\max}{Wx} = \frac{1808062{,}5kgcm}{1190cm^3} = 1519{,}38 \text{ kg/cm}^2 < \sigma = 1900$$

kg/cm²…….ok(eff 79,96 %)



Gambar 5.19 Diagram Tegangan Gelagar Memanjang

b. Tegangan geser

$$\tau = \frac{D}{Aw} = \frac{10537{,}25kg}{0{,}8cm * 40cm} = 329{,}289 \text{ kg/cm}^2 < 0{,}58*1900 = 1102 \text{kg/cm}^2 \text{.....ok}$$

5.3.3.5 Cek Kekakuan

$$\Delta = \frac{5 * qu * l^4}{384 * E * I.prof} + \frac{P * l^3}{48 * E * I.prof} \text{.....} < \bar{\Delta} = \frac{L}{500} = \frac{500}{500} = 1\text{cm}$$

$$\Delta =$$

$$\frac{5 * 27{,}25 * 500^4}{384 * 2 * 10^6 * 23700} + \frac{7854{,}5 * 500^3}{48 * 2 * 10^6 * 23700} = 0{,}4539 + 0{,}43152 = 0{,}8854$$

<1cm.....ok (eff 95%)

5.3.4 Gelagar Melintang (*komposit*)

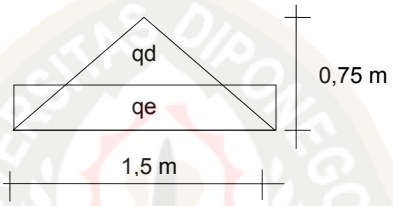
5.3.4.1 Gelagar Melintang Tengah

5.3.4.1.1 Perataan Beban

➢ Gelagar bagian tengah:

- Beban lantai = 0,2m*0,75m*25kN/m^3 = 3,75 kN/m
- Beban perkerasan = 0,05m*0,75m*22kN/m^3= 0,825kN/m
- Beban air hujan = 0,05m*0,75m*10kN/m^3= 0,375 kN/m
- beban metal dek (15 kg/m^2) = 0,15kN/m^2*0,75m =0,1122kN/m

qd = 5,0625kN/m



Gambar 5.20 Perataan Beban Gelagar Melintang Bagian Tengah

$\frac{1}{8}$*qe*l^2 = $\frac{1}{12}$*qd*l^2

$\frac{1}{8}$*qe*1,5^2 = $\frac{1}{12}$*qd*1,5^2

0,28125*qe = 0,1875*qd

qe = $\frac{0,1875}{0,28125} * qd$

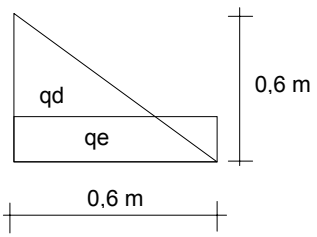
qe = 0.6666*qd

qe = 2*0,6666*qd = 0,674 t/m=6,74325 kN/m

➢ Gelagar bagian tepi:

- Beban lantai = 0,15m*0,6m*25kN/m^3= 2,25 kN/m
- Beban trotoar = 0,31m*0,5m*25kN/m^3 = 3,875 kN/m
- beban metal dek (15 kg/m^2) = 0,15kN/m^2*0,6m = 0,0009 kN/m +

qd = 6,215 kN/m



Gambar 5.21 Perataan Beban Gelagar Melintang Bagian Tepi

$\frac{1}{8}$*qe*l^2 = 0,0641*qd*l^2

$\frac{1}{8}$*qe*$0,6^2$ = 0,0641*qd*$0,6^2$

0,045*qe = 0,023076*qd

qe = $\frac{0,023076}{0,045} * qd$ = 0,5128*qd =2*0,5128*qd =0,6374 t/m

=6,374kN/m

5.3.4.1.2 Pembebanan

- Beban Mati

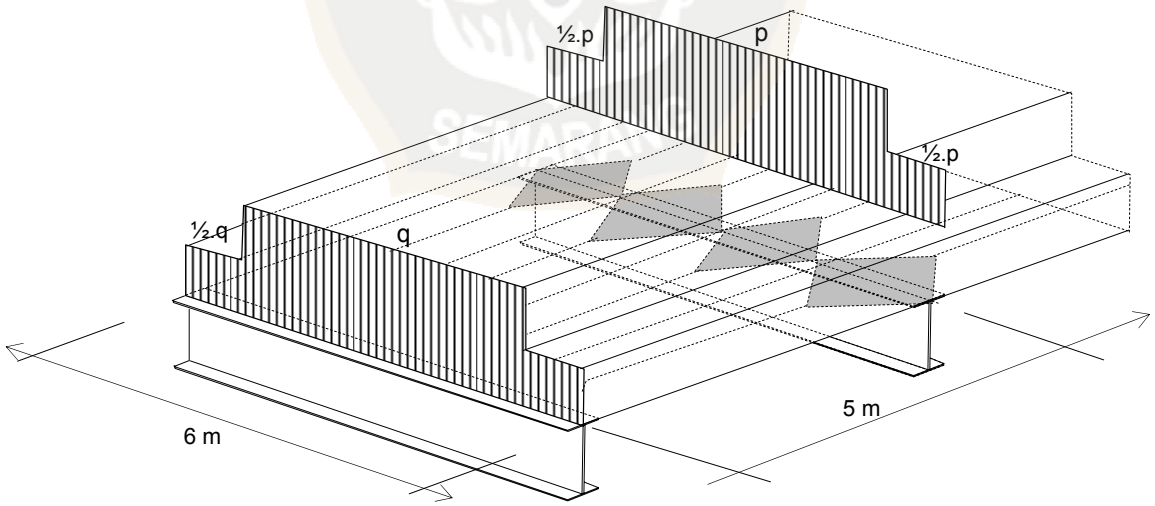
➢ Gelagar bagian tengah:

qe = 6,74 kN/m

➢ Gelagar bagian tepi:

qe = 6,374kN/m

- Beban D



Gambar 5.22 Pengaruh Beban D pada Gelagar Melintang

Sesuai buku PPPJJR 1987 untuk L = 50 m, maka:

q = 2,2-$\frac{1,1}{60}$*(L-30) = 2,2-$\frac{1,1}{60}$*(50m-30) = 18,33 kN/m

q tengah = 2*0,666*18,33kN/m = 24,42 kN/m

q tepi = 2*0,666*9,1665kN/m = 12,209kN/m

- Beban garis

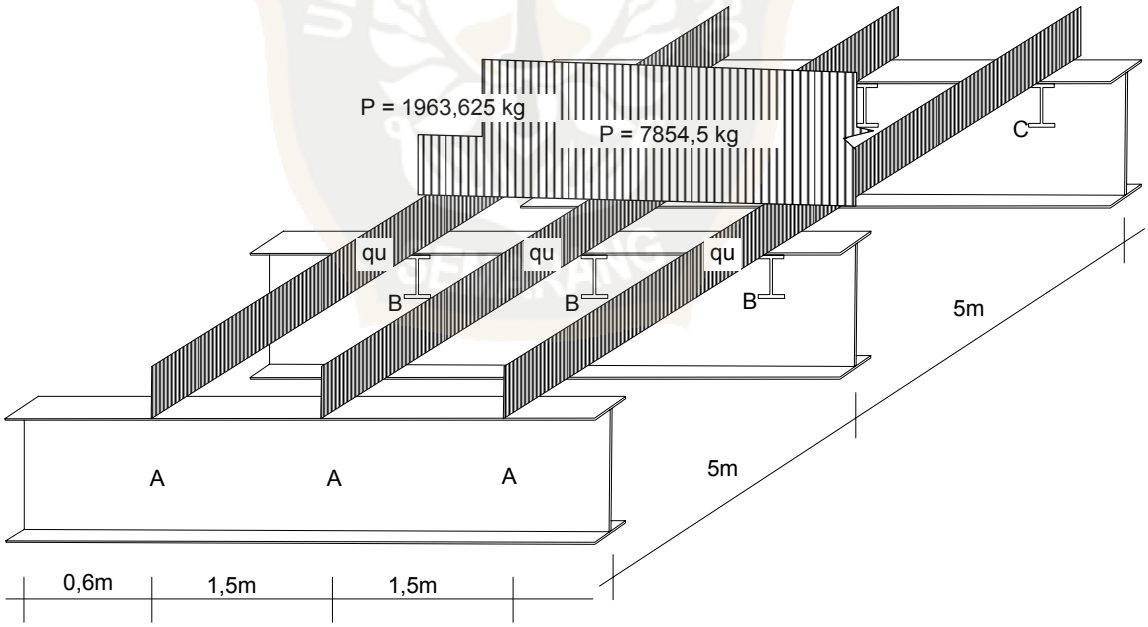
Menurut PPPJJR 1987

p tengah = 12 t

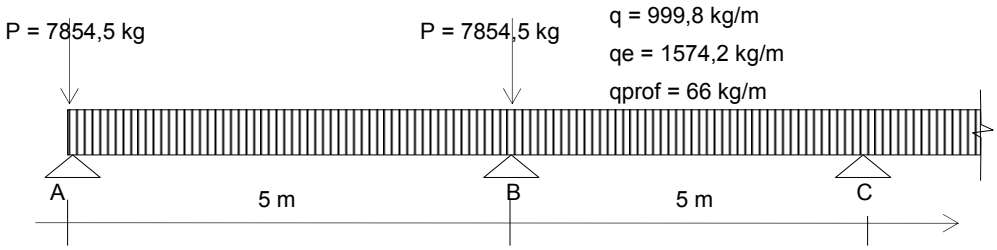
P tepi = $\frac{1}{2}$ p = 6 t

5.3.4.1.3 Perhitungan Beban P

Beban P merupakan beban reaksi dari pembebanan gelagar memanjang



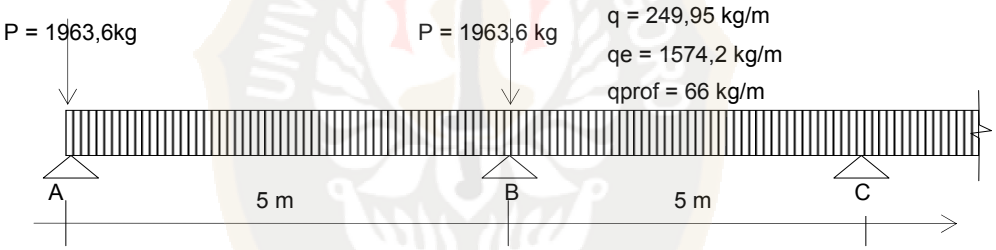
Gambar 5.23 Perspektif Beban Gelagar Memanjang Terhadap Gelagar Melintang



Gambar 5.24 Pembebanan Gelagar Memanjang Tengah

$$\text{RB}= 2*\frac{(qu*l)}{2}+P=2*\frac{(2725kg/m*5m)}{2}+7854{,}5kg=21479{,}5\,\text{kg}\ldots\textbf{P1(tengah)}$$

$$\text{RA}=\left[\frac{qu*l}{2}\right]+P=\left[\frac{2725{,}1kg/m*5m}{2}\right]+7854{,}5kg=14667kg\ldots\ldots\ldots\textbf{P1(tepi)}$$



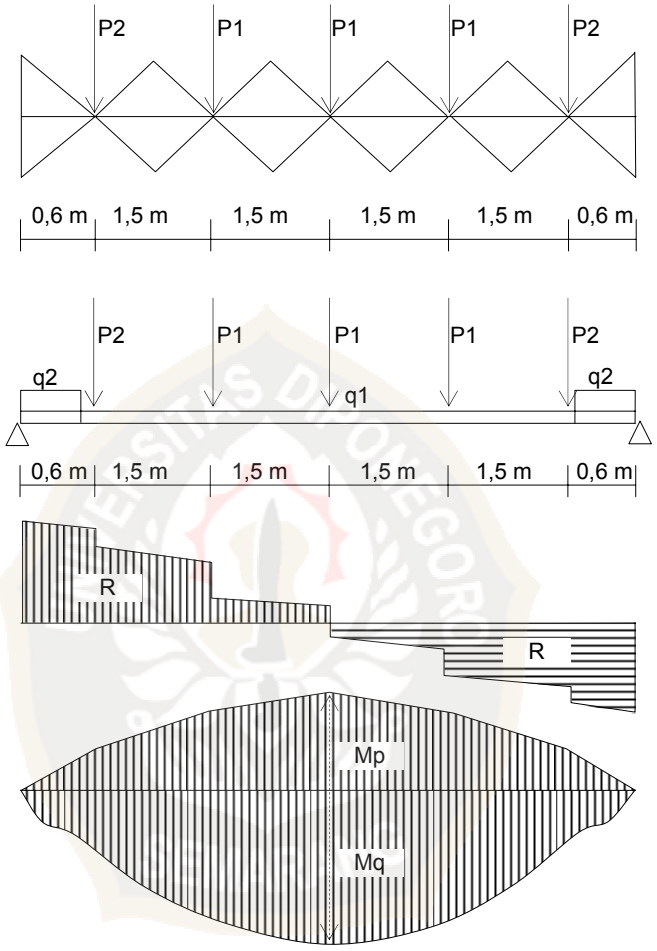
Gambar 5.25 Pembebanan Gelagar Memanjang Tepi

$$\text{RB}=2*\frac{(qu*l)}{2}+P=2*\frac{(1890kg/m*5m)}{2}+1963{,}6kg=11414{,}38\,\text{kg}\ldots\textbf{P2(tengah)}$$

$$\text{RA}=\left[\frac{qu*l}{2}\right]+P=\left[\frac{1890kg/m*5m}{2}\right]+1963{,}6kg=6689kg\ldots\ldots\ldots\ldots\textbf{P2(tepi)}$$

5.3.4.1.4 Perhitungan Momen dan Reaksi

- Beban mati



Gambar 5.26 Beban Mati, Reaksi dan Momen Gelagar Melintang Tengah

Berat profil gelagar melintang taksir = 300 kg/m

P1 = 21,4795 t q1 = 0,674t/m + 0,3t/m = 0,974 t/m

P2 = 11,414 t q2 = 0,6374t/m + 0,3t/m =0,9374 t/m

$$RA = \frac{(2*P2)+(3*P1)+P3+(q1*6,2)+(2*q2*0,5)}{2}$$

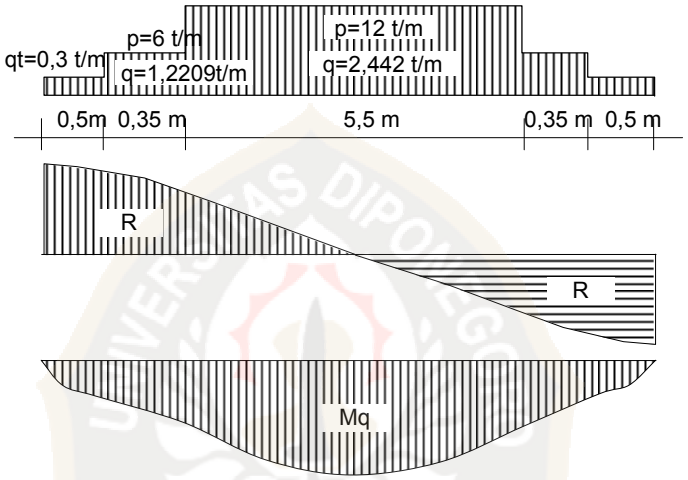
$$RA = \frac{(2*11,414)+(3*21,480)+(0,974*6,2)+(2*0,9374*0,5)}{2} = 47,1221\,t$$

M = (RA*3,6m)-(P2*3m)-(P1*1,5m)-(q2*0,5m*3,35m)-(q1*3,1m*1,55m)

M = (47,1221kg*3,6m)-(11,414kg*3m)-(21,480kg*1,5m)-
(0,9374kg/m*0,5m*3,35m)-(0,974kg/m*3,1m*1,55m) = 136,776 tm

- Beban hidup

Beban trotoar diambil 60%*500 kg/m = 300 kg/m = 0,3 t/m



Gambar 5.27 Beban Hidup, Reaksi dan Momen Gelagar Melintang Tengah

$$RA = \frac{(2*qt*0,5)+[2*(q+p)*0,35\ ]+[(q+p)*5,5]}{2}$$

$$RA = \frac{(2*0,3*0,5)+[2*6,6105*0,35]+[13,2209*5,5]}{2} = 38,82115\,t$$

M = (RA*3,6m)-[(qt*0,5m*3,35m]-[(q+p)*0,35m*2,925m]-
[(q+p)*2,75m*1,375m]

M = (38,82115*3,6)-[0,3*0,5*3,35]-[6,6105*0,35*2,925]-
[13,2209*2,75*1,375]
= 82,495 tm

Momen total :

M = 96,927tm + 90,111tm = 187,038 tm = 18703800 kgcm

5.3.4.1.5 Menentukan Profil

$$Wx = \frac{M\max}{\sigma} = \frac{18703800 kgcm}{1900 kg/cm^2} = 9844{,}105\ \text{cm}^3$$

Untuk Wx komposit dicoba 75%*9844,105 = 7383,079 cm^3

Pilih profil IWF 912*302*18*34 dengan data profil sebagai berikut:

Wx = 10900 cm^3.....> 7383,079 cm^3

A = 364 cm^2

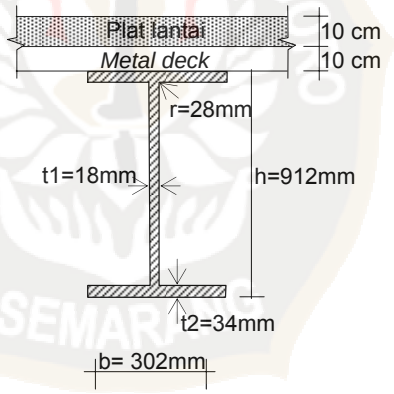
G = 286 kg/m.....< 300 kg/m (taksir)

Ix = 498000 cm^4

b = 302 mm

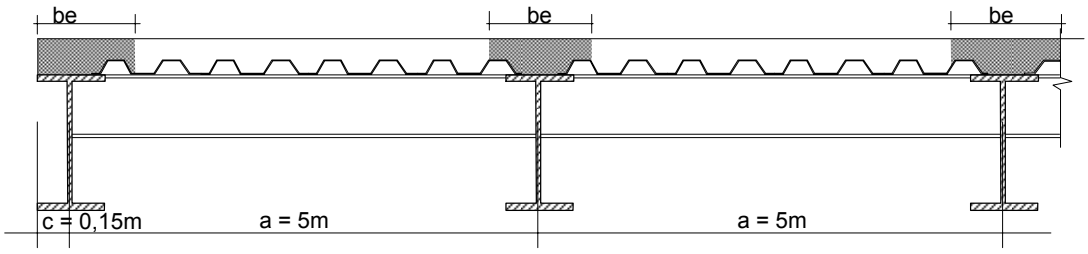
h = 912 mm

r = 28 mm



Gambar 3.28 Penampang Profil Gelagar Melintang Tengah

5.3.4.1.6 Perhitungan Ukuran-Ukuran Komposit



Gambar 5.29 Penampang Lebar Beton Ekivalen

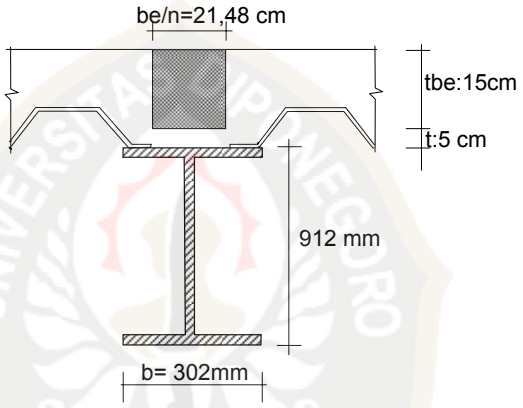
Lebar beton ekivalen menurut BMS 92 :

➢ Gelagar tengah

- be ≤ $\frac{l}{5}$ .....be = $\frac{9{,}13m}{5} = 1{,}826$ m
- be ≤ 12*t_{min}...be = 12*0,17m = 2,04 m
- be ≤ a.....be = 5 m

Dipilih yang terkecil be = 1,826 m

Tebal beton ekivalen (tbe) dicoba 15 cm, maka:



Gambar 5.30 Penampang Luas Beton Ekivalen Gelagar Melintang Tengah

Angka ekivalensi $n = \frac{Ec}{Es} = \frac{2*10^5}{4700*\sqrt{fc}} = \frac{2*10^5\ N/mm^2}{4700*\sqrt{25Mpa}} = 8{,}51 \approx 8{,}5$

Luas beton $Fc = \frac{be}{n}*tbe = \frac{182{,}6cm}{8{,}5}*15cm = 317{,}7\ cm^2$

Luas profil $Fs = 364\ cm^2$

Luas total $Ft = 364cm^2 + 317{,}7cm^2 = 681{,}7\ cm^2$

$Ybs = \frac{h}{2} = \frac{91{,}2cm}{2} = 45{,}6\ cm$

$Ybc = h + \frac{tbe}{2} + t = 91{,}2cm + \frac{15cm}{2} + 5cm = 103{,}7\ cm$

$Yb_{komp} = \frac{(Fc*Ybc)+(Fs*Ybs)}{Ft} = \frac{(317{,}7cm^2*103{,}7cm)+(364cm^2*45{,}6cm)}{681{,}7cm^2}$

$= 72{,}7$ cm

Yt_{komp} = Htot – Yb_{komp} = (91,2cm + 20cm) – 72,7cm = 38,5 cm

$Ys = Yb_{komp} - Ybs = 72,7cm - 45,6cm = 27,1\ cm$

$Yc = Yt_{komp} - \frac{t.be}{2} = 38,5cm - 7,5cm = 31\ cm$

$I_{komp} = I_{prof} + (Fs*Ys^2) + (Fc*Yc^2) + \frac{1}{12} * \frac{be}{n} * tbe^3$

$= 498000 + (364*27,1^2) + (317,7*31^2) + \frac{1}{12} * 21,48 * 15^3 = 1076591,815\ cm^4$

5.3.4.1.7 Cek Kekuatan

a. Tegangan Lentur

$$\sigma_c = \frac{M * Yt_{komp}}{I_{komp} * n} = \frac{18703800kgcm * 38,5cm}{1076591,815cm^4 * 8,5}$$

$\sigma_c = 78,69\,kg/cm^2 < 0,45*fc = 0,45*250 = 112,5\ kg/cm^2$.....ok

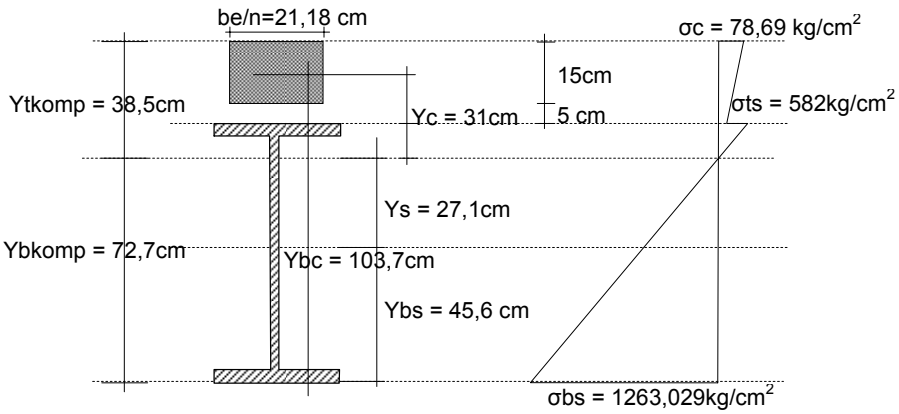
(eff 70 %)

$$\sigma_{ts} = \frac{\left[\frac{M * Yt_{komp}}{I_{komp}}\right] * \left[Yt_{komp} - td\right]}{Yt_{komp}}$$

$$\sigma_{ts} = \frac{\left[\frac{18703800 * 38,5}{1076591,815}\right] * \left[38,5 - 5\right]}{38,5} = 582\,kg/cm^2$$

$$\sigma_{bs} = \frac{M * Yb_{komp}}{I_{komp}} = \frac{18703800 * 72,7}{1076591,815} = 1263,029\,kg/cm^2 < \overline{\sigma} = 1900$$ ....ok

(eff 70 %)



Gambar 5.31 Diagram Tegangan Gelagar Melintang Tengah Komposit

b. Tegangan Geser

$$\tau = \frac{D}{Aw} = \frac{42440{,}1221kg}{1{,}8cm * 91{,}2cm} = 258{,}529\,kg/cm^2 < \bar{\tau} = 0{,}58 * 1900 = 1102\,kg/cm^2$$

5.3.4.1.8 Cek Kekakuan

- Beban Mati

$$\Delta = \frac{5 * qu * l^4}{384 * E * Ikomp} + \frac{P * l^3}{48 * E * Ikomp} + \frac{P * a\left(3 * l^2 - 4 * a^2\right)}{48 * E * Ikomp} < \bar{\Delta} = \frac{l}{500}$$

$$\Delta = \frac{5 * 6{,}8754 * 913^4}{384 * 2 * 10^6 * 1076591{,}815} + \frac{21479{,}5 * 913^3}{48 * 2 * 10^6 * 1076591{,}815} + 2 * \left[\frac{11414{,}375 * 60}{48 *}\right.$$

$$\left.\frac{*\left(3 * 913^2 - 4 * 60^2\right)}{2 * 10^6 * 1076591{,}815}\right] + 2 * \left[\frac{21479{,}5 * 210 * \left(3 * 913^2 - 4 * 210^2\right)}{48 * 2 * 10^6 * 1076591{,}815}\right]$$

$$+ 2 * \left[\frac{(6{,}374 * 0{,}5) * 30 * \left(3 * 913^2 - 4 * 30^2\right)}{48 * 2 * 10^6 * 1076591{,}815}\right] = 0{,}719cm$$

- Beban Hidup

$$\Delta = \frac{(144{,}42) * 913^3}{48 * 2 * 10^6 * 1076591{,}815} + 2 * \left[\frac{(3{,}00 * 60) * 30 * \left(3 * 913^2 - 4 * 30^2\right)}{48 * 2 * 10^6 * 1076591{,}815}\right] +$$

$$2 * \left[\frac{(72{,}209 * 35) * 67{,}5 * \left(3 * 913^2 - 4 * 67{,}5^2\right)}{48 * 2 * 10^6 * 1076591{,}815}\right] = 0{,}00952cm$$

δ total = 0,719cm + 0,00952cm = 0,728 cm < $\bar{\Delta} = \frac{913cm}{500} = 1{,}826cm$ .....ok

5.3.4.1.10 Perhitungan *Shear Connector* (Penghubung Geser)

Untuk penghubung geser digunakan *Stud* (paku) dengan Ø 22 mm dan H = 140 mm, dengan syarat $\frac{H}{d} = \frac{140mm}{22mm} = 6{,}4 \geq 6$

Luas 1 paku $A = \frac{\pi}{4} * D^2 = \frac{\pi}{4} * 22mm^2 = 380 \text{ mm}^2$

Kekuatan1paku $Q = \frac{0{,}0005 * As * \sqrt{fc * Ec}}{SF} = \frac{0{,}0005 * 380 * \sqrt{25 * 20000}}{2}$

Q = 67,175 KN.....6717,5 kg

Shear Connector diirencanakan pada balok komposit penuh (*full composit*) sehingga gaya geser horisontal ditentukan oleh kapasitas tekan beton atau kapasitas tarik baja, dengan besar gaya geser sebagai berikut:

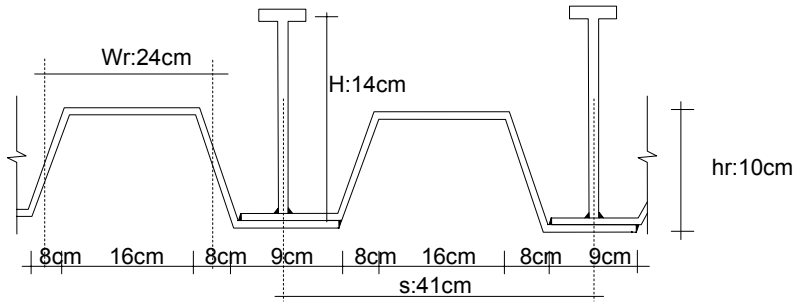
Vhc $= \frac{0{,}85 * fc * be * t}{SF} = \frac{0{,}85 * 250kg/cm^2 * 182{,}6cm * 15cm}{2} = 291018{,}8 \text{ kg}$

Vhs $= \frac{As * fy}{SF} = \frac{364cm^2 * 2900kg/cm^2}{2} = 527800 \text{ kg}$

Dipilih yang terkecil Vh=291018,8 kg,V=$\frac{Vh}{2} = 145509{,}4 \text{ kg}$ untuk setengah bentang

Posisi gelombang dek baja sejajar dengan penumpu, maka reduksi kekuatan paku adalah :

$r_s = 0{,}6 * \left(\frac{24}{10}\right) * \left(\frac{14}{10} - 1\right) = 0{,}576 \leq 1$, kekuatan1 paku = 0,576*6717,5= 3869,28 kg



Gambar 5.32 Penampang *Dek Baja* dan Tinggi *Stud*

Jumlah paku $n = \frac{V}{Q} = \frac{143437{,}5kg}{3869{,}28kg} = 38$ buah paku untuk setengah bentang.

Jarak setengah bentang :

$$L_2 = \left[\left(\frac{l}{2} + 6{,}5\right) - (6{,}5 + 15)\right] = \left[\left(\frac{700cm}{2} + 6{,}5cm\right) - (6{,}5cm + 15cm)\right] = 335\,\text{cm}$$

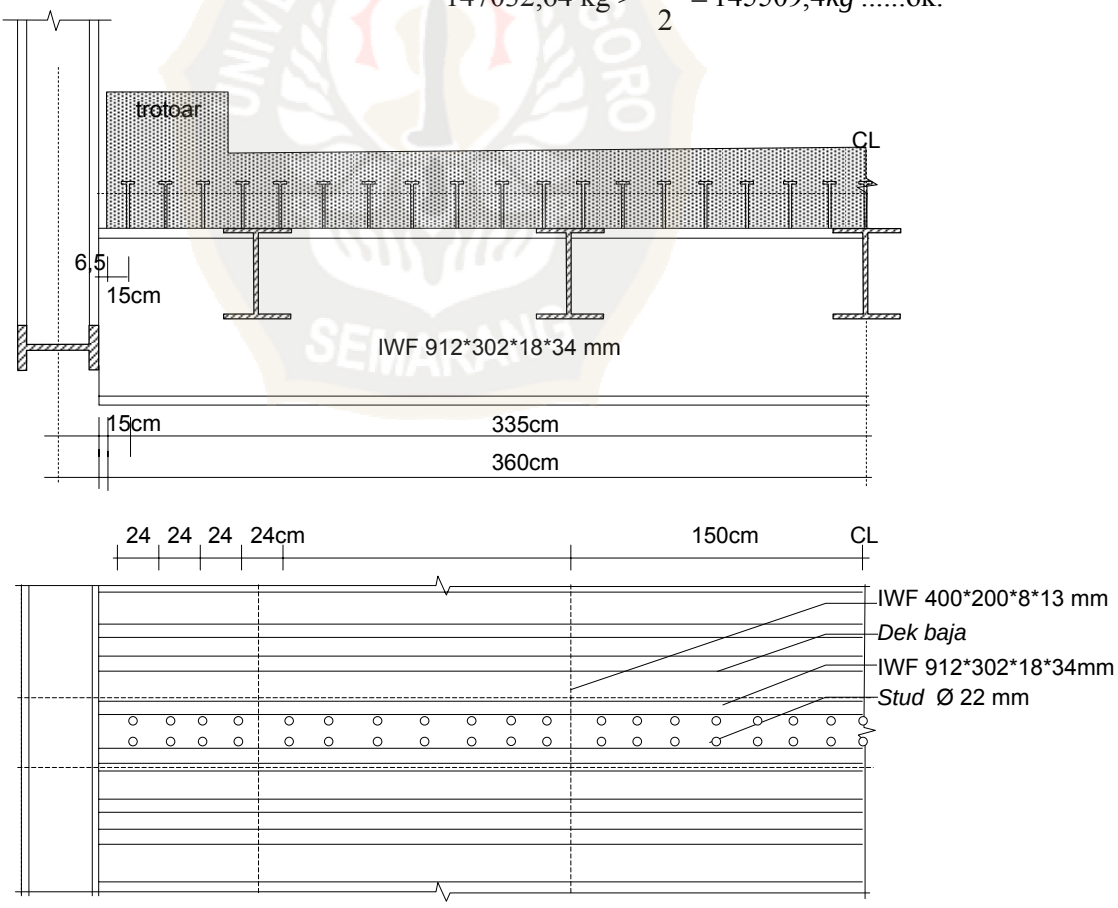
Direncanakan 1 baris terdapat 2 buah paku, sehingga jumlah baris = $\frac{38}{2} = 19$ baris

syarat jarak memanjang paku $s \geq 6*d$ $s \geq 6*2{,}2\text{cm} = 13{,}2$ cm.

Jarak antar paku $s = \frac{335cm}{(19-1)} = 18\,\text{cm} \geq 13{,}2$ cm.....ok

Cek kekuatan paku setengah bentang = 38 * 3869,28 kg

$= 147032{,}64$ kg $> \frac{Vh}{2} = 145509{,}4kg$ .....ok.



Gambar 5.32 Pemasangan *Stud* pada Gelagar Melintang Tengah

5.3.5.2 Gelagar Melintang Tepi

5.3.5.2.1 Pembebanan dan Pendimensian

- Beban mati RA = 32,1776 t Mmax = 67,52 tm
- Beban hidup RA = 38,82115 t Mmax = 82,495 tm

Total Mmax = 150,015 tm

$$Wx = \frac{M\max}{\sigma} = \frac{15001500kgcm}{1900kg/cm^2} = 7895{,}526\,\text{cm}^3$$

Untuk Wx komposit dicoba 75%*7895,526 cm^3 = 6921,645 cm^3

Pilih profil IWF 900*300*16*28 dengan data profil sebagai berikut:

Wx = 9140 cm^3.....> 6921,645 cm^3

A = 309,8 cm^2

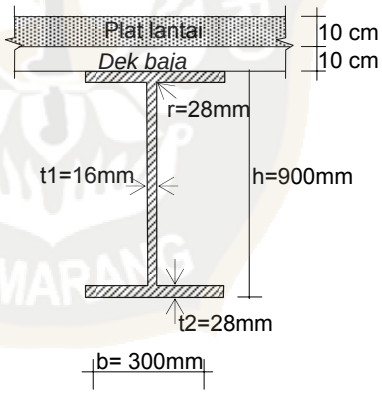
G = 243 kg/m.....< 300 kg/m (taksir)

Ix = 411000 cm^4

b = 300 mm

h = 900 mm

r = 28 mm



Gambar 3.38 Penampang Profil Gelagar Melintang Tepi

5.3.5.2.2 Perhitungan Ukuran-Ukuran Komposit

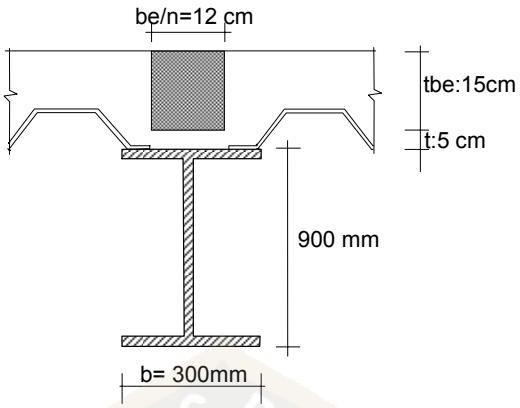
Lebar beton ekivalen menurut BMS 92:

➢ Gelagar tepi

- $be \le \frac{l}{10} + c$ .....$be = \frac{9{,}13m}{10} + 0{,}15m = 1{,}063$ m
- $be \le 6 * t_{min}$.....be = 6*0,17m = 1,02 m
- $be \le \frac{a}{2} + c$.....$be = \frac{5m}{2} + 0{,}15m = 2{,}65$ m

Dipilih yang terkecil be = 1,02 m

Tebal beton ekivalen (tbe) dicoba 15 cm, maka:



Gambar 5.39 Penampang Luas Beton Ekivalen Gelagar Melintang Tepi

Angka ekivalensi $n = \frac{Ec}{Es} = \frac{2*10^5}{4700*\sqrt{fc}} = \frac{2*10^5\ N/mm^2}{4700*\sqrt{25}Mpa} = 8{,}51 \approx 8{,}5$

Luas beton $Fc = \frac{be}{n}*tbe = \frac{102cm}{8{,}5}*15cm = 180\ cm^2$

Luas profil $Fs = 309{,}8\ cm^2$

Luas total $Ft = 309{,}8\ cm^2 + 180\ cm^2 = 669{,}8\ cm^2$

$Ybs = \frac{h}{2} = \frac{90cm}{2} = 45\ cm$

$Ybc = h + \frac{tbe}{2} + td = 90cm + \frac{15cm}{2} + 5cm = 102{,}5\ cm$

$Yb_{komp} = \frac{(Fc*Ybc)+(Fs*Ybs)}{Ft} = \frac{(180cm^2*102{,}5cm)+(309{,}8cm^2*45cm)}{669{,}8cm^2}$

$= 75{,}9cm$

$Yt_{komp} = Htot - Yb_{komp} = 110\ cm - 75{,}9\ cm = 34{,}1\ cm$

$Ys = Yb_{komp} - Ybs = 75{,}9\ cm - 45\ cm = 30{,}9\ cm$

$Yc = Yt_{komp} - \frac{t.be}{2} = 34{,}1\ cm - 7{,}5\ cm = 26{,}6\ cm$

$I_{komp} = I_{prof} + (Fs*Ys^2) + (Fc*Yc^2) + \frac{1}{12}*\frac{be}{n}*tbe^3$

$= 411000 + (309{,}8*30{,}9^2) + (180*26{,}6^2) + \frac{1}{12}*12*15^3$

$= 968271{,}738\ cm^4$

5.3.5.2.3 Cek Kekuatan

a. Tegangan Lentur

$$\sigma_c = \frac{M * Yt_{komp}}{I_{komp} * n} = \frac{15001500\text{kgcm} * 34{,}1\text{cm}}{968271{,}738cm^4 * 8{,}5} = 62{,}155\,kg/cm^2$$

$\sigma_c = 62{,}155\,kg/cm^2 < 0{,}45*\text{fc} = 0{,}45*250 = 112{,}5$ kg/cm^2....ok

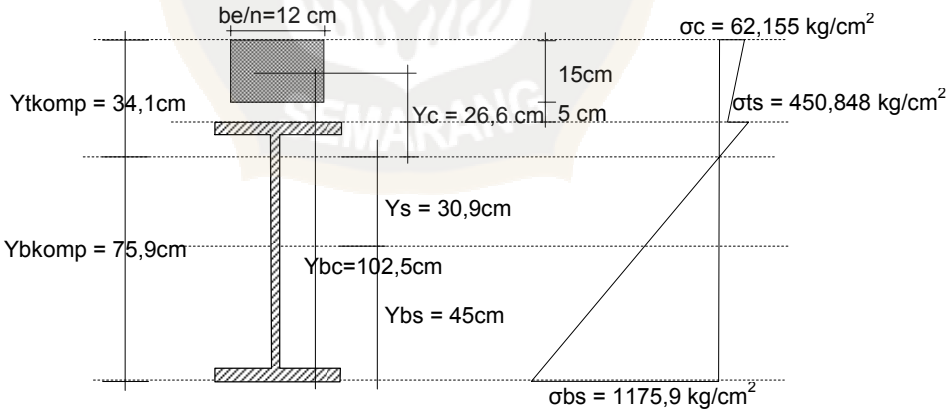
(eff 60 %)

$$\sigma_{ts} = \frac{\left[\frac{M * Yt_{komp}}{I_{komp}}\right] * \left[Yt_{komp} - td\right]}{Yt_{komp}}$$

$$\sigma_{ts} = \frac{\left[\frac{15001500 * 34{,}1}{968271{,}738}\right] * \left[34{,}1 - 5\right]}{34{,}1} = 450{,}848\,kg/cm^2 < \bar{\sigma} = 1900\,kg/cm^2$$

$$\sigma_{bs} = \frac{M * Yb_{komp}}{I_{komp}} = \frac{15001500 * 75{,}9}{968271{,}738} = 1175{,}9\,kg/cm^2 < \bar{\sigma} = 1900\,..\text{ok}$$

(eff 70 %)



Gambar 3.40 Diagram Tegangan Gelagar Melintang Tepi Komposit

b. Tegangan Geser

$$\tau = \frac{D}{Aw} = \frac{70999{,}1kg}{1{,}6cm * 90cm} = 493{,}049\,kg/cm^2 < \bar{\tau} = 0{,}58 * 1900 = 1102\,kg/cm^2$$

5.3.5.2.4 Cek Kekakuan

- Beban Mati

$$\delta = \frac{5*qu*l^4}{384*E*Ikomp} + \frac{P*l^3}{48*E*Ikomp} + \frac{P*a\left(3*l^2-4*a^2\right)}{48*E*Ikomp} < \bar{\delta} = \frac{l}{500}$$

$$\delta = \frac{5*1{,}890*733^4}{384*2*10^6*968271{,}738} + \frac{14667*733^3}{48*2*10^6*938271{,}738} + 2*\left[\frac{6689*}{48*}\right.$$

$$\left.\frac{60*\left(3*733^2-4*60^2\right)}{2*10^6*938271{,}738}\right] + 2*\left[\frac{14667*210*\left(3*733^2-4*210^2\right)}{48*2*10^6*938271{,}738}\right]$$

$$+2*\left[\frac{(9{,}374*50)*30*\left(3*733^2-4*30^2\right)}{48*2*10^6*938271{,}738}\right] = 0{,}172cm$$

- Beban Hidup

$$\delta = \frac{(132{,}209*550)*733^3}{48*2*10^6*938271{,}738} + 2*\left[\frac{(3{,}00*50)*25*\left(3*733^2-4*25^2\right)}{48*2*10^6*938271{,}738}\right] +$$

$$2*\left[\frac{(66{,}105*35)*67{,}5*\left(3*733^2-4*67{,}5^2\right)}{48*2*10^6*938271{,}738}\right] = 0{,}005904cm$$

δ total = 0,172 cm + 0,005904 cm = 0,1779 cm < $\bar{\delta} = \frac{733}{500} = 1{,}466cm$ .....ok.

5.3.5.2.6 Perhitungan *Shear Connector* (Penghubung Geser)

Untuk kebutuhan *Shear Connector*nya dianggap sama dengan kebutuhan untukgelagar melintang tengah.

5.3.6 Hubungan Antara Gelagar Memanjang dengan Gelagar Melintang

Beban yang bekerja :

- Beban Mati $= \frac{(qd+qprof)*l}{2} = \frac{(1574+66)kg/m*5m}{2}$ = 4100,5 kg
- Beban D (q) $= \frac{D*l}{2} = \frac{999{,}8kg/m*5m}{2}$ = 2499,5 kg
- Beban D (p) $= P = 7854{,}5\,\text{kg}$ = 7854,5 kg +

P = 14454,5 kg

P = 144545 N

Untuk plat penyambung digunakan ⌊ 100.100.12 dengan w = 55 mm

Baut digunakan Ø 24 mm

diameter lobang Ø 25 mm

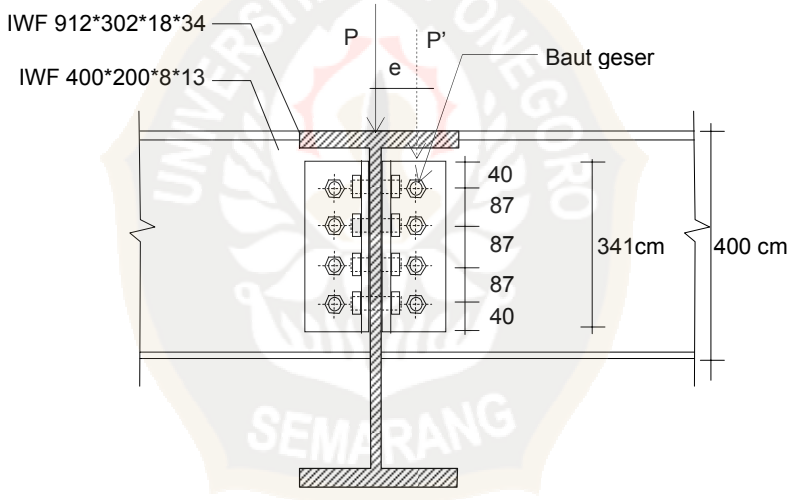
- Syarat jarak baut tengah

2,5*d < S < 7*d.....60 – 168 diambil 87 mm

- Syarat jarak baut dengan tepi

1,5*d < S1 < 3*d.....36 – 72 diambil 40 mm

5.3.6.1 Baut Geser



Gambar 5.41 Hubungan Gelagar Memanjang Terhadap Gelagar Melintang dengan Baut Geser

5.3.6.1.1 Cek kekuatan plat penyambung

e $= \frac{tw}{2} + w = \frac{18mm}{2} + 55mm = 64\,\text{mm}$

M = P*e = 155810,5 N*64 mm = 9250880 Nmm

A_{netto} = (341mm -4*25mm)*12mm = 2892 mm^2

$I_{netto} = \frac{1}{12} * 12 * 341^3 - 4 * \frac{1}{12} * 12 * 25^3 - 2 * 12 * 25 * 130{,}5^2 = 29355546\,mm^4$

$Wn = \frac{In}{h/2} = \frac{29355546mm^4}{341/2mm} = 172173{,}29\,mm^3$

$\tau = \frac{P}{An} = \frac{144545N}{2892mm^2} = 49{,}98Mpa$

$\sigma = \frac{M}{Wn} = \frac{9250880Nmm}{172173{,}29mm^3} = 53{,}73Mpa$

$\sigma i = \sqrt{\sigma^2 + 3*\tau^2} = \sqrt{53{,}73^2 + 3*49{,}98^2} = 56{,}442$ Mpa < σ =190 Mpa....ok

Plat penyambung cukup aman!

5.3.6.1.2 Cek pola baut

$N_{geser} = 2*\frac{1}{4}*\pi*24^2 mm^2*(0{,}6*190Mpa) = 103144{,}77$ N

N_{tumpu} = 24mm*12mm*(1,2*190Mpa)= 65664 N....ambil terkecil N = 65664 N

Gaya yang bekerja pada baut:

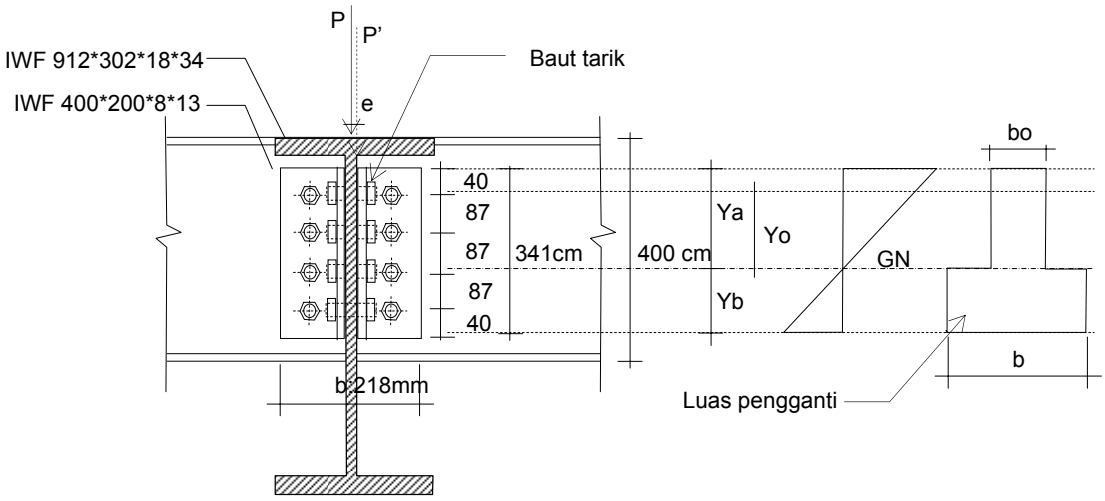
Akibat gaya geser $Kv = \frac{P}{n} = \frac{144545N}{4} = 36136{,}25$ N

Akibat momen $Kx = \frac{M*Y}{2*Y1^2 + 2*Y2^2} = \frac{9250880*130{,}5}{2*130{,}5^2 + 2*43{,}5^2} = 31899{,}586$ N

$R = \sqrt{Kv^2 + Kx^2} = \sqrt{36136{,}25^2 + 31899{,}586^2} = 48201{,}786$ <N=65664 N..ok

Pola baut bisa digunakan!

5.3.6.2 Baut Tarik



Gambar 5.42 Hubungan Gelagar Memanjang Terhadap Gelagar Melintang dengan Baut Tarik

➢ Metode Luas Pengganti

Akibat P $K = \frac{P}{n} = \frac{144545N}{4} = 36136{,}25\,\text{N}$

$$\tau = \frac{K}{A} = \frac{36136{,}25N}{1/4 * \pi * 25^2 mm^2} = 73{,}616\,\text{Mpa}$$

Akibat M $M = P*e = 144545\ \text{N} * \frac{18}{2} = 1300905\ \text{Nmm}$

b $= 218$ mm

bo $= \frac{A*n}{s} = \frac{1/4 * \pi * 25^2 * 2}{8} = 122{,}718\,\text{mm}$

$\frac{Yb}{Ya} = \sqrt{\frac{bo}{b}} = 0{,}75$ $\quad Yb = 0{,}75*Ya \quad Ya + Yb = H$

Ya + (0,75*Ya) = 341 mm didapat Ya = 194,857 mm, Yb = 146,143 mm

Yo = Ya – S1 = 194,857 – 40 = 154,857 mm

$I = \frac{1}{12} * bo * Ya^3 + \frac{1}{12} * b * Yb^3 = 132364945{,}8\,\text{mm}^4$

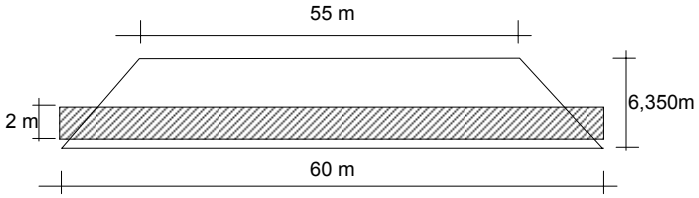
$\sigma_t = \frac{M * Yo}{I} = 1{,}522\,\text{Mpa}$

$\sigma_i = \sqrt{\sigma_t^{\,2} + (3 * \tau^2)} = 127{,}516 < \overline{\sigma} = 190\,\text{Mpa}...\text{ok}$

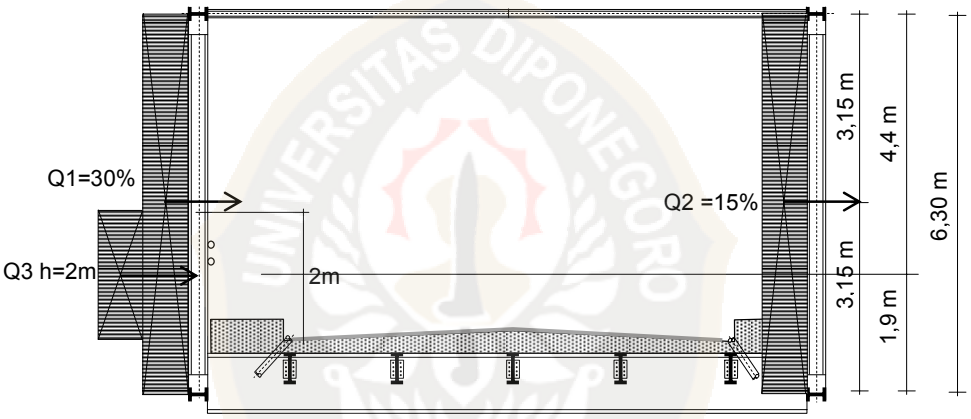
$\left(\frac{\tau}{=\tau}\right)^2 + \left(\frac{\sigma_t}{=\sigma_t}\right)^2 = (5{,}8 * 10^{-3}) + (1{,}5 * 10^{-4}) = 5{,}9 * 10^{-3} \le 1 \ldots.\text{ok}$

5.3.7 Pertambatan Angin

5.3.7.1 Pembebanan



Gambar 5.43. Bidang Sisi Rangka Utama dan Bidang Beban Hidup



Gambar 5.44. Pengaruh Angin dan Bidang Beban hidup Terhadap Rangka Utama

Tekanan angin W = 150 kg/m^2

Luas bidang rangka A = (60m+55m)*0,5*6,30m = 362,25 m^2

Beban angin yang timbul:

a. Rangka induk

Menurut PPPJJR 1987 *"untuk jembatan rangka diambil sebesar 30% luas bidang sisi jembatan yang langsung terkena angin, ditambah 15% luas bidang yang lain"*.

Q1 = 30%*362,25 m^2*150 kg/m^2 = 16301,25 kg

Q2 = 15%*362,25 m^2*150 kg/m^2 = 8150,625 kg

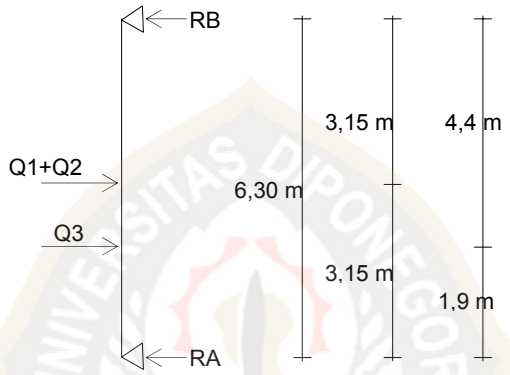
Total angin tekan dan angin hisap Q = 24451,875 kg

b. Beban hidup

Menurut PPPJJR 1987 *"untuk jembatan rangka dalam keadaan dengan beban hidup diambil sebesar 50% terhadap luas bidang menurut pasal 2.1(1.1a dan 1.1b)"*.

Q3 = 50%*[(30%+15%)*362,25]*150 kg/m^2 = 12225,9375 kg

Tekanan angin ditahan oleh pertambatan angin.



Gambar 5.45. Pola Pembebanan Pertambatan Angin

5.3.7.2 Pembebanan Angin Atas

Ikatan anginnya hanya bagian atas saja, sedangkan bagian bawah cukup di stabilkan oleh gelagar melintang, sehingga masing-masing buhul ikatan angin atas menerima beban:

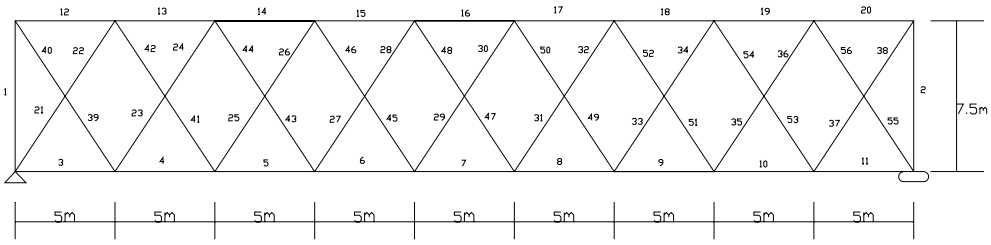
$$\text{RB} = \frac{(Q1+Q2)kg * 3{,}15m + Q3kg * 1{,}90m}{6{,}30m} = 15913{,}125 \text{ kg}$$

$$\text{P} = \frac{RB}{11} = \frac{15913{,}125kg}{11} = 1446{,}648 \text{ kg}$$

$$\frac{P}{2} = \frac{1446{,}648kg}{2} = 723{,}323 \text{ kg}$$

5.3.7.3 Perhitungan Gaya Batang Angin Atas

Tipe ikatan anginnya seperti di bawah ini dan dianggap terletak pada tumpuan sederhana:



Perhitungan menggunakan bantuan program SAP 2000 v8.0.8.

Tabel 5.1 Gaya Batang Ikatan Angin

batang	Gaya		batang	Gaya	
	tekan(-)	tarik(+)		tekan(-)	tarik(+)
S1	3463,2		S38		3496,2
S2	3463,2		S39		3496,2
S21	3933,8		S40		3496,2
S22	3933,8		S41		3055
S23	2634,7		S42		3055
S24	2634,7		S43		1755,9
S25	2193,5		S44		1755,9
S26	2193,5		S45		1314,7
S27	894,4		S46		1314,7
S28	894,4		S47	453,2	
S29	453,2		S48	453,2	
S30	453,2		S49	894,4	
S31		1314,7	S50	894,4	
S32		1314,7	S51	2193,5	
S33		1755,9	S52	2193,5	
S34		1755,9	S53	2634,7	
S35		3055	S54	2634,7	
S36		3055	S55	3933,8	
S37		3496,2	S56	3933,8	

5.3.7.4 Pendimensian Ikatan Angin Atas

5.3.7.4.1 Batang Vertikal

Besar gaya batang terbesar menurut hasil SAP 2000 v8.0.8 adalah (S1) atau (S2) dengan P = -34632,03 kg (tekan)

Setelah dicoba-coba didapat profil IWF 294*200*8*12, dengan data profil :

A = 72,38 cm^2

i_{min} = iy = 4,71 cm

G = 56,8 kg/m

Koefisien tekuk (sendi-sendi) menurut PPBBG 87 didapat K=1

L_k = K*L = 1*750 cm = 750 cm

- Angka kelangsingan

$$\lambda = \frac{L_k}{i_{min}} = \frac{750cm}{4,71cm} = 159,23 \leq 200 \text{ (batas kelangsingan batang tekan)}$$

- Kelangsingan batas

$$\lambda g = \pi * \sqrt{\frac{E}{0,7 * f_y}} = \pi * \sqrt{\frac{2000000kg/cm^2}{0.7 * 2900kg/cm^2}} = 98,6$$

- Rasio kelangsingan

$$\lambda s = \frac{\lambda}{\lambda g} = \frac{193,8}{98,6} = 1,966 \geq 1$$ .....termasuk batang langsing, sehingga

faktor tekuk: $\omega = 2,381*\lambda^2 = 2,381* 1,966^2 = 9,2$

- Cek tegangan
  - Akibat gaya P

$$\sigma = \frac{P * \omega}{A} = \frac{3463,203kg * 9,2}{72,38cm^2} = 440,20 \leq \sigma = 1900 \text{ kg/cm}^2$$.....ok

  - Akibat berat sendiri

$$\sigma = \frac{M}{Wx} = \frac{1/8 * 0,568 * 750^2}{771} = 51,8 \text{ kg/cm}^2$$

σ total = 440,20 + 51,8 = 492,00 kg/cm^2 < σ =1900 kg/cm^2.....ok

5.3.7.4.2 Batang Diagonal

Besar gaya batang (S21, S22) atau (S55, S56) dengan P = -3933,8 kg (tekan). Setelah dicoba-coba didapat profil IWF 169*125*5,5*8, dengan data profil:

A = 29,65 cm^2

i_{min} = iy = 2,97 cm

G = 23,3 kg/m

Koefisien tekuk (sendi-sendi) menurut PPBBG 87 didapat K=1

L_k = K*L = 1*450,6 cm = 450,6 cm

- Angka kelangsingan

$$\lambda = \frac{L_K}{i_{\min}} = \frac{450,6cm}{2,97cm} = 151,72 \le 200 \text{ (batas kelangsingan batang tekan)}$$

- Kelangsingan batas

$$\lambda g = \pi * \sqrt{\frac{E}{0,7 * f_y}} = \pi * \sqrt{\frac{2000000kg/cm^2}{0.7 * 2900kg/cm^2}} = 98,6$$

- Rasio kelangsingan

$$\lambda s = \frac{\lambda}{\lambda g} = \frac{175,3}{98,6} = 1,8 \ge 1$$.....termasuk batang langsing, sehingga faktor tekuk: $\omega = 2,381*\lambda^2 = 2,381* 1,8^2 = 7,7$

- Cek tegangan
  - Akibat gaya P

$$\sigma = \frac{P * \omega}{A} = \frac{3933,86kg * 7,7}{29,65cm^2} = 1021,61 \le \sigma = 1900 \text{ kg/cm}^2$$.....ok

  - Akibat berat sendiri

$$\sigma = \frac{M}{Wx} = \frac{1/8 * 0,233 * 450,6^2}{181} = 32,67 \text{ kg/cm}^2$$

σ total = 1021,61 + 32,67 = 1054,28 kg/cm^2 < σ =1900 kg/cm^2.....ok

5.3.7.4.3 Batang Diagonal

Besar gaya batang (S37 s/d S40) sebesar P = 3496,22 kg (tarik). Dipakai IWF 169*125*5,5*8, dengan data profil :

A =29,65 cm^2

I_{min} = Iy = 1530 cm^4

- Angka kelangsingan

$$I = \sqrt{\frac{I_{\min}}{A}} = \sqrt{\frac{1530cm^4}{29,65cm^2}} = 7,78 \text{ cm}, \lambda = \frac{L}{I} = \frac{450,6cm}{7,78cm} = 57,93$$

≤ 300 (konstruksi sekunder).....ok

- Cek tegangan

  Dalam PPBBG 1987 disebut bahwa *"dalam suatu potongan jumlah lobang tidak boleh lebih besar daripada 15% luas penampang utuh"*, disini dipakai 15%, sehingga besar tegangannya adalah:

  $\sigma = \frac{P}{An} = \frac{3496,22kg}{0,85 * 29,65cm^2} = 138,73 \quad \leq \quad \sigma_r = 0,75*1900 = 1425$ kg/cm^2....ok

5.3.7.5 Sambungan

5.3.7.5.1 Batang diagonal dengan plat buhul ikatan angin

P = 3496,22 kg (tarik)

$Ø_{baut}$ = 16 mm

t_{plat} = 10 mm

- Kekuatan geser baut

  Ng = m*1/4*π*d^2*τ

  = 1*1/4* π*1,6^{2}cm*0,6*1900kg/cm^2 = 2292,1 kg

- Kekuatan tumpu plat

  Ntu = d*t* σtu

  = 1,6cm*1,0cm*1,2*1900kg/cm^2 = 3648 kg

  Pilih yang terkecil N = 2292,1 kg

- Jumlah baut

  $n = \frac{P}{N} = \frac{3552,06kg}{2292,1kg} = 1,5$ dipakai 2 baut untuk sayap atas dan 2 baut untuk sayap bawah.

- Cek tegangan

  $\sigma_r = \frac{P}{A} = \frac{3496,2}{29,65 - (4*1,7*0,55)} = 134,94$ kg/cm^2< $\overline{\sigma_r}$ =0,75*1900 = 1425 kg/cm^2 .....ok

- Susunan baut

  Syarat:

Tepi 1,5*d ≤ S1≤ 3*d

24 – 48 .....dipakai S1= 35 mm

Tengah 2,5*d ≤ U ≤ 7*d

40 – 112 .....dipakai U = 55 mm

3.3.7.5.2 Plat buhul ikatan angin dengan rangka utama

P = 2*3496,22*sin $68,5^0$ = 6505,89 kg (tarik)

$Ø_{baut}$ = 16 mm

t_{plat} = 10 mm

- Kekuatan geser baut

  Ng = m*1/4*π*d^2*τ

  = 1*1/4* π*$1,6^2$cm*0,6*1900kg/cm^2 = 2292,1 kg

- Kekuatan tumpu plat

  Ntu = d*t* σtu

  = 1,6cm*1,0cm*1,2*1900kg/cm^2 = 3648 kg

  Pilih yang terkecil N = 2292,1 kg

- Jumlah baut

  $n = \frac{P}{N} = \frac{6505,89kg}{2292,1kg} = 2,8$ dipakai 4 baut

- Susunan baut

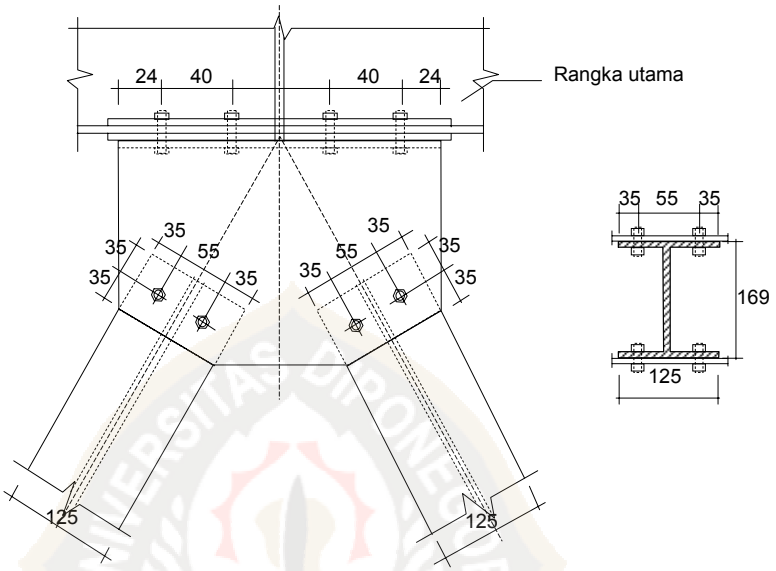
  Syarat:

  Tepi 1,5*d ≤ S1≤ 3*d

  24 – 48 .....dipakai S1= 24 mm

  Tengah 2,5*d ≤ U ≤ 7*

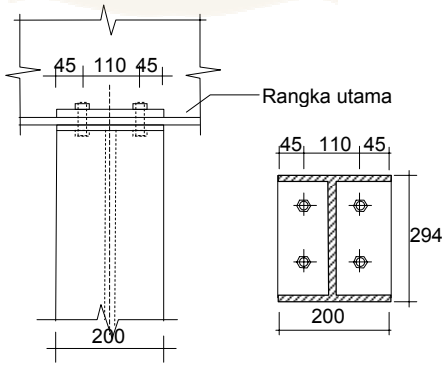
  40 – 112 .....dipakai U = 40 mm



Gambar 5.47 Hubungan Batang Diagonal dengan Buhul

5.3.7.5.3 Batang vertikal dengan rangka utama

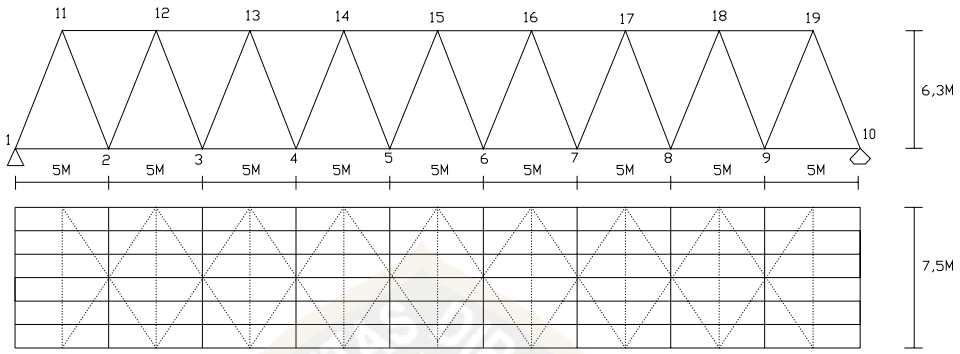
Karena merupakan batang tekan maka dipakai pola baut sederhana



Gambar 5.48 Hubungan Batang Vertikal dengan Rangka Utama

5.3.8 Rangka Utama

5.3.8.1 Pembebanan



Gambar 5.49 Rangka Utama, Gelagar dan Ikatan Angin

Rangka utama batang miring $= \sqrt{(6{,}30^2 + 2{,}5^2)} = 6{,}78m$

Ikatan angin batang miring $= \sqrt{(7{,}5^2 + 5^2} = 9{,}01m$

5.3.8.1.1 Beban Mati

A. Rangka Utama

Berat asumsi= 300 kg/m

- Joint 1&10= (1/2*6,78m + 1/2*5m)*300kg/m = 1767 kg
  Sambungan + baut = 5%*1767kg = 88,35 kg.....total = 1855,35 kg
- Joint 11&19= 2*(1/2*6,78m) + (1/2*5m)*300kg/m = 2784 kg
  Sambungan + baut = 5%*2784kg = 139,2 kg.....total = 2923,2 kg
- Joint 2-9,12-18 = 2*(1/2*6,78m) + 2*(1/2*5m)*300kg/m = 3534 kg
  Sambungan + baut = 5%*3534kg = 176,7 kg.....total = 3710,7 kg

B. Ikatan Angin

- Joint 11&19 = (1/2*7,5m*56,8kg/m) + (1/2*9,01m*23,3kg/m)
  = 317,97 kg
- Joint 12-18 = 2*(1/2*9,01m*23,3kg/m) = 209,93 kg

C. Gelagar Melintang

- Joint 2-9 = (1/2*7,5m*286kg/m) = 1072,5 kg
- Joint 1&10 = (1/4*7,5m*243kg/m) = 455,63 kg

D. Gelagar Memanjang

- Joint 2-9 = (1/2*5*5m*66kg/m) = 825 kg
- Joint 1&10 = (1/2*5*2,5m*66kg/m) = 412,5 kg

E. Plat, Trotoar, Aspal, Dek, Air hujan

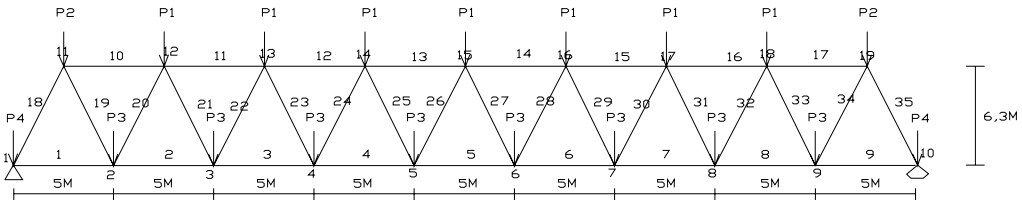
- P Joint 2-9 = (1/2*7,2m*5m*0,185m*2500kg/m^3) = 8325 kg
  Joint 1&10 = (1/2*7,2m*2,5m*0,185m*2500kg/m^3) = 4162,5 kg
- T Joint 2-9 = (1m*5m*0,31m*2500 kg/m^3) = 3875 kg
  Joint 1&10 = (1m*2,5m*0,31m*2500 kg/m^3) = 1937,5 kg
- As Joint 2-9 = (1/2*6m*5m*0,05m*2200 kg/m^3) = 1650 kg
  Joint 1&10 = (1/2*6m*2,5m*0,05m*2200 kg/m^3) = 825 kg
- D Joint 2-9 = (1/2*7m*5m*15 kg/m^2) = 262,5 kg
  Joint 1&10 = (1/2*7m*2,5m*15 kg/m^2) = 131,25 kg
- Ah Joint 2-9 = (1/2*6m*5m*0,05m*1000 kg/m^3) = 750 kg
  Joint 1&10 = (1/2*6m*2,5m*0,05m*1000 kg/m^3) = 375 kg

Total P1 = Joint A 12-18 + Joint B 12-18 = 3920,63 kg

P2 = Joint A 11&19 + Joint B 11&19 = 3241,17 kg

P3 = Joint A 2-9 + Joint C 2-9 + Joint D 2-9 + Joint E 2-9
= 20470,7 kg

P4 = Joint A 1&10 + Joint C 1&10 + Joint D 1&10 + Joint E 1&10
= 10154,73 kg



Gambar 5.50 Pembebanan Rangka Utama Beban Mati

Perhitungan gaya batangnya menggunakan bantuan program SAP 2000

Tabel 3.2 Gaya Batang Rangka Utama Beban Mati

batang	gaya batang (kg)		batang	gaya batang (kg)	
	tekan(-)	tarik(+)		tekan(-)	tarik(+)
S1		41519,85	S19		104015,29
S2		111691,35	S20	81917,86	
S3		162373,42	S21		78113,65
S4		192718,2	S22	55796,88	
S5		202838,16	S23		51270,92
S6		192718,2	S24	29061,91	
S7		162373,42	S25		24619,28
S8		111691,35	S26		2386,88
S9		41519,85	S27	2386,88	
S10	80542,97		S28		24619,28
S11	141225,12		S29	29061,91	
S12	181693,18		S30		51270,92
S13	201932,49		S31	55796,88	
S14	201932,49		S32		78113,65
S15	181693,18		S33	81917,86	
S16	141225,12		S34		104015,29
S17	80542,97		S35		110377,69
S18	110377,69				

5.3.8.1.2 Beban Satu-satuan (Beban Berjalan/ Garis Pengaruh)

➢ Beban D

- Beban q

  Sesuai buku PPPJJR 1987 untuk L = 50 m, maka:

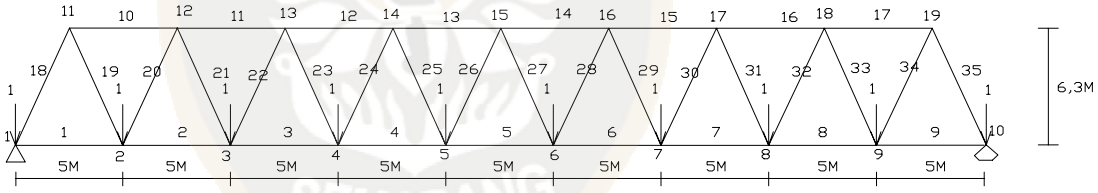
  $q = 2{,}2 - \frac{1{,}1}{60} * (L-30) = 2{,}2 - \frac{1{,}1}{60} * (50m-30) = 1{,}83$ t/m

  Untuk 1 rangka $q = \frac{1{,}83 t/m}{2} = 0{,}917 t/m$

- Beban p

  Menurut PPPJJR 1987 beban p sebesar 12 t

  Untuk 1 rangka $p = \frac{12t}{2} = 6t$



Setelah dihitung dengan program SAP 2000 maka dapat dicari pengaruh gaya batang akibat beban berjalan yaitu:

Rumus **S = (Pmax*P beban garis) + (luas bidang garis pengaruh*q)**

S1=S9 = [0,35*6t] + [(1/2*0,35*45m)*0,917 t/m] = 9,321 t

S2=S8 = [0,92*6t] + [(1/2*0,92*35m)+(1/2*0,57*5m)+((0,57+0,92)*0,5*5m) *0,917t/m] = 25,006 t

S3=S7 = [1,31*6t] + [(1/2*1,31*30m)+(1/2*1,67*10m)+((1,67+1,31)*0,5*5m) *0,917t/m] = 40,367 t

S4=S6 = [1,53*6t] + [(1/2*1,53*25m)+(1/2*2,22*15m)+((1,53+2,22)*0,5*5m) *0,917t/m] = 50,582 t

S5 = [1,58*6t] + [(1/2*1,58*45m)*0,917t/m] = 42,079 t

S10=S17= [-0,70*6t] + [(1/2*-0,70*45m)*0,917t/m] = -18,642 t

S11=S16= [-1,22*6t] + [(1/2*-1,22*45m)*0,917t/m] = -32,491 t

S12=S15= [-1,57*6t] + [(1/2*-1,57*45m)*0,917t/m] = -41,813 t

S13=S14= [-1,75*6t] + [(1/2*-1,75*45m)*0,917t/m] = -46,606 t

S18=S35= [-0,94*6t] + [(1/2*-0,94*45m)*0,917t/m] = -25,034 t

S19=S34= [0,92*6t] + [(1/2*0,92*45m)*0,917t/m] = 24,501 t

S20=S33= [-0,80*6t] + [(1/2*-0,80*39m)*0,917t/m] = -19,105 t

= [0,80*6t] + [(1/2* 0,80*6m)*0,917t/m] = 7,001 t

S21=S32= [0,81*6t] + [(1/2*0,81*36m)*0,917t/m] = 18,229 t

= [-0,81*6t] + [(1/2*-0,81*9m)*0,917t/m] = -7,088 t

S22=S31= [-0,69*6t] + [(1/2*-0,69*34m)*0,917t/m] = -14,896 t

= [0,69*6t] + [(1/2*0,69*11m)*0,917t/m] = 7,620 t

S23=S30= [0,70*6t] + [(1/2*0,70*31m)*0,917t/m] = 9,949 t

= [-0,70*6t] + [(1/2*-0,70*14m)*0,917t/m] = -8,693 t

S24=S29= [-0,57*6t] + [(1/2*-0,57*24m)*0,917t/m] = -9,692 t

= [0,57*6t] + [(1/2*0,57*21)*0,917t/m] = 5,488 t

S25=S28= [0,58*6t] + [(1/2*0,58*26m)*0,917t/m] = 10,394 t

= [-0,58*6t] + [(1/2*-0,58*19m)*0,917t/m] = -8,532 t

S26=S27= [0,46*6t] + [(1/2*0,46*45m)*0,917t/m] = 12,250 t

5.3.8.2 Kombinasi Gaya Batang

Tabel 5.3 Kombinasi Gaya Batang Rangka Utama

batang	beban mati		beban angin		beban hidup berjalan		kombinasi (kg)	
	tekan (-)	tarik(+)	tekan (-)	tarik(+)	tekan (-)	tarik(+)	tekan (-)	tarik(+)
S1		41519,85				9321		50840,85
S2		111691,35				25006		136697,35
S3		162373,42				40367		202740,42
S4		192718,2				50582		243300,2
S5		202838,16				42079		244917,16
S6		192718,2				50582		243300,2
S7		162373,42				40367		202740,42
S8		111691,35				25006		136697,35
S9		41519,85				9321		50840,85
S10	80542,97			2128,91	18642		99184,97	2128,91
S11	141225,12			5269,69	32451		173676,12	5269,69
S12	181693,18			7921	41813		223506,18	7921
S13	201932,49			9131,08	46606		248538,49	9131,08
S14	201932,49			9851,69	46606		248538,49	9851,69
S15	181693,18			9131,08	41813		223506,18	9131,08
S16	141225,12			7921	32451		173676,12	7921
S17	80542,97			5269,69	18642		99184,97	5269,69
S18	110377,69			2128,91	25034		135411,69	2128,91
S19		104015,29						104015,29
S20	81917,86				19105	7001	101022,86	7001
S21		78113,65			7088	18229	7088	96342,65
S22	55796,88				14896	7620	70692,88	7620
S23		51270,92			8693	9949	8693	61219,92
S24	29061,91				9692	5488	38753,91	5488
S25		24619,28			8532	10394	8532	35013,28
S26		2386,88				12250		14636,88
S27	2386,88					12250	2386,88	12250
S28		24619,28			8532	10394	8532	35013,28
S29	29061,91				9692	5488	38753,91	5488
S30		51270,92			8693	9949	8693	61219,92
S31	55796,88				14896	7620	70692,88	7620
S32		78113,65			7088	18229	7088	96342,65
S33	81917,86				19105	7001	101022,86	7001
S34		104015,29						104015,29
S35		110377,69			25034		25034	110377,69

5.3.8.3 Pendimensian

Untuk mempermudah perakitan profilnya maka batang–batang diagonal maupun batang-batang horisontal ukurannya dibuat sama, dengan nilai gaya yang terbesar adalah P = -248538,49 kg untuk batang tekan dan P = 244917,16 kg untuk batang tarik.

5.3.8.3.1 Batang Tekan

$L_{horisontal}$ = 500cm, $L_{diagonal}$ = 677 cm, dengan besar P = -248538,49kg.

Setelah dicoba-coba didapat profil IWF 428*407*20*35, dengan data profil :

A = 360,7 cm^2

i_{min} = iy = 10,4 cm

G = 283 kg/m

Koefisien tekuk (sendi-sendi) menurut PPBBG 87 didapat K=1

L_k = K*L = 1*677 cm = 677 cm

- Angka kelangsingan

$$\lambda = \frac{L_K}{i_{\min}} = \frac{677cm}{10{,}4cm} = 65{,}09 \le 200 \text{ (batas kelangsingan batang tekan)}$$

- Kelangsingan batas

$$\lambda g = \pi * \sqrt{\frac{E}{0{,}7 * f_y}} = \pi * \sqrt{\frac{2000000kg/cm^2}{0.7 * 2900kg/cm^2}} = 98{,}6$$

- Rasio kelangsingan

$$\lambda s = \frac{\lambda}{\lambda g} = \frac{65{,}09}{98{,}6} = 0{,}66 \le 1$$ .....termasuk batang sedang, sehingga

faktor tekuk: $\omega = \frac{1{,}41}{1{,}593 - \lambda_s} = \frac{1{,}41}{1{,}596 - 0{,}66} = 1{,}50$

- Cek tegangan

$$\sigma = \frac{P * \omega}{A} = \frac{248538{,}49kg * 1{,}50}{360{,}7cm^2} = 1038{,}21 \le \sigma = 1900 \text{ kg/cm}^2$$ .....ok

5.3.8.3.2 Batang Tarik

$L_{horisontal}$ = 500cm, $L_{diagonal}$ = 677 cm, dengan besar P = 244917,16 kg.

Dipakai profil IWF 428*407*20*35, dengan data profil :

A = 360,7 cm^2

I_{min} = Iy = 119000 cm^4

- Angka kelangsingan

$$I = \sqrt{\frac{I_{min}}{A}} = \sqrt{\frac{119000cm^4}{360,7cm^2}} = 18,16 \text{ cm}, \lambda = \frac{L}{I} = \frac{677cm}{18,16cm} = 37,27$$

≤ 240 (konstruksi utama).....ok

- Cek tegangan

Dalam PPBBG 1987 disebut bahwa *"dalam suatu potongan jumlah lobang tidak boleh lebih besar daripada 15% luas penampang utuh"*, disini dipakai 11%, sehingga besar tegangannya adalah:

$$\sigma = \frac{P}{An} = \frac{244917,16kg}{0,89 * 360,7cm^2} = 762,927 \leq \quad \sigma_r = 0,75*1900 = 1425$$

kg/cm^2...ok

5.3.8.4 Jumlah Baut

Tebal plat buhul t = 15 mm

Diameter baut d = 24 mm

- Kekuatan geser baut

Ng = m*1/4*π*d^2*τ

= 2*1/4* π*2,4^2cm*0,6*1900kg/cm^2 = 10314,78 kg

- Kekuatan tumpu plat

Ntu = d*t* σtu

= 2,4cm*1,5cm*1,2*1900kg/cm^2 = 8208 kg

Pilih yang terkecil N = 8208 kg

- Jumlah baut

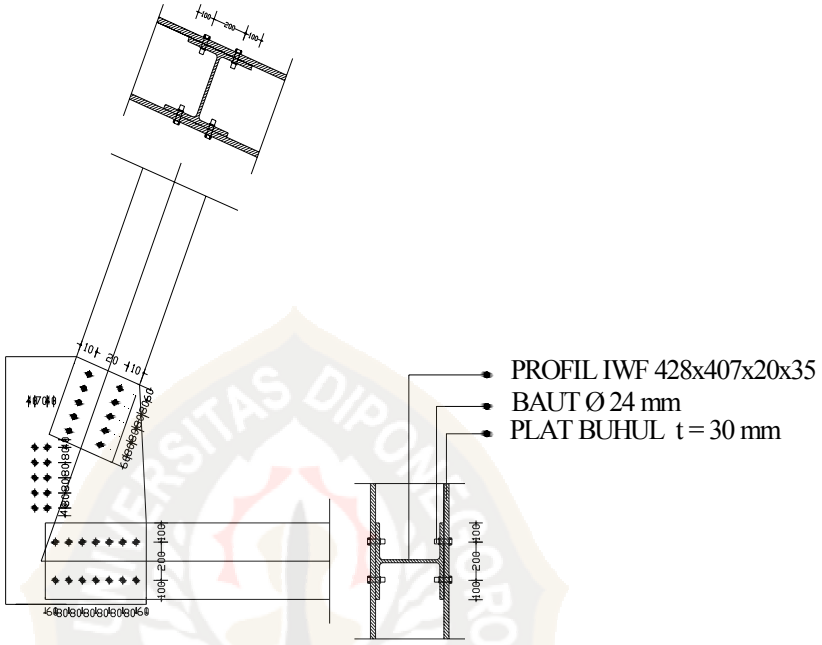
$$n = \frac{P}{N}$$

Tabel 5.4 Jumlah Baut Sambungan Rangka Utama

batang	gaya batang	gaya geser	jumlah baut	batang	gaya batang	gaya geser	jumlah baut
	P(kg)	Ng(kg)	n(buah)		P(kg)	Ng(kg)	n(buah)
S1	50840,85	8208	6	S19	104015,29	8208	14
S2	136697,35	8208	18	S20	101022,86	8208	12
S3	202740,42	8208	26	S21	96342,65	8208	12
S4	243300,2	8208	30	S22	70692,88	8208	10
S5	244917,16	8208	30	S23	61219,92	8208	8
S6	243300,2	8208	30	S24	38753,91	8208	6
S7	202740,42	8208	26	S25	35013,28	8208	4
S8	136697,35	8208	18	S26	14636,88	8208	4
S9	50840,85	8208	6	S27	12250	8208	4
S10	99184,97	8208	12	S28	35013,28	8208	4
S11	173676,12	8208	22	S29	38753,91	8208	6
S12	223506,18	8208	28	S30	61219,92	8208	8
S13	248538,49	8208	30	S31	70692,88	8208	10
S14	248538,49	8208	30	S32	96342,65	8208	12
S15	223506,18	8208	28	S33	101022,86	8208	12
S16	173676,12	8208	22	S34	104015,29	8208	14
S17	99184,97	8208	12	S35	110377,69	8208	14
S18	135411,69	8208	16				

5.4.6.4 Perhitungan Stabilitas Pelat Buhul

a. Buhul 1



Gambar 5.79 Detail Buhul 1

Tinjau Pot. A – A

Analisa Penampang :

- A bruto = 2 x 130 = 260 cm^2
- A baut = 2 x (3 x 2,4) = 14,40 cm^2
- A netto = A bruto - A netto = 260 – 14,40 = 245,6 cm^2
- Titik berat penampang pada pot. A – A

$$Y = \frac{(260\,x\,65) - ((3\,x\,2{,}4)\,x\,(12{,}5+32{,}5))}{245{,}6} = 67{,}49 \text{ cm}$$

- I_{netto} $= \left(\left(\frac{1}{12}\,x\,2\,x130^3\right) + \left(260\,x\left(65-67{,}49\right)^2\right)\right) - \left(3\,x\,2{,}4\,x\left(\left(12.5-67{,}49\right)^2 + \left(32{,}5-67{,}49\right)^2\right)\right)$

  $= (366166{,}667 + 1612{,}026) – (7{,}2 \text{ x } (3023{,}9001 + 1224{,}2001))$

  $= 337191{,}6516 \ cm^4$

- Watas $= \frac{Inetto}{H-Y} = \frac{337191{,}6516}{130-67{,}19} = 5394{,}203 \ cm^3$

- Wbawah $= \frac{Inetto}{Y} = \frac{337191{,}6516}{67{,}49} = 4996{,}172\ cm^3$

Gaya – Gaya yang bekerja :

- N = ½ x $\left(\left(\frac{115{,}56581x10}{14}\right)+\left(-309{,}924\,x\cos\ 69{,}75\right)\right)$ = -24,72 Ton
- D = ½ x (-309,24 sin 69,75) = -145,384 Ton
- M = ½ x $\left(\left(\frac{115{,}56581x10x(67{,}49-22{,}5)}{14}\right)+\left(-309{,}924\cos 69{,}75x(67{,}49-32{,}5)\right)\right)$

  = -19,79 Ton.cm

Tegangan Yang Terjadi :

- Akibat N

$$\sigma_n = \frac{N}{Anetto} = \frac{-24720}{245{,}6} = -100{,}65\,kg/cm^2$$

- Akibat D

$$\tau = \frac{D}{Anetto} = \frac{-145384}{245{,}6} = -591{,}95\,kg/cm^2$$

- Akibat M

$$\sigma_{atas} = \frac{M}{W_{atas}} = \frac{-19790}{5394{,}203} = -3{,}669\ kg/cm^2$$

$$\sigma_{bawah} = \frac{M}{W_{bawah}} = \frac{-19790}{4996{,}172} = -3{,}961\ kg/cm^2$$

Tegangan total :

σ_{atas} = 3,669 - 100,65 = -96,981 kg/cm^2

σ_{bawah} = 3,961 - 100,65 = -96,688 kg/cm^2

Tegangan idiil :

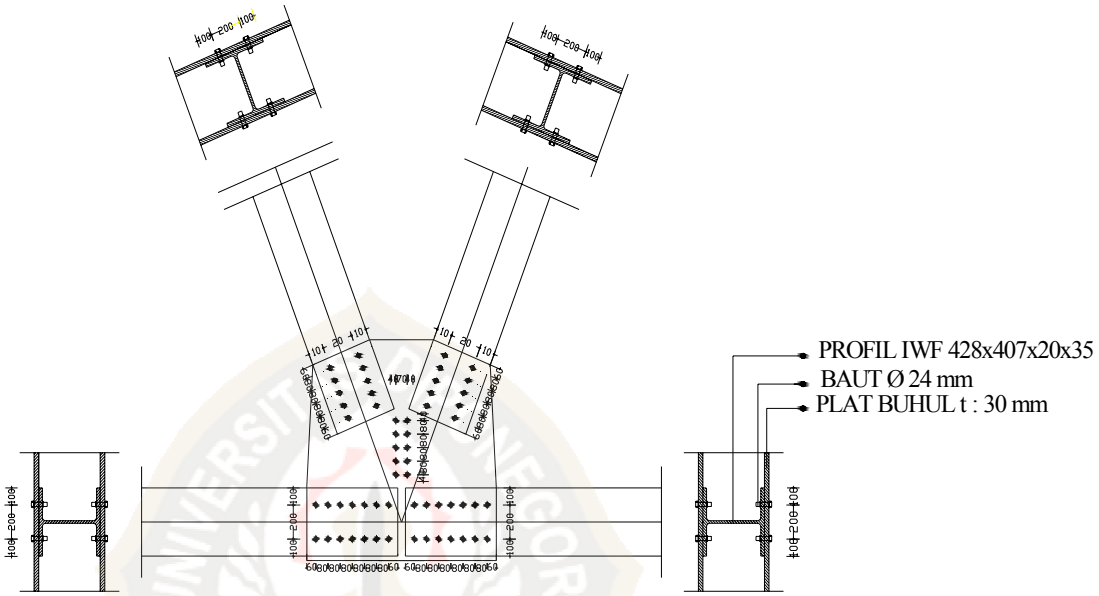
$\sigma_{idiil} = \sqrt{(96{,}981)^2 + \left(3\left(-591{,}95\right)^2\right)}$ = 1029,86 kg/cm^2

Syarat Keamanan :

$\sigma_{idiil} < \overline{\sigma}$

1029,86 kg/cm^2 < 1867 kg/cm^2 .....**OK**

b. Buhul 6



Gambar 5.80 Detail Buhul 6

Tinjau Pot. A – A

Analisa Penampang :

- A bruto = 2 x 130 = 260 cm^2
- A baut = 2 x (3 x 2,4) = 14,40 cm^2
- A netto = A bruto - A netto = 260 – 14,40 = 245,6 cm^2
- Titik berat penampang pada pot. A – A

$$Y = \frac{(260\,x\,65) - ((3\,x\,2{,}4)\,x\,(12{,}5+32{,}5))}{245{,}6} = 67{,}49 \text{ cm}$$

- $I_{netto} = \left(\left(\frac{1}{12}\,x\,2\,x\,130^3\right) + \left(260\,x\,(65-67{,}49)^2\right)\right) - \left(3\,x\,2{,}4\,x\left((12.5-67{,}49)^2 + (32{,}5-67{,}49)^2\right)\right)$

  = (366166,667 + 1612,026) – (7,2 x (3023,9001+ 1224,3001))

  = 337191,6516 cm^4

- Watas $= \frac{Inetto}{H-Y} = \frac{337191{,}6516}{130-67{,}49} = 5394{,}203\ cm^3$

- Wbawah $= \frac{Inetto}{Y} = \frac{337191{,}6516}{67{,}49} = 4996{,}172\ cm^3$

Gaya – Gaya yang bekerja :

- N = ½ x $\left(\left(\frac{604{,}390\,x10}{14}\right)+\left(-7{,}315\,x\cos\ 69{,}75\right)\right)$ = 214,587 Ton
- D = ½ x (-7,315 sin 69,75) = -3,431 Ton
- M = ½ x $\left(\left(\frac{604390\,x10x(67{,}49-22{,}5)}{14}\right)+\left(-7{,}315\cos 69{,}75x(67{,}49-32{,}5)\right)\right)$

  = 9666,958 Ton.cm

Tegangan Yang Terjadi :

- Akibat N

$$\sigma_n = \frac{N}{Anetto} = \frac{214587}{245{,}6} = 873{,}73\ kg/cm^2$$

- Akibat D

$$\tau = \frac{D}{Anetto} = \frac{-3431}{245{,}6} = -13{,}969\ kg/cm^2$$

- Akibat M

$$\sigma_{atas} = \frac{M}{W_{atas}} = \frac{9666958}{5394{,}203} = 1792{,}657\ kg/cm^2$$

$$\sigma_{bawah} = \frac{M}{W_{bawah}} = \frac{9666958}{4996{,}172} = 1934{,}873\ kg/cm^2$$

Tegangan total :

σ_{atas} = 1792,657 - 873,73 = 918,927 kg/cm^2

σ_{bawah} = 1934,873 - 873,73 = 1061,143 kg/cm^2

Tegangan idiil :

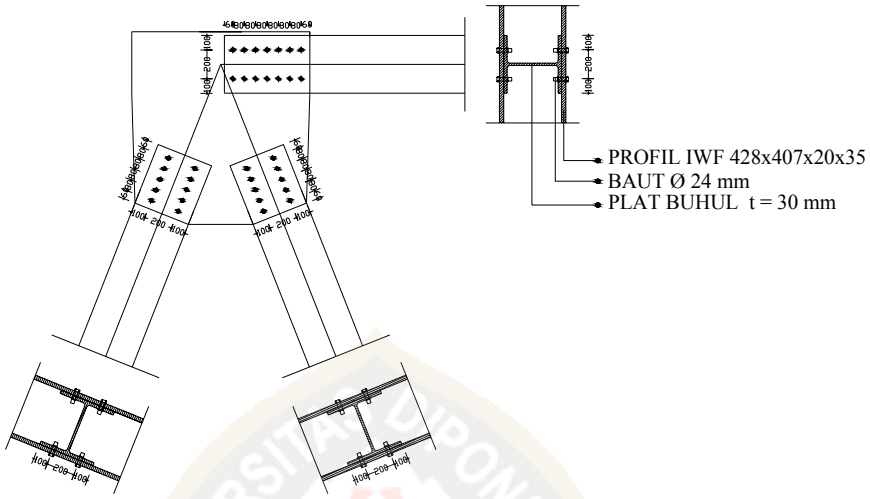
$\sigma_{idiil} = \sqrt{(1061{,}143)^2 + \left(3\left(-13{,}969\right)^2\right)}$ = 1061,418 kg/cm^2

Syarat Keamanan :

$\sigma_{idiil} < \overline{\sigma}$

1061,418 kg/cm^2 < 1867 kg/cm^2 .....**OK**

c. Buhul 12



Gambar 5.81 Detail Buhul 12

Tinjau Pot. A – A

Analisa Penampang :

- A bruto = 2 x 130 = 260 cm^2
- A baut = 2 x (3 x 2,4) = 14,40 cm^2
- A netto = A bruto - A netto = 260 – 14,40 = 245,6 cm^2
- Titik berat penampang pada pot. A – A

$$Y = \frac{(260\,x\,65) - ((3\,x\,2{,}4)\,x\,(12{,}5+32{,}5))}{245{,}6} = 67{,}49 \text{ cm}$$

- $I_{netto} = \left(\left(\frac{1}{12}\,x\,2\,x\,130^3\right) + \left(260\,x\,(65-67{,}49)^2\right)\right) - \left(3\,x\,2{,}4\,x\left((12.5-67{,}49)^2 + (32{,}5-67{,}49)^2\right)\right)$

  = (366166,667 + 1612,026) – (7,2 x (3023,9001+ 1224,3001))

  = 337191,6516 cm^4

- Watas $= \frac{Inetto}{H-Y} = \frac{337191{,}6516}{130-67{,}49} = 5394{,}203\ cm^3$
- Wbawah $= \frac{Inetto}{Y} = \frac{337191{,}6516}{67{,}49} = 4996{,}172\ cm^3$

Gaya – Gaya yang bekerja :

- N = ½ x $\left(\left(\frac{-221{,}375\,x10}{14}\right)+\left(266{,}916\,x\cos\ 69{,}75\right)\right)$ = -32,8705 Ton
- D = ½ x (266,916 sin 69,75) = 125,209 Ton
- M = ½ x $\left(\left(\frac{-221{,}375x10x(67{,}49-22{,}5)}{14}\right)-\left(266{,}916x\cos 69{,}75x(67{,}49-32{,}5)\right)\right)$

  = -10346,566 Ton.cm

Tegangan Yang Terjadi :

- Akibat N

$$\sigma_n = \frac{N}{Anetto} = \frac{32870{,}5}{245{,}6} = 133{,}838\ kg/cm^2$$

- Akibat D

$$\tau = \frac{D}{Anetto} = \frac{125209}{245{,}6} = 509{,}808\ kg/cm^2$$

- Akibat M

$$\sigma_{atas} = \frac{M}{W_{atas}} = \frac{10346566}{5394{,}203} = 1618{,}089\ kg/cm^2$$

$$\sigma_{bawah} = \frac{M}{W_{bawah}} = \frac{10346566}{4996{,}172} = 1770{,}898\ kg/cm^2$$

Tegangan total :

σ_{atas} = 1618,089 - 133,838 = 1484,251 kg/cm^2

σ_{bawah} = 1770,898 - 133,838 = 1637,6 kg/cm^2

Tegangan idiil :

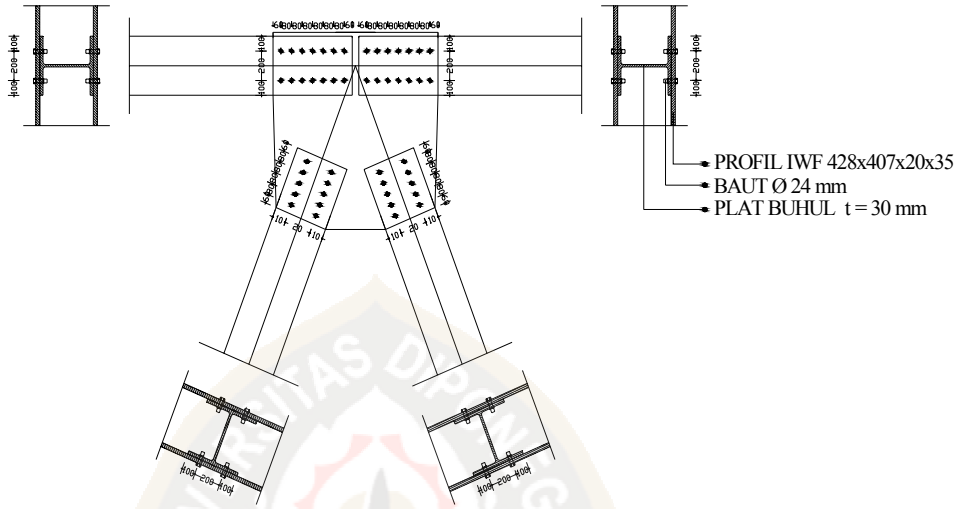
$\sigma_{idiil} = \sqrt{(1637{,}06)^2 + \left(3\ (-509{,}808)^2\right)}$ = 1860,02 kg/cm^2

Syarat Keamanan :

$\sigma_{idiil} < \overline{\sigma}$

1860,02 kg/cm2 < 1867 kg/cm^2 .....**OK**

d. Buhul 16



Gambar 5.82 Detail Buhul 16

Tinjau Pot. A – A

Analisa Penampang :

- A bruto = 2 x 130 = 260 cm^2
- A baut = 2 x (3 x 2,4) = 14,40 cm^2
- A netto = A bruto - A netto = 260 – 14,40 = 245,6 cm^2
- Titik berat penampang pada pot. A – A

$$Y = \frac{(260\,x\,65) - ((3\,x\,2{,}4)\,x\,(12{,}5+32{,}5))}{245{,}6} = 67{,}49 \text{ cm}$$

- I_{netto} $= \left(\left(\frac{1}{12}\,x\,2\,x\,130^3\right) + \left(260\,x\,(65-67{,}49)^2\right)\right) -$
$\left(3\,x\,2{,}4\,x\left((12.5-67{,}49)^2 + (32{,}5-67{,}49)^2\right)\right)$
$= (366166{,}667 + 1612{,}026) - (7{,}2 \text{ x } (3023{,}9001 + 1224{,}3001))$
$= 337191{,}6516 \text{ cm}^4$
- Watas $= \frac{Inetto}{H-Y} = \frac{337191{,}656}{130-67{,}49} = 5394{,}203 \text{ cm}^3$
- Wbawah $= \frac{Inetto}{Y} = \frac{337191{,}656}{67{,}49} = 4996{,}172 \text{ cm}^3$

Gaya – Gaya yang bekerja :

- N = ½ x $\left(\left(\frac{-616{,}587\,x10}{14}\right)+\left(32{,}236\,x\cos\ 69{,}75\right)\right)$ = -214,631 Ton
- D = ½ x (32,236 sin 69,75) = 15,12 Ton
- M = ½ x $\left(\left(\frac{-616{,}587x10x(67{,}49-22{,}5)}{14}\right)-\left(32{,}236x\cos 69{,}75x(67{,}49-32{,}5)\right)\right)$

  = -10102,430 Ton.cm

Tegangan Yang Terjadi :

- Akibat N

$$\sigma_n = \frac{N}{Anetto} = \frac{214631}{245{,}6} = 873{,}904\ kg/cm^2$$

- Akibat D

$$\tau = \frac{D}{Anetto} = \frac{15120}{245{,}6} = 61{,}56\ kg/cm^2$$

- Akibat M

$$\sigma_{atas} = \frac{M}{W_{atas}} = \frac{10102430}{5394{,}203} = 1872{,}830\,kg/cm^2$$

$$\sigma_{bawah} = \frac{M}{W_{bawah}} = \frac{10102430}{4996{,}172} = 2622{,}034\ kg/cm^2$$

Tegangan total :

σ_{atas} = 1872,830 - 873,904 = 998,926 kg/cm^2

σ_{bawah} = 2022,034 - 873,904 = 1148,130 kg/cm^2

Tegangan idiil :

σ_{idiil} = $\sqrt{(1148{,}130)^2 + \left(3\ (61{,}56)^2\right)}$ = 1153,070 kg/cm^2

Syarat Keamanan :

$\sigma_{idiil} < \overline{\sigma}$

1153,070 kg/cm2 < 1867 kg/cm^2 .....**OK**

5.4.6.5 Lendutan dan Lawan Lendut (*camber*) Rangka Utama

1. Lendutan rangka utama

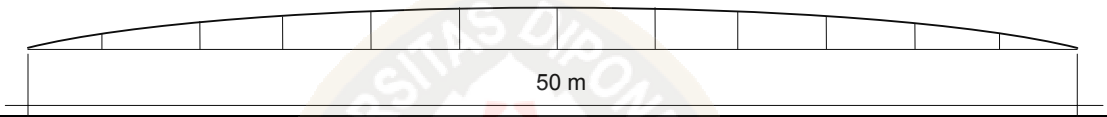
Lendutan dicek pada keadaan elastis, sedangkan hasil *output* program SAP 2000 didapatkan lendutan total (akibat beban tetap dan sementara) ditengah bentang adalah sebesar 141 mm $\leq$ lendutan ijin maksimal teoritis jembatan rangka baja *Centunion* Spanyol 156mm.

2. Lawan lendut/*camber* rangka utama

Sedangkan untuk memberikan kenyamanan bagi pengguna lalu lintas yang lewat jembatan ini, diberikanlah lawan lendut/*camber*.

Camber untuk jembatan rangka baja dari peraturan *Transfield* Australia yaitu:

a. *Camber* 1 bentang jembatan rangka tipe A-50



I	0	50	91	123	146	160	164	160	146	123	91	50	0
II	0	42	76	102	120	131	135	131	120	102	76	42	0
III	0	27	48	63	75	79	81	79	75	63	48	27	0

Ket:

Kondisi I = Kelengkungan awal teoritis

Kondisi II = Kelengkungan setelah pekerjaan ereksi rangka baja termasuk *metal deck*

Kondisi III = Kelengkungan setelah pekerjaan ereksi rangka baja,*metal deck* dan pekerjaan beton

b. Jembatan rangka 2 bentang tipe A-50