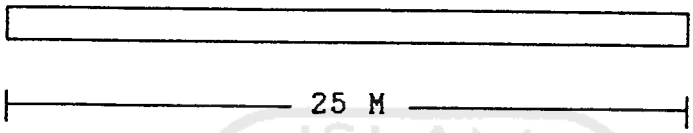
BAB IV

DESAIN

BALOK BETON PRATEGANG TAMPANG T

4.1. Perencanaan balok prategang sistem pasca tarik (Post Tension)



Diketahui:

L = 25 M
fpu = 1860 Mpa
fpy = 0,85 fpu
= 0,85 (1860)
= 1581 Mpa
f´c = 45 Mpa
U_{36} = 3600 kg/cm^2
= 360 N/mm^2
= 360 Mpa
20% (LOP)
R = (1 - 0.2)
= 0,8

Tegangan ijin

1. Tegangan beton ijin awal.

- Serat desak : f_{ci} = 0,6.f´c
= 0,6.(45)
= 27 Mpa

- Serat tarik : f_{ti} = 0,25.√f´c
= 0,25.√45
= 1,677 Mpa

2. Tegangan beton ijin akhir.

- Serat tarik : $f_{ts} = 0,5.\sqrt{f'c}$
  $= 0,5.\sqrt{45}$
  $= 3,354$ Mpa

- Serat desak : $f_{cs} = 0,45.(f'c)$
  $= 0,45.(45)$
  $= 20,25$ Mpa

a) Menghitung momen

- Akibat berat sendiri balok (Wo=11 KN/M)

$$Mo = 1/8.g.l^2$$
$$= 1/8\ (11)\ (25)^2$$
$$= 859,375\ KN\text{-}M$$

- Akibat beban mati (Wda=27,8362 KN/M)

$$Mda = 1/8.g.l^2$$
$$= 1/8\ (27,8362)\ (25)^2$$
$$= 2174,7031\ KN\text{-}M$$

- Akibat beban hidup (Wl=8,75 KN/M)

$$Ml = 1/8.g.l^2$$
$$= 1/8\ (8,75)\ (25)^2$$
$$= 683,5937\ KN\text{-}M$$

b) Menghitung modulus penampang rencana (e.variable)

$$S_a = \frac{(1-R)\ Mo + (Md + Ml)}{R.f_{ti} - f_{cs}}$$

$$= \frac{[\ (1-0,8)\ 859,375 + (2858,2968)]\ 10^6}{0,8\ (1,677) - (-20,25)}$$

$$= 140340308,3\ mm^3$$

$$S_b = \frac{(1-R)\,Mo + (Md + Ml)}{f_{ts} - R.f_{ci}}$$

$$= \frac{[\,(1-0,8)\;859,375 + (2858,2968)]\;10^6}{3,354 - 0,8\;(-27)}$$

$$= 121430303,8\ mm^3$$

Sebagai perencanaan diambil S yang terbesar yaitu Sa = 140340308,3 mm^3

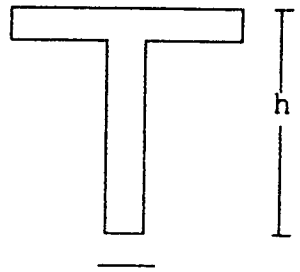
c) Perhitungan dimensi penampang (l=25 m)

Diambil : $h = \frac{1}{17} L - \frac{1}{25} L$

$$= \frac{1}{17}(25) - \frac{1}{25}(25)$$

$$= 1,47 - 1,00$$

Dipakai h = 1,3 m



Menentukan lebar badan profil (b_w)

ambil : $\frac{b_w}{b} = 0,3$

$\frac{h_f}{h} = 0,2$

$C_t = 0,374.h$
$C_b = 0,626.h$
$I_c = 0,0408.bh^3$
$A_c = 0,440.bh$

$$S_t = \frac{I_c}{C_t} = \frac{0,0408.bh^3}{0,374.h}$$

$$= 0,1091.bh^2$$

$$S_b = \frac{I_c}{C_b} = \frac{0,0408.bh^3}{0,626.h}$$

$$= 0,0652.bh^2$$

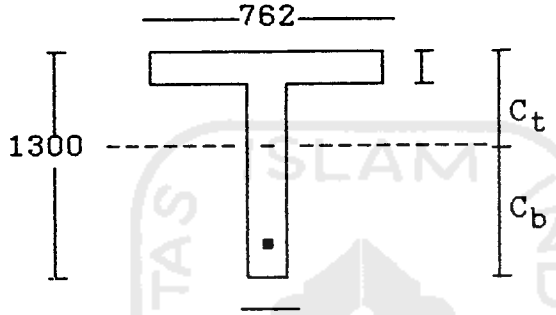
$S_a = S_t \longrightarrow 140340308,3 = 0,1091.bh^2$

$$b = \frac{140340308,3}{0,1091.(1300)^2}$$

$b = 761,8495$ mm $\approx$ 762 mm

Maka dimensi penampang:

$h = 1300$ mm
$b = 762$ mm
$h_f = 0{,}2.h = 260$ mm
$b_w = 0{,}3.b = 229$ mm
$A_c = 0{,}440.bh = 130988\ mm^2$
$I_c = 0{,}0408.bh^3 = 2{,}0527.10^{10}\ mm^4$



$C_t = 0{,}374.h = 486{,}2$ mm

$C_b = h - C_t = 813{,}8$ mm

* Luas flens : $A_f = 762.260 = 198120\ mm^2$
Luas webb : $A_w = 1040.229 = 238160\ mm^2$ +

$A_c = A_f + A_w = 436280\ mm^2$

$Wo = A_c . bj$
$= 436280.10^{-6} . 24$
$= 10{,}4707$ KN/M < Wo taksiran = 11 KN-M

$Mo = 1/8.Wo.l^2$
$= 1/8.10{,}4707.(25)^2$
$= 818{,}025$ KN-M < 859,375 KN-M

f_{ps} = 0,82.fpy
= 0,82.1581
= 1296,4 Mpa

dipakai:

f_{ps} = 1296,4 Mpa

Luas baja prategang yang diperluhkan

$$A_{ps} = \frac{P_i}{f_{ps}}$$

$$= \frac{3947,5478.10^3}{1296,4}$$

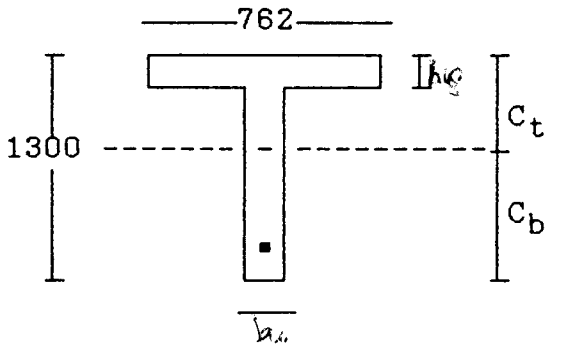
$$= 3045,0075 \text{ mm}^2$$

dipakai sesuai tabel VSL

P_i = 3947,5478 KN dipakai type 22Sc

luas selongsong prategang (A_s) = 6361,725 mm^2

f) Rencana letak tendon



C_t = 0,374.h
= 486,2 m

C_b = h - C_t
= 813,8 m

Perencanaan PASCA TARIK dipakai Ac netto

$A_{cnetto} = Ac - A_s$
$= 436280 - 6361,725$
$= 429918,2749\ mm^2$

Mencari garis netral

$C_t = [hf.bf\ (1/2.hf) + bw.hw.(hf+hw/2)$
$- A_s.(h-d')]/A_{cnetto}$
$= [260.762.(130) + 229.1040.(260+1040/2)$
$- 6361,725(1300-150)] / 429918,2749$
$= 474,9842\ mm$

$C_b = h - C_t$
$= 1300 - 474,9842$
$= 824,0158\ mm$

$ER = C_b - d'$
$= 824,0158 - 150$
$= 674,0158\ mm$

$I_{cnetto} = 1/12.b_f.h_f^3 + A_f.(C_t-h_f/2)^2$
$+ 1/12.b_w.h_w^3 + A_w.(C_b-h_w/2)^2$
$- A_s \cdot ER^2$
$= 1/12.762.260^3$
$+ 762.260.(474,9842-260/2)^2$
$+ 1/12.229.1040^3$
$+ 229.1040.(824,0158-1040/2)^2$
$- 6361,7251.(674,0158)^2$
$= 6,52832.10^{10}\ mm^4$

$S_a = I_{cnetto}/C_t$

$= 6,52832.10^{10}/474,9842$

$= 137442887,6\ mm^33$

$S_b = I_{cnetto}/C_b$

$= 6,52832.10^{10}/824,0158$

$= 79225665,33\ mm^3$

g) Menghitung eksentrisitas

* Serat atas

$$E = (f_{ti}-f_{cci}).\frac{S_a}{P_i} + \frac{Mo}{P_i}$$

$$E = (10,72519).\frac{137442887,6}{3947547,823} + \frac{818,025.10^6}{3947547,823}$$

$= 580,8129$ mm

* Serat bawah

$$E = (f_{cci}-f_{ci}).\frac{S_b}{P_i} + \frac{Mo}{P_i}$$

$$E = (17,95181).\frac{79225665,33}{3947547,823} + \frac{818,025.10^6}{3947547,823}$$

$= 567,4726$ mm

dipakai E = 580,8129 mm

i) Kontrol tegangan beton dan tendon
Sistem Pasca Tarik (post tension) dengan grouting

Beban mati sudah bekerja 75%

$Wd = 0,75.16,8362 = 12,627$ KN/M

$Wd = 12,6271 + 10,47072$

$= 23,0977$ N/M

$Md = 1/8.Wo.L^2$

$= 1/8.23,0977.(25)^2$

$= 1804,50937$ KN-M

- Tegangan Beton
  * Pada saat Transfer

Serat atas

$$f_a = -\frac{P_i}{Ac_{net}} + \frac{P_i.E.C_t}{I_{c\ net}} - \frac{Mo.C_t}{I_{c\ net}} \leq 0,25\sqrt{fc'}$$

$$= -\frac{3947547,82}{429918,275} + \frac{3947547,82.580,813.474,99}{6,52832.10^{10}}$$

$$- \frac{1804,509.10^6.474,99}{6,52832.10^{10}}$$

$= -5,62949$ Mpa $<$ 1,677 Mpa

Serat bawah

$$f_b = -\frac{P_i}{Ac_{net}} - \frac{P_i.E.C_b}{I_{c\ net}} + \frac{Mo.C_b}{I_{c\ net}} \leq -0,6.fc'$$

$$= -\frac{3947547,82}{429918,275} + \frac{3947547,82.580,813.824,01}{6,52832.10^{10}}$$

$$- \frac{1804,509.10^{6}.824,01}{6,52832.10^{10}}$$

$$= -15,3451 \text{ Mpa} < -27 \text{ Mpa}$$

- Tegangan tendon

$$f_{si} = P_i/A_{ps}$$

$$= 3947547823/3045,0075$$

$$= 1296,4 \text{ Mpa}$$

$$f_{ct} = \frac{(h-d').f_b}{h}$$

$$= \frac{(1300-150).-15,3451}{1300}$$

$$= -13,574 \text{ Mpa}$$

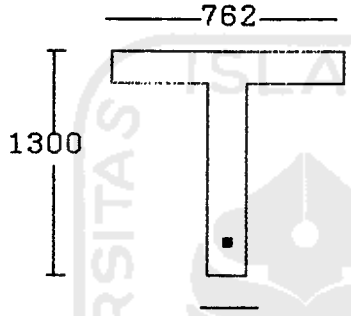
$f_{se} = f_{si} + n.f_{ct}$

$= 1296,4 + 6.(-13,574)$

$= 1214,952$ Mpa

- Tegangan Beton
  * Pada saat akhir (layan)

dipakai penampang transformasi



Perencanaan PASCA TARIK dipakai At

$A_t = Ac + Ac'$

$= 436280 + (6-1).3045,0075$

$= 451505,0375\ mm^2$

Mencari garis netral

$C_t = [hf.bf\ (1/2.hf) + bw.hw.(hf+hw/2)$

$- Ac'.(h-d')]/A_t$

$= [260.762.(130) + 229.1040.(260+1040/2)$

$- 3045,0075.(1300-150)] / 451505,0375$

$= 429,6997$ mm

$C_b = h - C_t$

$= 1300 - 429,6997$

$= 870,3003$ mm

$ER = C_b - d'$

$= 870,3003 - 150$

$= 720,3003$ mm

dipakai E = 720,3003 mm

$I_t = 1/12.b_f.h_f^3 + A_f.(C_t-h_f/2)^2$
$+ 1/12.b_w.h_w^3 + A_w.(C_b-h_w/2)^2$
$+ Ac \ . \ ER^2$
$= 1/12.762.260^3$
$+ 762.260.(429,6997-260/2)^2$
$+ 1/12.229.1040^3$
$+ 229.1040.(870,3003-1040/2)^2$
$+ 3045,0075.(720,3003)^2$
$= 7,750116.10^{10}$ mm^4

Beban mati sudah bekerja 100 %

$Wd = 16,8362$ KN/M

$Wd' = 16,8362 + 10,47072$

$= 27,3069$ N/M

$$Md' = 1/8.Wd'.L^2$$

$$= 1/8.27,3069.(25)^2$$

$$= 2133,3531 \text{ KN-M}$$

$$Mt = Md' + Ml$$

$$= 2133,3531 + 683,5937$$

$$= 2816,9468 \text{ KN-M}$$

Serat atas

$$f_a = -\frac{P_e}{A_t} + \frac{P_e.E.C_t}{I_c} - \frac{Mt.C_t}{I_c} \leq 0,45.f'c$$

$$= -\frac{3158038,25}{451505,037} + \frac{3158038,25.720,30.429,69}{7,750116.10^{10}} - \frac{2816,9468.10^6.429,69}{7,750116.10^{10}}$$

$$= -10,0072 \text{ Mpa} \leq 20,25 \text{ Mpa}$$

Serat bawah

$$f_b = -\frac{P_e}{A_t} - \frac{P_e.E.C_b}{I_c} + \frac{Mt.C_b}{I_c} \leq 0,5.\sqrt{f'c}$$

$$= -\frac{3158038,25}{451505,037} - \frac{3158038,25.720,30.870,30}{7,750116.10^{10}} + \frac{2816,9468.10^6.870,30}{7,750116.10^{10}}$$

$$= -0,9056 \text{ Mpa} \leq 3,354 \text{ Mpa}$$

- Tegangan tendon

$f_{ct} = (d'/h).f_a - f_b$

$= (150/1300).10,0072 - 0,9056$

$= -2,0602$ Mpa

$f_s = f_{si} + n.f_c$

$= 1296,4 + 6.(-2,0602)$

$= 1284,0383$ Mpa $< f_{si} = 1296,45$ Mpa

j) Menghitung kapasitas momen

$f'c = 45$ Mpa
$P_e = 3158038,258$ N
$A_{ps} = 3045,0075$ mm^2
$f_{pu} = 1860$ Mpa

Metode pendekatan SKSNI-T15.1991

$f'c \geq 30$ Mpa $= 45$ Mpa
$fpu \geq 1700$ Mpa $= 1860$ Mpa
$fsc \geq 0,5\ fpu$

$$\rho_p = \frac{A_{ps}}{b.(h-d')}$$

$$= \frac{3045,0075}{762.115}$$

$= 0.003474$

$$f_{ps} = f_{pu}\left[1 - \frac{\tau_p \cdot \rho_p \cdot f_{pu}}{\beta 1 \ . \ f'c}\right]$$

$\rightarrow fpy/fpu = 0,85$

$\delta_p = 0,4$

$\beta_1 = 0,850-0,008.(45-30) = 0,73$

$$f_{ps1} = 1860\left[1 - \frac{0,4 \;.\; 0,003474 \;.\; 1860}{0,73 \;.\; 45}\right]$$

$$= 1713,6541 \text{ Mpa}$$

$$w_p = \frac{\rho_p \cdot f_{ps1}}{f'c} \leq 0,36\beta_1 \text{ atau } q \leq 0,3$$

$$= \frac{0,003474.1713,6541}{45} = 0,132 < 0,3$$

Maka besarnya f_{ps1} dengan (Tulangan non-prategang tidak diperhitungkan) adalah :

Menentukan letak garis netral daerah desak

$$a = \frac{A_{ps} \cdot f_{ps1}}{0,85.\beta_1.b.f'c}$$

$$= \frac{3045,0075.1713,6541}{0,85.0,73.762.45}$$

$$= 245,246 < hf=260 \text{ mm (disayap)}$$

Karena $w_p < 0,3$

$$Mn = A_{ps}.f_{ps1}.[(h-d')-(a/2)]$$

$$= 3045,0075.1713,6541.[(1150)-(122,623)]$$

$$= 5360945225 \text{ N-mm}$$

$$= 5360,945225 \text{ KN-M}$$

$$M_{ultimit} = 1,2.Md' + 1,6.Ml$$

$$= 1,2.(2133,3531) + 1,6.(683,5937)$$

$$= 3653773640 \text{ N-mm}$$

$$= 3653,77364 \text{ KN-M}$$

$$Mn \text{ perlu} = \frac{M_{ult}}{\phi}$$

$$= \frac{3653,77364}{0,8}$$

$$= 4567,2170 \text{ KN-M} < 5360,9452 \text{ KN-M}$$

4.2. Perencanaan balok Prategang Parsial 15% sistem pasca tarik (Post tension)

a) Gaya Prategang Awal

$$P_{ip} = 0,85.P_i$$
$$= 0,85.3947547,823$$
$$= 3355415,65 \text{ N}$$

$$P_{ep} = 0,80.P_{ip}$$
$$= 0,80.3355415,65$$
$$= 2684332,52 \text{ N}$$

b) Luas Baja Prategang

$$A_{psp} = \frac{P_{ip}}{f_{ps1}}$$

$$= \frac{3355415,65}{1713,6541}$$

$$= 1958,0472 \text{ mm}^2$$

dipakai tendon VSL type 19Sc

luas selongsong prategang (A_s) = 5541.769 mm^2

c) Luas baja non-prategang yang diperluhkan

$$Mnp = A_{psp}.f_{ps1}.[(h-d')-a/2] + A_s.f_y.[(h-40)-a/2]$$

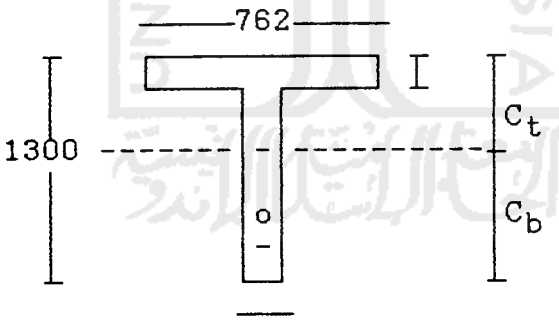
$$A_{sn} = \frac{Mnp - A_{psp}.f_{ps1}.[(h-d')-a/2]}{f_y.[(h-d')-a/2]}$$

$$= \frac{4567,2170.10^6 - 3447,2768.10^6}{360.[(1260)-245,246/2]}$$

$$= \frac{1119940200}{409455,72}$$

$$= 2735,1924 \text{ mm}^2$$

d) Rencana letak tendon



$C_t = 0,374.h$
$= 486,2$ m

$C_b = h - C_t$
$= 813,8$ m

Perencanaan PASCA TARIK dipakai Ac netto

$$A_{cnetto} = Ac - A_s - (n-1).A_{sn}$$
$$= 436280 - 5541.769 - (7-1).2735,1924$$
$$= 414327,0766 \text{ mm}^2$$

Mencari garis netral

$$C_t = [hf.bf\ (1/2.hf) + bw.hw.(hf+hw/2) - A_s.(h-d') - (n-1).A_{sn}.(h-40)] / A_{cnetto}$$

$$= [260.762.(130) + 229.1040.(260+1040/2) - 5541,769.(1300-150) - (7-1).2735,1924.(1260)] / 414327,0766$$

$$= 445,2262 \text{ mm}$$

$$C_b = h - C_t$$
$$= 1300 - 445,2262$$
$$= 854,7737 \text{ mm}$$

$$ER = C_b - d'$$
$$= 854,7737 - 150$$
$$= 704,7737 \text{ mm}$$

$$I_{cnetto} = 1/12.b_f.h_f^3 + A_f.(C_t-h_f/2)^2 + 1/12.b_w.h_w^3 + A_w.(C_b-h_w/2)^2 - [A_s.ER^2 + (n-1).A_{sn}.(C_b-40)^2]$$

$$= 1/12.762.260^3 + 762.260.(445,2262-260/2)^2 + 1/12.229.1040^3 + 229.1040.(854,7737-1040/2)^2 - [5541,769.(704,7737)^2 + 6.2735,1924.(854,7737-40)^2]$$

$$= 5,53130.10^{10} \text{ mm}^4$$

$S_a = I_{cnetto}/C_t$

$= 5,53130.10^{10}/445,2262$

$= 124235859,5\ mm^3$

$S_b = I_{cnetto}/C_b$

$= 5,53130.10^{10}/854,7737$

$= 64710768,69\ mm^3$

e) Menghitung eksentrisitas

* Serat atas

$$E = (f_{ti}-f_{cci}).\frac{S_a}{P_i} + \frac{Mo}{P_i}$$

$$E = (10,72519).\frac{124235867,5}{3947547,823} + \frac{818,025.10^6}{3947547,823}$$

$= 544,7630\ mm$

* Serat bawah

$$E = (f_{cci}-f_{ci}).\frac{S_b}{P_i} + \frac{Mo}{P_i}$$

$$E = (17,95181).\frac{64710768,69}{3947547,823} + \frac{818,025.10^6}{3947547,823}$$

$= 567,4726\ mm$

dipakai E = 544,763 mm

f) Kontrol tegangan beton dan tendon
Sistem Pasca Tarik (post tension) dengan grouting

Beban mati sudah bekerja 75%

$Wd = 0,75.16,8362 = 12,627$ KN/M

$Wd = 12,6271 + 10,47072$

$= 23,0977$ N/M

$Md = 1/8.Wo.L^2$

$= 1/8.23,0977.(25)^2$

$= 1804,50937$ KN-M

- Tegangan Beton

* Pada saat Transfer

Serat atas

$$f_a = -\frac{P_i}{Ac_{net}} + \frac{P_i.E.C_t}{I_{c\ net}} - \frac{Mo.C_t}{I_{c\ net}} \leq 0,25\sqrt{fc'}$$

$$= -\frac{3947547,82}{414327,076} + \frac{3947547,82.544,763.445,22}{5,53130.10^{10}}$$

$$- \frac{1804,509.10^6.445,22}{5,53130.10^{10}}$$

$= -6,7428$ Mpa $<$ 1,677 Mpa

Serat bawah

$$f_b = -\frac{P_i}{Ac_{net}} - \frac{P_i.E.C_b}{I_{c\ net}} + \frac{Mo.C_b}{I_{c\ net}} \leq -0,6.fc'$$

$$= -\frac{3947547,82}{414327,076} + \frac{3947547,82.544,763.854,77}{5,53130.10^{10}}$$

$$- \frac{1804,509.10^{6}.854,77}{5,53130.10^{10}}$$

$$= -14,8739 \text{ Mpa} < -27 \text{ Mpa}$$

- Tegangan tendon

$$f_{si} = 1296,45$$

$$f_{ct} = \frac{(h-d').f_b}{h}$$

$$= \frac{(1300-150).-14,8739}{1300}$$

$$= -13,1576 \text{ Mpa}$$

$$f_{se} = f_{si} + n.f_{ct}$$

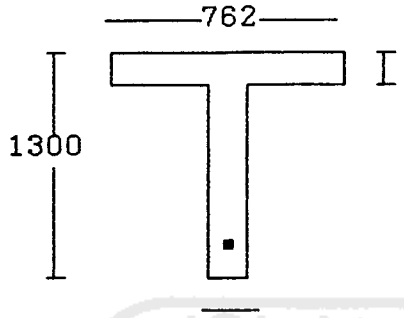
$$= 1296,45 + 6.(-13,1576)$$

$$= 1217,504 \text{ Mpa}$$

- Tegangan Beton

  * Pada saat akhir (layan)

    dipakai penampang transformasi



Perencanaan PASCA TARIK dipakai At

$A_t = Ac + Ac' + A_{sn}$
$= 436280 + (6-1)_2 1958,047 + (7-1).2735,1924$
$= 462481,3904\ mm^2$

Mencari garis netral

$C_t = [hf.bf\ (1/2.hf) + bw.hw.(hf+hw/2)$
$- Ac'.(h-d') - A_{sn}.(h-40)] / A_t$
$= [260.762.(130) + 229.1040.(260+1040/2)$
$- (6-1).1958,0472.(1300-150)$
$- (7-1).2735,1924(1300-40)] / 462481,3904$
$= 388,3044\ mm$

$C_b = h - C_t$
$= 1300 - 388,3044$
$= 911,6955\ mm$

$ER = C_b - d'$

$= 911,6955 - 150$

$= 761,6955$ mm

dipakai E = 761,6955 mm

$$I_t = 1/12.b_f.h_f^3 + A_f.(C_t-h_f/2)^2 + 1/12.b_w.h_w^3 + A_w.(C_b-h_w/2)^2 + (n-1).Ac'.ER^2 + (n-1).A_{sn}.(C_b-40)$$

$$= 1/12.762.260^3 + 762.260.(388,3044-260/2)^2 + 1/12.229.1040^3 + 229.1040.(911,6955-1040/2)^2 + (6-1).1958,0472.(761,6955)^2 + (7-1).2735,1924.(911,6955-40)$$

$= 9,049097.10^{10}$ mm^4

Beban mati sudah bekerja 100 %

Wd = 16,8362 KN/M

Wd' = 16,8362 + 10,47072

= 27,3069 N/M

$Md' = 1/8.Wd'.L^2$

$= 1/8.27,3069.(25)^2$

$= 2133,3531$ KN-M

$Mt = Md' + Ml$

$= 2133,3531 + 683,5937$

$= 2816,9468$ KN-M

Serat atas

$$f_a = -\frac{P_e}{A_t} + \frac{P_e.E.C_t}{I_c} - \frac{Mt.C_t}{I_c} \leq 0,45.f'c$$

$$= -\frac{3158038,25}{462481,390} + \frac{3158038,25.761,69.388,30}{9,049097.10^{10}} - \frac{2816,9468.10^6.388,30}{9,049097.10^{10}}$$

$= -8,5941$ Mpa $\leq 20,25$ Mpa

Serat bawah

$$f_b = -\frac{P_e}{A_t} - \frac{P_e.E.C_b}{I_c} + \frac{Mt.C_b}{I_c} \leq 0,5.\sqrt{f'c}$$

$$= -\frac{3158038,25}{462481,390} - \frac{3158038,25.761,69.911,69}{9,049097.10^{10}} + \frac{2816,9468.10^6.911,69}{9,049097.10^{10}}$$

$= -2,6826$ Mpa $< 3,354$ Mpa

- Tegangan tendon

$f_{ct} = (d'/h).f_a - f_b$

$= ((150/1300).-8,5941) - 2,6826$

$= -2,5834$ Mpa

$f_s = f_{si} + n.f_c$

$= 1296,4 + 6.(-2,5834)$

$= 1280,8993$ Mpa $< f_{si} = 1296,45$ Mpa

g) Menghitung kapasitas momen

$$\rho = \frac{A_{sn}}{b.(h-40)}$$

$$= \frac{2735,1924}{762.1260}$$

$$= 0.002848$$

$$\rho_p = \frac{A_{psp}}{b.(h-d')}$$

$$= \frac{1958,0472}{762.1150}$$

$$= 0.002234$$

$$f_{ps} = f_{pu}\left[\,1 - \frac{\tau_p \cdot \rho_p \cdot f_{pu}}{\beta 1 \;.\; f'c}\,\right]$$

$\rightarrow$ fpy/fpu = 0,85

δ_p = 0,4

β_1 = 0,850-0,008.(45-30) = 0,73

$$f_{ps1} = 1860\left[1 - \frac{0,4 \;.\; 0,002234 \;.\; 1860}{0,73 \;.\; 45}\right]$$

= 1765,8904 Mpa

$$w_p = \frac{\rho_p \cdot f_{ps1}}{f'c}$$

$$= \frac{0,002234.1765,8904}{45} = 0,087$$

$$w = \frac{\rho \cdot f_y}{f'c}$$

$$= \frac{0,002848.360}{45} = 0,0227$$

$w = w_p + w \leq 0,3$

$= 0,087 + 0,0227$

$= 0,1097 \leq 0,3$

Maka besarnya f_{ps1} dengan (Tulangan non-prategang tidak diperhitungkan) adalah :

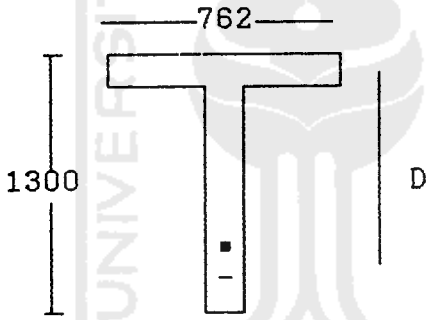
Menentukan letak garis netral daerah desak

$$a' = \frac{A_{ps} \cdot f_{ps1} + A_{sn} \cdot f_y}{0,85 . \beta_1 . b . f'c}$$

$$= \frac{1958,0475 . 1765,8904 + 2735,1924 . 360}{0,85 . 0,73 . 762 . 45}$$

$$= 208,7878 < hf = 260 \text{ mm} \quad (\text{disayap})$$

Karena $w_p < 0,3$



$$D = \frac{A_{psp} \cdot f_{ps1} \cdot (H-DD) + A_{sn} \cdot f_y \cdot (H-40)}{A_{psp} \cdot f_{ps1} + A_{sn} \cdot f_y}$$

$$= \frac{3457696,75 . (1150) + 984669,26 . (1260)}{1958,0472 . 1765,8904 + 2735,1924 . 360}$$

$$= 1174,3819 \text{ mm}$$

$$Mn = A_{psp}.f_{ps1}.(D-(a'/2) + A_{sn}.f_y.(D-(a'/2))$$

$$= 1958,0472.1765,8904.(1069,988)$$

$$+ 2735,1924.360.(1069,988)$$

$$= 4753278330 \text{ N-mm}$$

$$= 4753,278330 \text{ KN-M}$$

$$M_{ultimit} = 1,2.Md' + 1,6.Ml$$

$$= 1,2.(2133,3531) + 1,6.(683,5937)$$

$$= 3653773640 \text{ N-mm}$$

$$= 3653,77364 \text{ KN-M}$$

$$Mn \text{ perlu} = \frac{M_{ult}}{\phi}$$

$$= \frac{3653,77364}{0,8}$$

$$= 4567,2170 \text{ KN-M} < 4753,2783 \text{ KN-M}$$