BAB V
ANALISIS TAMPANG ELEMEN

5.1 Umum

Langkah selanjutnya dalam analisis portal ini adalah pemeriksaan kekuatan masing-masing elemen struktur. Pemeriksaan kekuatan elemen struktur ini meliputi:

a) kekuatan pelat ,

b) kekuatan balok,

c) kekuatan kolom,

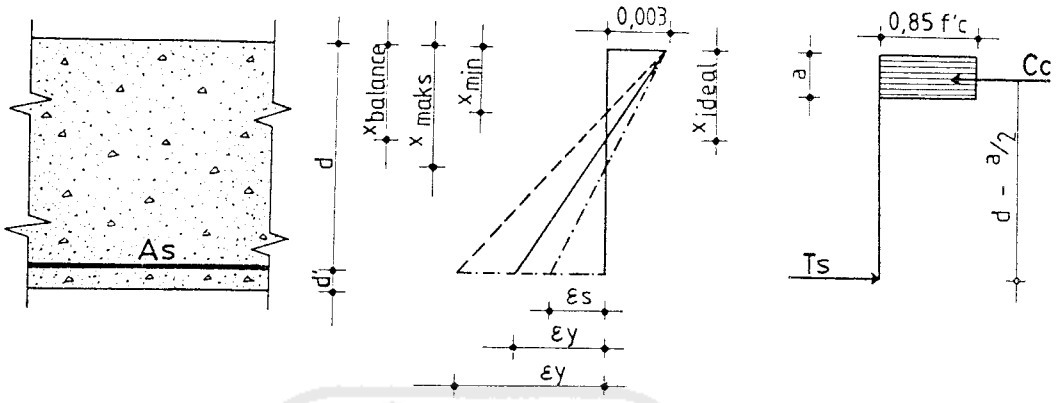
d) kekuatan sambungan (baut).

dalam mendukung beban baru akibat terjadinya perubahan perilaku struktur karena kurangnya satu balok induk.

Pengerjaan pemeriksaan kekuatan elemen struktur ini menggunakan cara pengerjaan yang mengacu pada referensi dan rumus-rumus yang telah disebutkan pada bab terdahulu.

Hasil akhir dari pemeriksaan kekuatan elemen struktur ini, berupa perbandingan dari perhitungan analisis kekuatan tampang elemen struktur dengan hasil perhitungan mekanika portal. Elemen struktur akan diketahui aman atau tidaknya dari hasil perbandingan tersebut.

5.2 Beban Batas Pada Pelat



Gambar 5.1 Diagram tegangan pelat

Plat terjepit sempurna pada keempat sisinya :

$$\frac{ly}{lx} = \frac{9200}{5575} = 1.6502 < 2 \text{ (pelat dua arah)}$$

Kapasitas Momen Tulangan Arah *lx*

Data lapangan:

Tebal pelat 130 mm , tulangan D12 - 200 mm

fy = 400 MPa , f'c = 35 MPa $\beta 1 = 0,81$

d' = 20 + 12/2 = 26 mm

d = 130 - 26 = 104 mm

As = As'(tulangan tumpuan sama dengan tulangan lapangan)

Penyelesaian:

As = $(1000. 0,25 . \pi .12^2) / 200 = 565,4867 \text{ mm}^2$

$$xb = \frac{0{,}003.d}{0{,}003 + fy / Es}$$

$$= \frac{600.d}{600 + fy} = \frac{600.104}{600 + 400} = 62{,}4 \text{ mm}$$

x max $= 0{,}75 \,.\, xb$

$= 0{,}75 \,.\, 62{,}4 = 46{,}8$ mm

a max $= 0{,}81 \,.\,$ x max

$= 0{,}81 \,.\, 46{,}8 = 37{,}91$ mm

Cc $= 0{,}85.\, f'c.\, b.\, a$

Cc $=$ Ts $=$ As. fy

As.fy $= 0{,}85.\, f'c.\, b.\, a$

a $= As.fy / (0{,}85.f'c.b)$

$= 565{,}4867 \,.\, 400/(0{,}85.35.1000)$

$= 7{,}6032$ mm $<$ a max $= 37{,}91$ mm

maka:

Mn $= As \,.\, fy\, (d - ½.a)$

$= 565{,}4867 \,.\, 400\, (\, 104 - ½.7{,}6032) = 22664347$ Nmm

Mn^{+} (lap) $=$ Mn^{-} (tumpuan) $= 22664347$ Nmm

Kapasitas Momen Tulangan Arah *ly*

Data lapangan:

Tebal pelat 130 mm , tulangan D10 - 200 mm

fy $= 240$ MPa , f'c $= 35$ MPa

d' = 20 + 12 +10/2 = 37 mm

d = 130 - 37 = 93 mm

As = 1000.0,25 .π. 10^2/200 = 392,6991 mm^2

penyelesaian:

$$x\,b = \frac{600.d}{600 + fy} = \frac{600.93}{600 + 240} = 66{,}4286 \text{ mm}$$

x max = 0,75. x b

= 0,75 . 66,4286 = 49,8217 mm

Ts = Cc

As.fy = 0,85 . f'c. b. a

a = As.fy /(0,85. F'c . b)

= 392,6991 . 240 / (0,85 .35. 1000)

= 3,168 mm

Mn = Ts (d-a/2)

= 392.6991 . 240 .(93 - 3,168/2)

= 8615755,764 Nmm

Mn^+ (lap) = Mn^- (tumpuan) = 8615755,764 Nmm

-Perhitungan beban batas dengan teori garis leleh

Mnn$x$ + Mnp$x$ = 22664347 + 22664347 = 45,3287 KNm

Mnny + Mnpy = 8615755,764 + 8615755,764 = 17,2315 KNm

$$\frac{Mnny + Mnpy}{Mnnx + Mnpx} = \frac{17{,}2315}{45{,}3287} = 0{,}3802 < a^2/b^2 = 1{,}6502$$

Mennghitung panjang x

$4.a.(Mnnx+Mnpx) \cdot x^2 + 4.b^2.(Mnny + Mnpy).x - 3.a.b^2.(Mnny + Mnpy) = 0$

$4 \cdot 9,2.(45,3287).x^2 + 4.5,575^2.(17,2315).x - 3.9,2.5.5575^2.(17,2315) = 0$

$1668,0959 \cdot x^2 + 2142,2646 \cdot x - 14781,6257 = 0$

$x^2 + 1.2843 \cdot x - 8,8614 = 0$

$x = 2,4032$ m

Beban batas yang terjadi Wu/∅:

$$\frac{Wu}{\varnothing} = \frac{12.(b^2 \cdot (Mnny + Mnpy) + 2.a.x.(Mnnx+Mnpx)}{b^2.(3.a.x - 2.x^2)}$$

$$= \frac{12.(5,575^2.(17,2315) + 2.9,2 \cdot 2,403^2 (45,3287)}{5,575^2 (3.9,2.2,403 - 2.2,4032^2)}$$

$= 17.9025$ KN/m^2

$$\frac{Wu}{\varnothing} = \frac{24.a.(Mnnx + Mnpx)}{2.b^2.x + 3.b^2.(a - 2.x)}$$

$$= \frac{24.9,2(45,3287)}{2.5,575^2\ 2.4032 + 3 \cdot 5,575^2 \cdot (9,2 - 2.2,403^2)}$$

$= 17,9025$ KN/m^2

$$\frac{Wu}{\varnothing} = \frac{6.(Mnny + Mnpy)}{x^2}$$

$$= \frac{6.(17,2315)}{2,4032^2}$$

$= 17,9025$ KN/m^2

Jadi beban merata yang terjadi pada pelat tersebut :

q ult $= \varnothing.Wu$

$= 0,8 \ 17,9025$

$= 14,3220 \ KN/m^2 > q = 10,144 \ KN/m^2$

Pelat tersebut aman untuk mendukung beban walaupun terjadi pembesaran bentang akibat balok induk yang tidak dicor.

5.3 Balok

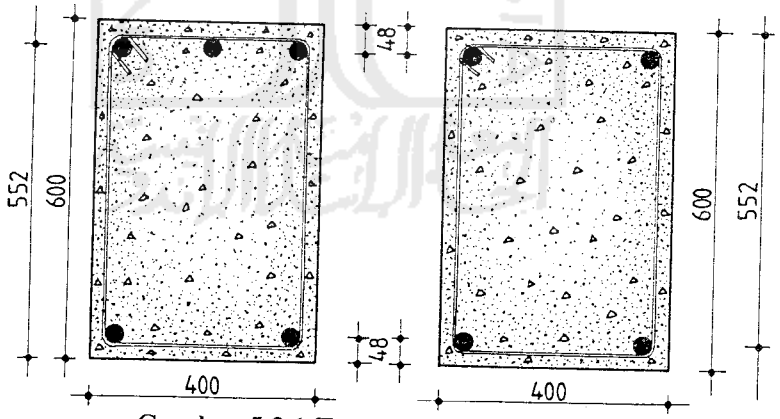
5.3.1 Balok Induk B-8

a . Bagian Lapangan

Dari tampang yang terdapat dilapangan didapat data sebagai berikut:

d' = 25 + 12 + 22/2 =48 mm; As=As'= 2.AD22= $2.\pi.0,25.22^2 = 760,2654 \ mm^2$,

fy = 400 MPa , f'c = 35 MPa , $\beta = 0,81$.



Gambar 5.3.1 Tampang balok B-8

Penyelesaian :

d = 600 - 48 = 552 mm

Mengacu pada prinsip keseimbangan

$Ts = Cc + Cs$

$Ts = As.fy = 760,2654 \cdot 400 = 304106,1689\ mm^2$

$Cc = 0,85 \cdot f'c.\ b.\beta 1.x$

$Cs = ((x - d') / x \cdot 0,003.\ Es - 0,85\ .f'c)\ .As'$

maka :

$Ts = Cs + Cc$

$304106,1689 = 0,85.f'c.b.\beta 1.x + ((x - d') / x.),003.Es - 0,85.fd'c).\ As'$

$$304106,1689 = 0,85.\ 35.400.0,81.x + \frac{((x-48)/x.0,003.2.10^5 - 0,85.35)}{760.2654}$$

$9639.x^2 + 456159,253.x - 21995644,16 - 22617,896.x = 304106,1689.x$

$9639.x^2 + 129435,1881.x = 2189644,16 = 0$

$x^2 + 13,4283 - 2271,5680 = 0$

$x = 41,4174\ mm$

$a = 0,81\ .41,4174 = 33,5481\ mm$

Apabila daerah beton desak tidak dikurangi luasan tulangan atas maka :

$304106,1689 = 0,85 \cdot 35.400.0,81.x + ((x - 48)/x \cdot 0,003.2.10^5.\ 760,2654)$

$304106,1689 = 9639.x + 456159,24 - 21895643,52/x$

$9639.x^2 + 172053,0711.x - 21895643 = 0$

$x^2 + 15,778.x + 2271,5679 = 0$

$x = 40,4218\ mm$

$a = 0,81.40,4218 = 32,7417\ mm$

Kontrol kesetimbangan

$Cc = 0.85.f'c.b.a = 0{,}85.35.400.32{,}7417$

$= 389625{,}8477$ N

$\varepsilon's = (d'-x)/x \,.\, 0.003 = \dfrac{(48-40{,}4218)}{40{,}4218} .0{,}003$

$= 0.00056 \leq fy/Es = 0{,}002$ Baja desak belum leleh

$Ts' = \varepsilon's.\, Es.\, As' = 0{,}00056 \,.\, 2.10^5 \,.\, 750{,}2654$

$= 85519{,}6788$ N

$Ts = As.fy = 760{,}2654 \,.\, 400 = 304106{,}16$ N

$Cc = Ts' + Ts = 85519{,}6788 + 304106{,}16$

$= 389625{,}8388$ N ok .....

Kapasitas Momen Tampang:

$Mn = Ts'.(d' - a/2) + Ts.(d - a/2)$

$= 85519{,}6788 \left(48 - \dfrac{32{,}7147}{2}\right) + 304104{,}16\left(552 - \dfrac{32{,}7147}{2}\right)$

$= 165593045$ Nmm

$Mu = \varphi.Mn = 0{,}8 \,.\, 165593045 =$ **132474436** Nmm

Perhitungan kapasitas tampang dengan balok B-8 dianggap tulangan sebelah

$a = \dfrac{As.fy}{0{,}85.f'c.b} = \dfrac{760{,}2654.400}{0{,}85.35.400}$

$= 25{,}5551$ mm

x = 25,5551/0,81 = 31,5496 mm

$\varepsilon's = \frac{d'-x}{x} . 0,003 = \frac{48-31,5496}{31,5496} . 0,003$

= 0,00156 < fy/Es =0,002 Baja belum leleh

Kontrol kapasitas momen :

Mn = As.fy.(d - a/2)

$= 760,2654 . 400 . (552 - \frac{25,5551}{2}) = 163980687,30$ Nmm

Mu = φ.Mn = 0,8 . 163980687,30 = **131184639,9** Nmm

b. bagian tumpuan

Dari data di lapangan didapat:

As = 3.D22 = 1140,3981 mm^2: As' = 2.D22 = 760,2654 mm^2 : d' = 48 mm

d = 600-48 = 552 mm: f'c = 35 MPa: fy = 400 MPa

$\rho' = As' / b.d = \frac{760,2654}{400.552} = 0,00344$

$\rho = As / b.d = \frac{1140,3981}{400.552} = 0,00516$

Penyelesaian:

As1 = As - As' = 1140,3981 - 760,2654

= 380,1327 mm^2

ρ - ρ' = 0,0051 - 0,00344 = 0,00172

Untuk mengontrol tulangan tekan sudah leleh

$$\rho - \rho' \geq \frac{0.85.f'c.d'}{fy.d} \cdot \frac{600}{600 - fy}$$

$$\geq \frac{0,85.35.48}{400.552} \cdot \frac{600}{600 - 400}$$

$$\geq 0,0194$$

$\rho - \rho' = 0,00172 < 0,0194$ maka tukangan tekan belum leleh

$Cc + Cs = Ts$

$0,85 . f'c . b . \beta 1 . x + ((x-d')/x . 0,003 . Es - 0.85 . f'c) As' = As . fy$

$0,85 .35 . 400.0,81 . x + ((x-48)/x .2.10^5 - 0,85.35) 760,2654 = 1140,3981 .$

400

$9639 . x^2 + 456159,24 . x - 21895643,52 - 22617,897 . x = 456159,24 .$

$9639 . x^2 + 22617,8957 . x + 21895643,52 = 0$

$x^2 + 2,3465 . x - 2271,5679 = 0$

$x = 48,8487$ mm

$a = 0,81 . 48,8487 = 39,5674$ mm

Apabila luas daerah desak tidak dikurangi luasan tulangan

$Cc + Cs = Ts$

$0,85 . f'c . b.\beta 1 . x + (x-d') / x . 0,003. Es. As' = As . fy$

$0,85. 35.400.0.81. x + (x-48) / x . 0,003 . 2.10^5. 760,2654 = 1140,3981$

$.400$

$9639.x^2 - 21895643,52 = 0$

$$x^2 = \frac{21895643,52}{9639}$$

x = 47,6609 mm

a = 0,81 . 47,6609 = 38,6054 mm

Kontrol keseimbangan:

Cc = 0,85 . 35 . 400. 38,6054

= 459404,0791 N

$\varepsilon's = (d'- x) / x \,.0,003 = \frac{(48 - 47,6609)}{47,6609} \,.0,003$

$\varepsilon's$ = 0,000021 < εy = 0,002 tulangan desak belum luluh

Ts' = $\varepsilon's$. Es . As'

= 0,000021 . 2.10^5. 760,2654

= 3244,8391 N

Ts = As . fy

= 1140,3981 . 400

= 456159,24 N

Cc = Ts' + Ts

= 3244,8391 + 456159,24

= 459404,071 N ------- ok

Kontrol kapasitas momen tampang:

Mn = Ts' (d'-a/2) + Ts (d-a/2)

= 3244,8391 (48 - 38,6054/2) + 456159,24 (552 - 38,6054/2)

= 243087917,10 Nmm

Mu = φ.Mn = 0,8. 243087917,10

= **194470333,70** Nmm

Perhitungan kapasitas tampang dengan balok dianggap tulangan sebelah:

Cc = Ts

0,85 .f'c . b . a = As . fy

$$a = \frac{1140.400}{0,85.35.400} = 38,3327 \text{ mm}$$

x = 38,327/0,81 = 47,3243

$$\varepsilon's = (d'-x)/x.0,003 = \frac{48-47,3243}{47,3243} . 0,003 = 0,000043$$

Cc = 0,85 . 35 . 400 . 38,3327 = 456159,13 N

Ts = As . fy = 1140,3981 .400 = 456159,24 N

Kontrol kapasitas Momen tampang

Mn = Ts. (d-a/2)

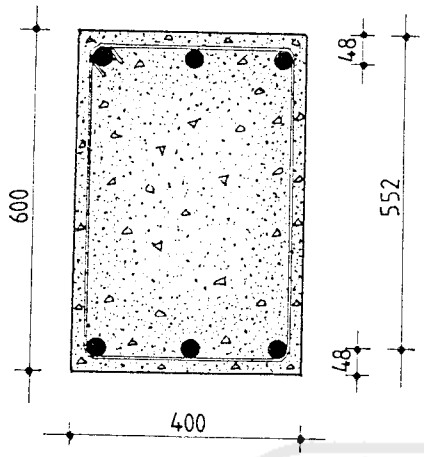
= 456159,24 . (552 - 38,3327/2)

= 243056992,8 Nmm

Mu = φ.Mn = 0,8 . 243056992,8

= **192285594,24** Nmm

5.3.2 Balok B - 37



h = 600 mm , b = 400 mm

d' = 25 + 12 + 22/2 =48 mm

d = 600 - 48 = 552 mm

f'c = 35 MPa , β = 0,81

fy = 400 MPa

Gambar 5.3.2 Tampang Balok B-37

$As = As' = 3 . D22 = 3 .0,25 .\pi . 22^2 = 1140,381\ mm^2$

$Ts = Cc + Cs$

$As.fy = (0,003 . (x-d')/x . Es - 0,85 . f'c) As' + 0,85 . f'c . b. \beta 1. x$

$1140,3981. \ 400 = (0,003.(\frac{x-48}{x}). \ 2.10^5 - 0.85. \ 35).1140,3981 + 0,85.$

$35.400.0,81.x$

$456159,24 = 684238,86 - \frac{32843465,28}{x} - 3326,8435 + 9639 . x$

$9639.x - \frac{32843465,28}{x} + 191452,7765 = 0$

$9639.x^2 + 191452,7765.x - 32843465,28 = 0$

$x^2 + 20,1424.x - 3407,3519 = 0$

$x = 49,1638$ mm

Apabila luas beton desak tidak dikurangi luasan tulangan desak maka,

$Ts = Cs + Cc$

$As \cdot fy = 0{,}85.f'c.b.\beta 1.x + (x - d')/x \cdot 0{,}003 \cdot Es \cdot As'$

$$1140{,}3981.400 = 0{,}85.35.400.0{,}81.x + \frac{x-48}{x} \cdot 0{,}003 \cdot 2.10^5 \cdot 1140{,}3981$$

$$456159{,}24 = 9639.x + 684238{,}86 - \frac{32843465{,}28}{x}$$

$$9639 \cdot x^2 + 228079{,}62 \cdot x - 32843465{,}28 = 0$$

$$x^2 + 23{,}6622 \cdot x - 3407{,}3519 = 0$$

$x = 47{,}7248$ mm

$a = 0{,}81 \cdot 47{,}7248 = 38{,}6599$ mm

Kontrol keseimbangan

$Cc = 0{,}85 \cdot f'c \cdot b \cdot a$

$= 0{,}85 \cdot 35 \cdot 400 \cdot 38{,}6599$

$= 460053{,}5971$ N

$\varepsilon's = (d'-x)/x \cdot 0{,}003$

$$= \frac{(48 - 47{,}7284)}{47{,}7284} \cdot 0{,}003$$

$= 0.000017 < fy/Es = 0{,}002$ baja tekan belum luluh

$Ts' = \varepsilon's \cdot Es \cdot As'$

$= 0{,}000017 \cdot 2 \cdot 10^5 \cdot 1140{,}3981$

$= 3894{,}3571$ N

$Ts = As \cdot fy = 1140{,}3981 \cdot 400$

$= 456159{,}24$ N

Cc = Ts' + Ts

= 3894,3571 + 456159,24

= 460053,5971 N -------- ok

Kapasitas momen tampang

Mn = Ts' . (d'-a/2) + Ts . (d-a/2)

= 3894,3571. (48 - 38,6599/2) + 456159,24 . (552 - 38,6599/2)

= 243094001,40 Nmm

Mu = φ. Mn = 0,8 . 243094001,40

= **194475201,10** Nmm

5.3.3 Balok Anak B - 21

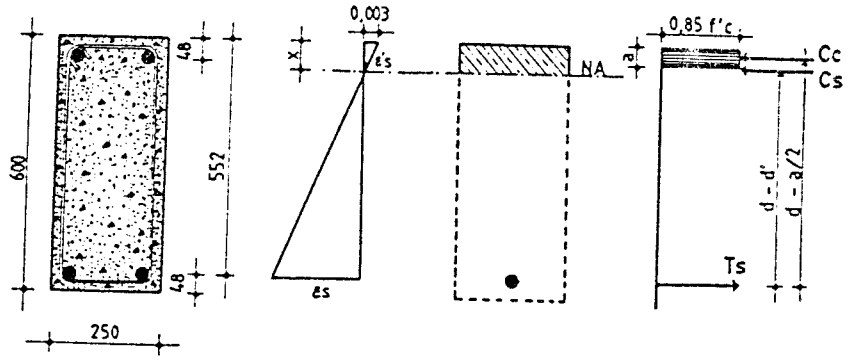
Data :

d' = 25 + 22/2 + 12 = 48 mm

d = 552 mm

As = As' = 2 . D22 = 760,2654 mm^2

f'c = 35 MPa ,β1 = 0,81 ; fy = 400 MPa



Gambar 5.3.3 Tampang Balok Anak B-21

-penyelesaian

Ts = Cc + Cs

As.fy = 0,85.F'c.b.β1.x +((x-d')/x.0,003.Es - 0,85.f'c) As'

$$760,2654.400 = 0,85.35.250.0.81.x + \left(\left(\frac{x-48}{x}\right).0,003 .2.10^5 - 0,85.35\right)760,2654$$

304106, 16.x = 6024,375 x^2 + ((x - 48). 600 - 2975.x).760,2654

6024,375. x^2 + 456159,24 . x - 21895643,52 - 226178957 . x - 304106,16 . x = 0

6024,375. x^2 + 129435,1844.x - 21895643,52 = 0

x^2 + 21,4852 . x - 3634,5087 = 0

x = 50,4939 mm ,

a = 0,81 . 50,4939

= 40,9 mm

Kontrol keseimbangan

Cc = 0.85.f'c.b.a

= 0,85 . 35 .250 . 40,9

= 304194,3487 N

$$\varepsilon's = \frac{50,4939-48}{50,4939} . 0,003 = 0,000148 < fy/Es = 0,002$$

Cs = (0.000148 . 2.10^5 - 0,85 . 35) 760,2654

= -114,03981 N

Ts = 760,2654 . 40 = 304106,16 N

Kontrol kapasitas momen tampang

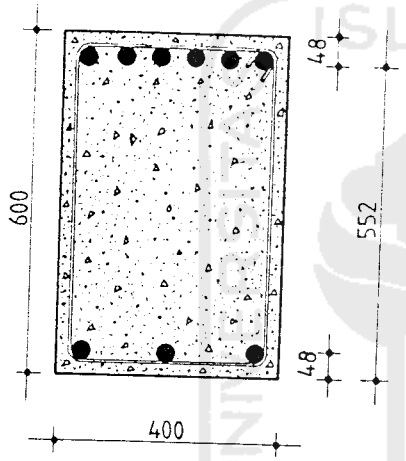
Mn = Cc (d-a/2) + Cs (d - d')

= 304194,34194 (552 - 40,9/2)+ 114,03981 (552 - 48) = 161751982,54 Nmm

Mu = φ.Mn = 0,8 . 161751982,54 = **129401586,032** Nmm

5.3.4 Balok B-1

- Bagian Tumpuan Kiri



Dari data dilapangan di-peroleh:

d'= 25 +12 + 22/2 = 48 mm

b = 400 ; h = 600

f'c = 35 MPa ; fy = 400 MPa

Gambar 5.3.4 Tampang Balok B-1

As' = 3 D 22 = 1140,381 mm2; As = 6 D 22 = 2280,7962 mm2

$$\rho = \frac{As}{b.d} = \frac{2280,7962}{400..552} = 0,01033$$

$$\rho' = \frac{As'}{bd} = \frac{1140,3981}{400.552} = 0,00516$$

$\rho - \rho' = 0,01033-0,00516 = 0,00516$

Kontrol lelehnya tulangan tekan

$$\rho - \rho' \geq \frac{0{,}85.0{,}81.f'c.d'}{fy.d} \cdot \frac{600}{600 - fy}$$

$$\rho - \rho' \geq \frac{0{,}85.0{,}81.35.48}{400.552} \cdot \frac{600}{600 - 400}$$

$\rho - \rho' \geq 0{,}0152$

$0{,}00516 < 0{,}0152$ jadi tulangan tekan belum leleh

$Ts = Cc + Cs$

$As.fy = 0{,}85.f'c.b.\beta 1.x + ((x\text{-}d')/x.0{,}003.Es - 0{,}85.f'c)\ As'$

$$2280{,}7962.400 = 0{,}85.35.400.0{,}81.x + ((\frac{x - 48}{x}).0{,}003\ .2.10^5 - 0{,}85.35)1140{,}398$$

$912318{,}48.x = 9639.x^2 + ((x\text{-}48).600 - 29{,}75.x).1140{,}398$

$9639.x^2 + 684238{,}8.x - 32843462{,}40 - 33926{,}8405.x = 0$

$9639.x^2 + 650311{,}96.x - 32843462{,}40 = 0$

$x^2 + 27{,}1819.x - 3407{,}3516 = 0$

$x = 73{,}5248$ mm ,

$a = 0{,}81\ .\ 73{,}5248$

$= 59{,}551$ mm

Maka,

$Cc = 0{,}85.f'c.a.b$

$= 0{,}85.35.59{,}551.400$

$= 708705{,}5956$ N

$$\varepsilon s' = \frac{(x - d')}{x} .0{,}003 = \frac{(73{,}5248 - 48)}{73{,}5248} . 0{,}003 = 0{,}00104 < 0{,}002$$

$$Cs = (\frac{x - d'}{x} .0{,}003. 2.10^5. - 0{,}85.35)$$

$$= (\frac{73{,}5248 - 48}{73{,}5248} .0{,}003.2.10^5 - 0{,}85.f'c)$$

$$= 203612{,}8844 \text{ N}$$

$$Ts = Cc + Cs$$

$$912318{,}48 \text{ N} = 708705{,}5956 \text{ N} + 203612{,}8844 \text{ N}$$

$$= 912318{,}48 \text{ N} \quad \text{Ok}$$

Kapasitas Momen Tampang

$$Mn = Cc. (d-½.a) + Cs.(d-d')$$

$$= 708705{,}5956.(552-½.59{,}551) + 203612{,}8844.(552-48)$$

$$= 472722869 \text{ Nmm}$$

$$Mu = \varphi. Mn = 0{,}8.472722869$$

$$= \mathbf{378178295{,}20} \text{ Nmm}$$

- Bagian Lapangan

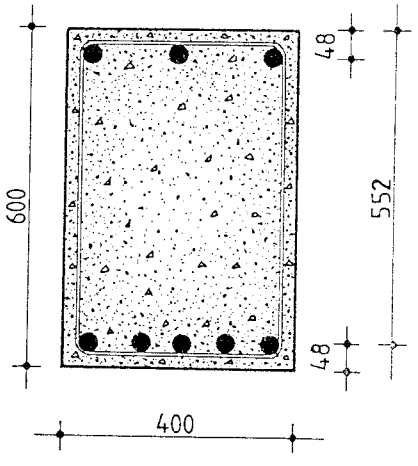
d = 25 + 12 + 22/2 = 48 mm

b = 400 mm ; h = 600 mm

d'= 600-48 = 552 mm

As = 3 D 22 = 1140,390 mm^2

As'= 5 D 22 = 1900,664 mm^2



f'c = 35 MPa ; fy = 400 MPa

$$\rho = \frac{As}{b.d} = \frac{1900.644}{400..552} = 0{,}0086$$

$$\rho' = \frac{As'}{bd} = \frac{1140{,}3981}{400.552} = 0{,}00516$$

$\rho - \rho' = 0.0086 - 0{,}00516 = 0{,}00345$

Kontrol lelehnya tulangan tekan

$$\rho - \rho' \geq \frac{0.85.0.81.f'c.d'}{fy.d} \cdot \frac{600}{600 - fy}$$

$$\rho - \rho' \geq \frac{0{,}85.0.81.35.48}{400.552} \cdot \frac{600}{600 - 400}$$

$\rho - \rho' \geq 0{,}01572$

$0{,}00345 < 0{,}01572$ jadi tulangan tekan belum leleh

Ts = Cc + Cs

$As.fy = 0{,}85.f'c.b.\beta 1.x + ((x\text{-}d')/x.0{,}003.Es - 0{,}85.f'c)\ As'$

$$1900{,}644.400 = 0{,}85.35.400.0{,}81.x + ((\frac{x - 48}{x}).0{,}003\ .2.10^5 - 0{,}85.35)1140{,}398$$

$760265{,}422.x = 9639.x^2 + ((x\text{-}48).600 - 29{,}75.x).1140{,}398$

$9639.x^2 + 684238.8.x - 32843462{,}40 - 33926{,}8405.x = 760265{,}4222\ .x$

$x^2 - 11{,}4071.x - 3407{,}3516 = 0$

x = 64,3541 mm ,

a = 0,81 . 64,3541

= 52,1268 mm

Maka,

Cc = 0,85.f'c.a.b

= 0,85.35.52,1268.400

= 620308,9981 N

$\varepsilon s' = \frac{(x - d')}{x}.0{,}003 = \frac{(64{,}3541 - 48)}{64.3541}.\ 0{,}003 = 0{,}00076 < 0{,}002$

$Cs = (\frac{x - d'}{x}.0{,}003.\ 2.10^5.\ - 0{,}85.f'c).As'$

$= (\frac{64{,}3541 - 48}{64{,}3541}.0{,}003.2.10^5 - 0{,}85.35).1140{,}398$

= 139956,4353 N

Ts = As.fy = 1900,644 . 400 = 760265,4222 N

Ts = Cc + Cs

760265,4222 N = 620308,991 N + 139956,4353 N

= 760265,4222 N Ok

Kapasitas Momen Tampang

Mn = Cc. (d-½.a) + Cs.(d-d')

= 620308,991.(552-½.59,551) + 139956,4353.(552-48)

= 396781246,80 Nmm

Mu = φ.Mn

= 0,8.396781246,80

= **317424997,40** Nmm

- Bagian Tumpuan Kanan

Spesifikasi bahan sama dengan bagian lain kecuali,

As'= 4 D 22 = 1520,531 mm^2

As = 7 D 22 = 2660,929 mm^2

d = 600 - 63 = 537 mm

$$\rho = \frac{As}{b.d} = \frac{2660,929}{400..537} = 0,01238$$

$$\rho' = \frac{As'}{bd} = \frac{1520.531}{400.537} = 0,00708$$

$\rho - \rho' = 0,01236 - 0,00708 = 0,0053$

Kontrol lelehnya tulangan tekan

$$\rho - \rho' \geq \frac{0,85.0,81.f'c.d'}{fy.d} \cdot \frac{600}{600 - fy}$$

$$\rho - \rho' \geq \frac{0,85.0,81.35.48}{400.537} \cdot \frac{600}{600 - 400}$$

$\rho - \rho' \geq 0,0162$

0,00345 < 0,01572 jadi tulangan tekan belum leleh

Ts = Cc + Cs

As.fy = 0,85.f'c.b.β1.x +((x-d')/x.0,003.Es - 0,85.f'c) As'

$$2660,929.400 = 0,85.35.400.0,81.x + ((\frac{x-48}{x}).0,003 .2.10^5 - 0,85.35)1520,531$$

$1064371,591.x = 9639.x^2 + ((x-48).600 - 29,75.x).150,531$

$9639.x^2 + 912318,5066.x - 43791288,32 - 45235,7926.x = 1064371,591.x$

x^2 - 20,4678.x - 4543,1360 = 0

x = 78,4092 mm ,

a = 0,81 . 78,4092

= 63,5114 mm

Maka,

Cc = 0,85.f'c.a.b

= 0,85.35.63,5114.400

= 755785,9403 N

$\varepsilon s' = \frac{(x - d')}{x} .0,003 = \frac{(78,4092 - 48)}{78,4092} . 0,003 = 0,0012 < 0,002$

$Cs = (\frac{x - d'}{x} .0,003. 2.10^5. - 0,85.f'c).As'$

$= (\frac{78,4092 - 48}{78,4092} .0,003.2.10^5 - 0,85.35).1520,531$

= 308585,6507 N

Ts = As.fy = 2660,929 . 400 = 1064371,591 N

Ts = Cc + Cs

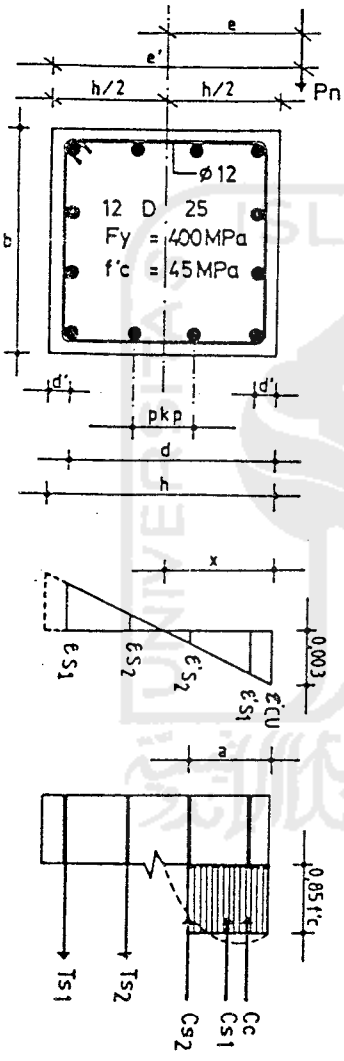
1064371,591 N = 755785,9403 N + 308585,6507 N

= 1064371,591 N Ok

Kapasitas Momen Tampang

Mn = Cc. (d-½.a) + Cs.(d-d')

=755785,9403.(537-½.63,5114) + 308585,6507.(537-48)



Dengan :

h	=	500 mm
b	=	500 mm
d'	=	50 mm
d	=	450 mm
pkp	=	133,333 mm
x	=	231,61277 mm
a	=	169,0773 mm
ε'_{s1}	=	0,00235
ε'_{s2}	=	0,00063
ε_{s1}	=	0,00283
ε_{s2}	=	0,0011

Gaya internal :

Cc	=	3233603,755 N
Cs_2	=	85235,5498 N
Cs_1	=	710294,461 N
Ts_1	=	785398,160 N
Ts_2	=	216313,2104 N

Kapasitas tampang :

Pn	=	3027422,40 N
Mn	=	854278195,60 Nmm
e	=	282,1802 mm

Gambar 5.4.1 Tampang dan diagram tegangan Kolom K11

$$\varepsilon'_{s2} = \frac{x-(d'+pkp)}{x}.0{,}003 = \frac{257{,}1492-(50+133{,}33)}{257{,}1942}.\ 0{,}003$$

$=0{,}00086 < 0{,}002$ baja tulangan belum leleh

$$\varepsilon_{s1} = \frac{d-x'}{x}.0{,}003 = \frac{450-257{,}1492}{257{,}1492}.0{,}003 = 0{,}00225 > 0{,}002$$

$$\varepsilon_{s2} = \frac{(d-x)-pkp}{(d-x)}.0{,}003 = \frac{(450-257{,}1492)-133{,}333}{(450-257{,}1492)}.0{,}003$$

$= 0.00069 < 0{,}002$

$Cc = 0{,}85.f'c.ab.b = 0{,}85.45.187{,}7143.500 = 3590035{,}714$ N

$Cs = As'1.f's1 + As'2.f's2$

$= 1963{,}4954.400 + 981{,}7477.0{,}00086.2.10^5$

$= 954258{,}7651$ N

$Ts = As1.fs1 + As2.fs2$

$= 1963{,}4954.400 + 981{,}7477.0{,}00069.2.10^5$

$= 920879{,}3426$ N

$Pb = Cc+Cs+Ts = 3590035{,}714 + 954258{,}7651 - 920879{,}3426$

$= 3623415{,}137$ N

Mb = Cc.(½h-½a)+C's1.(½h-d')+Cs2.[½h-(d'-pkp)]

+ Ts1.(½h-d')+ Ts2.[½h-(d'-pkp)]

= 3590035,714.(250-93,85715)+785398,1634(250-50)

+ 168860,6051.[250-(-(50+133,333)]+785398,1643

. (250-50)+135481,1832. [250-(-(50+133,333)]

= 895007161,70 Nmm

$$eb = \frac{Mb}{Pb} = \frac{895007161,7}{3623415,137} = 247,0065 \text{ mm}$$

Beban Aksial dan momen Kolom K11 yang didapat dari analisis struktur adalah sebagai berikut ini.

Momen = 112990000 Nmm

Aksial = 364418,08 N + berat sendiri

= 364418,08 N + 3600 N

= 400418,08 N

$$e = \frac{112990000}{400418,08} = 282,1801 \text{ mm} > eb = 247,0065 \text{ mm}$$

kolom mengalami patah tarik

Regangan yang terjadi lebih kecil atau lebih besar dari εy =0,002, luasan beton diperhitungkan penuh.

- Tulangan tekan As'1 dimisalkan sudah leleh :

Cs1 = (fy-0,85.f'c).As'1 = (400-0,85,45).1963,4954

= 710294,464 N

- Tulangan tekan As'2 dimisalkan belum leleh:

$$Cs2 = \left(\frac{x-(d'+pkp)}{x} . 0,003.Es - 0,85.f'c\right).A's2$$

$$= \left(\frac{x-183,333}{x}.600 - 38,25\right).981.7477$$

$$= 589048.62 - \frac{107992227,4}{x} - 37551,8495$$

- Tulangan tarik As2 dianggap sudah leleh:

$$Ts2 = [\frac{(d - pkp) - x}{x}.0,003.Es].As2$$

$$= (\frac{316.6667 - x}{x}.600).981,7477$$

$$= \frac{186532082.60}{x} - 589048,620$$

- gaya tekan beton

$$Cc = 0,85.f'c.b.\beta.x$$

$$= 0,85.45.500.0,73.x$$

$$= 13961.25.x$$

$$Pn = Cc - Cs1 + Cs2 - Ts1 - Ts2$$

$$= 13961.25.x + 710294,464 + 589048,62 - \frac{107992227,4}{x} - 37551,8495 -$$

$$785398.16 - \frac{186532082,60}{x} - 589048,620$$

$$= 13961,25.x - \frac{294524310}{x} + 1065441,695$$

$$\Sigma M\ Ts1 = 0$$

$$Pn.[e+½(d-d')] + Ts2.(pkp) = Cc\ (d-½(\beta 1.x)) + Cs1.(d-d') + Cs2.[d-(d'+pkp)]$$

$$(13961.25.x - \frac{294524310}{x} + 1065441,695).(282,1801+½(450-50))$$

$$+ \left(\frac{186532082,60}{x} - 589048,62\right).133,333 = 13961,25.x.(450 - \tfrac{1}{2}(0,73.x)$$

$$+ 710294,464.(450-50) + \left(589048,62 - \frac{107992227,4}{x} - 37551,8495\right)$$

$$.[450.(50+133,333)]$$

Persamaan diatas menghasilkan persamaan pangkat tiga beri-kut ini:

$$x^3 + 88,16465664.x^2 + 787,18414.x + 17336613,7 = 0$$

Dengan metode Newton Raphson didapat

$X = 231,6127678$ mm

kontrol x:

$(231,6127678)^3 + 88,16465664.(231,6127678)^2 + 787,18414.\ 231,6127678 -$

$17336613,70 = 0$ ---- ok

Kontrol regangan

$$\varepsilon's1 = \frac{x - d'}{x}.0,003 = \frac{231,6127678 - 50}{231,6127678}.0,003 = 0,00235 > 0,002$$

baja sudah leleh

$$\varepsilon's2 = \frac{x - (d'+pkp)}{x}.0,003 = \frac{231,6127678 - (50 + 133,33)}{231,6127678}.\ 0,003$$

$= 0,00063 < 0,002$ baja tulangan belum leleh

$$\varepsilon s1 = \frac{d - x'}{x}.0,003 = \frac{450 - 231,6127678}{231,6127678}.0,003 = 0,00283 > 0,002$$

$$\varepsilon s2 = \frac{(d - x) - pkp}{(d - x)}.0,003 = \frac{(450 - 231,6127678) - 133,333}{(450 - 231,6127678)}.0,003$$

$= 0.0011 < 0,002$

Jadi semua regangan yang terjadi sesuai dengan anggapan semula.

$$Pn = 13961{,}25.x - \frac{294524310}{x} + 1065441{,}695$$

$$= 13961{,}25.231{,}6127678 - \frac{294524310}{231{,}6127678} + 1065441{,}695$$

$$= 3027420{,}641 \text{ N.}$$

$$Pn.e = Cc.(\frac{h}{2} - \frac{\beta 1.x}{2}) + Cs1(\frac{h}{2} - d') + Cs2[\frac{h}{2} - (d'+pkp)]$$

$$+ Ts1(\frac{h}{2} - d') + Ts2\,[\frac{h}{2} - (d'+pkp)]$$

dengan,

$Cc = 0{,}85.f'c.\beta 1.x.b = 0{,}85.45.0{,}73.231{,}6127678.500$

$= 3233603{,}755$ N

$Cs = [\frac{x-(d'+pkp)}{x}.0{,}003.Es - 0{,}85.f'c].As2$

$= [\frac{231{,}6127678-(50+133{,}333)}{231{,}6127678}.0{,}003.2.10^5 - 0{,}85.45].981{,}7477$

$= 85235{,}5498$ N

$Cs1 = (f's - 0{,}85.f'c).As'1$ ---- $\varepsilon's > \varepsilon y$ jadi $f's = fy$

$= (400 - 0{,}85.45).1963{,}4954 = 710294{,}461$ N

$Ts1 = fy.As1$

$= 400.1963{,}4954$

$= 785398{,}160$ N

$$Ts2 = \frac{(d - pkp) - x}{x}.0{,}003.Es.As2$$

$$= \frac{(450 - 133{,}33) - 231{,}6127678}{231{,}6127678}.0{,}003.200000.981{,}7477$$

$$= 216313{,}2104 \text{ N}$$

$$Pn.e = 3233603{,}755.(\frac{500}{2} - \frac{0{,}73.231{,}6127678}{2}) + 710294{,}461 .(\frac{500}{2} - 50') +$$

$$85235{,}5498[\frac{500}{2} - (50'+133{,}33) + 785398{,}160 .(\frac{500}{2} - 50') +$$

$$216313{,}2104 [\frac{500}{2} - (50 + 133{,}333)]$$

3027420,641.282,1801 = 3233603,755.(165,46134) +710294,461

.(200) + 85235,5498.(66,667) +785398,160 .(200) + 216313,2104 .(66,667)

854277,859,20 Nmm ≈ 854278195,60 Nmm

selisih 336,359 Nmm ----- 0k

Maka kapasitas ultimit tampang kolom tersebut adalah:

Pu = φ.Pn = 0,65. 3027420,641 = 1967823,417 N

Mu = φ.Mn = 0,65. 854278195,60 = 55280827,10 Nmm

5.4.2 Kolom 14

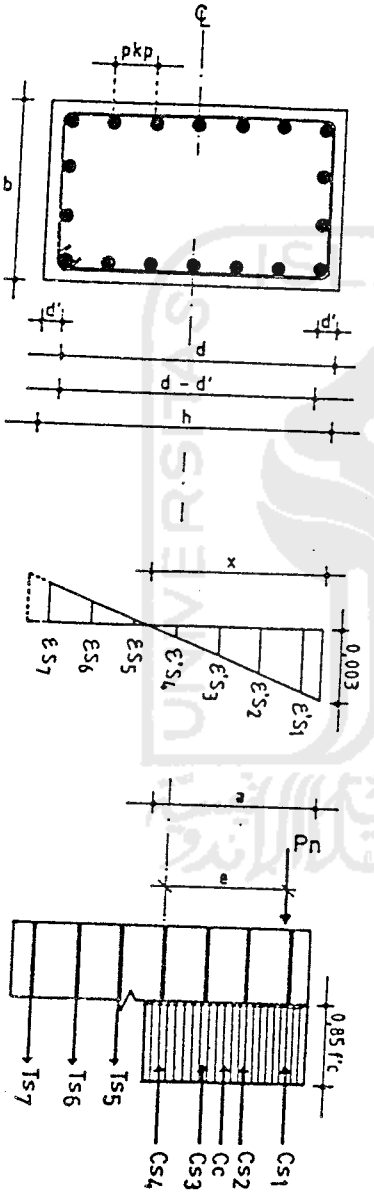
Dari data di lapangan diketahui:

1. dimensi Kolom = 400 mm x 650 mm,

2. d' = 25 + 12 + ½.25 = 50 mm ; d = 650 - 50 = 600 mm,

3. f'c = 45 MPa ; fy = 400 MPa,

4. jarak tulangan (p.k.p)= $\frac{650-2.(50)}{6}$ = 91,667 mm.



Dengan :

h	=	650 mm
b	=	400 mm
d'	=	50 mm
d	=	600 mm
pkp	=	91,6667 mm
x	=	399,87487 mm
a	=	291,90866 mm
ε'_{s1}	=	0,00262
ε'_{s2}	=	0,001937
ε_{s7}	=	0,00150

Gaya internal :

Cc	=	4466202,423	N
Cs_1	=	710294,464	N
Cs_2	=	342810,0527	N
Cs_3	=	207777,4532	N
Cs_4	=	72744,8539	N
Ts_5	=	24735,60134	N
Ts_6	=	233422,3193	N
Ts_7	=	589601,6005	N

Kapasitas tampang :

Pn	=	4952069,725	N
Mn	=	1284081897	Nmm
e	=	259,3021 mm	

Gambar 5.4.2 Diagram Tegangan dan Regangan Tampang Kolom K14

Penyelesaian analisis adalah sebagai berikut ini.

a. Analisis pada kondisi regangan seimbang.

$$xb = \frac{0{,}003.d}{(fy/es) + 0{,}003} = \frac{0{,}003.(600)}{(400/200000) + 0{,}003} = 360 \text{ mm}$$

$ab = 0{,}73.360 = 262{,}8$ mm.

Regangan yangterjadi pada Baja Tulangan.

$$\varepsilon's1 = \frac{x - d'}{x}.0{,}003 = \frac{360 - 50}{360}.0{,}003 = 0{,}002583 > 0{,}002$$ baja sudah leleh

$$\varepsilon's2 = \frac{x - (d' + pkp)}{x}.0{,}003 = \frac{360 - (50 + 91{,}6667)}{360}.0{,}003$$

$=0{,}001819 < 0{,}002$ baja tulangan belum leleh

$$\varepsilon's3 = \frac{x - (d' + 2.pkp)}{x}.0{,}003 = \frac{360 - (50 + 2.91{,}6667)}{360}.0{,}003 = 0{,}00106 < 0{,}002$$

$$\varepsilon's4 = \frac{x - (d' + 3.pkp)}{x}.0{,}003 = \frac{360 - (50 + 3.91{,}667)}{360}.0{,}003$$

$= 0.000292 < 0{,}002$

$$\varepsilon s7 = \frac{d - x}{x}.0{,}003 = \frac{600 - 360}{360}.0{,}003 = 0{,}002$$

$$\varepsilon s6 = \frac{d - (x + pkp)}{x}.0{,}003 = \frac{600 - (360 + 91{,}6667)}{x}.0{,}003$$

$= 0{,}001236$

$$\varepsilon s5 = \frac{d - (x + 2.pkp)}{x}.0{,}003 = \frac{600 - (360 + 2.91{,}6667)}{360}.0{,}003$$

$= 0{,}000472$

Maka:

Cc = 0,85.f'c.ab.b = 0,85.45.262,8.500 = 4020840 N

Cs1 = (f's1 - 0,85.f'c).As1 = (400 - 0,85.45).1963,4954

= 710294,464 N

Cs2 = (f's2 - 0,85.f'c).As2

= (0,0019.2.10^5 - 0,85.45).981,74

= 319607,9637 N

Cs3 = (f's3 - 0,85.f'c).As3

= (0,00106.2.10^5 - 0,85.45).981,74

= 170578,6629 N

Cs4 = (f's4 - 0,85.f'c).As4 = (0,00292.2.10^5 - 0,85.45).981,74

= 19782,2162 N

Ts5 = fs5 . As5 = 0,000472.2.10^5 .981,7477 = 92676,9829 N

Ts6 = fs6 . As6 = 0,001236.2.10^5 .981,7477 = 242688,0314 N

Ts7 = fs7 . As7 = 400 . 1963,4954 = 785398,16 N

Pb = 4020840 + 710294,464 + 319607,9637

+ 170578,6629 + 19782,2162 + 92676,9829

+ 242688,0314 + 785398,16 = 4130340,133 N

Mb = Cc.(½h-½a)+Cs1.(½h-d')+Cs2.[½h-(d'-pkp)]

+ Cs3.(½h-(d'-2.pkp)]+ Cs4.(½h-(d'-3.pkp)]

+ Ts5.(½h-(d'-2.pkp)] + Ts6.[½h-(d'-pkp)] + Ts7.(½h-d')

Mb =4020840.(193,6)+710294,464.(275)+319607,9637.(183,33)

+170578,6629.(91,667)+19782,2162.(0)+ 92676,9829.(91,667)

+242688,0314.(183,33)+ 785398,16.(275)

= 1316969426 Nmm

$$eb = \frac{Mb}{Pb} = \frac{1316969426}{4120340,133} = 319,6264 \text{ mm}$$

Beban Aksial dan momen Kolom K14 yang didapat darianalisis struktur adalah sebagai berikut ini.

Momen = 155960000 Nmm

Aksial = 563039,94 N + berat sendiri

= 563039,94 N + 37440 N

= 600479,94 N

$$e = \frac{155960000}{600479,94} = 259,7526 \text{ mm} > eb = 319,6264 \text{ mm}$$

kolom mengalami patah desak.

Kontrol regangan yang terjadi lebih kecil atau lebih besar dari εy =0,002, luasan beton diperhitungkan penuh.

- Tulangan tekan As'1 dimisalkan sudah leleh,

- Tulangan daerah tarik sudah leleh.

gaya tekan beton

$Cc = 0.85.f'c.b.\beta.x$

$= 0.85.45.400.0,73.x$

$= 11169.x$

$Cs1 = (f's1-0.85.f'c).As1 = (400-0,85.45).1963,4954$

$= 710294,464\ N$

$Cs2 = \left(\frac{(x-141,6667)}{x}.0,003.2.10^5-0,85.45\right)$

$= 55149,7705 - \frac{83448574,13}{x}$

$Cs3 = \left(\frac{(x-233,3334)}{x}.0,003.2.10^5-0,85.45\right)$

$= 55149,7705 - \frac{137444717,30}{x}$

$Cs4 = \left(\frac{(x-325)}{x}.0,003.2.10^5-0,85.45\right)$

$= 55149,7705 - \frac{191440860,4}{x}$

$Ts5 = \frac{416,666-x}{x}.0,003.2.10^5.918,17477$

$= \frac{245436885,7}{x} - 589048,62$

$Ts6 = \frac{558,3333-x}{x}.0,003.2.10^5.918,7477$

$$= \frac{328885459,9}{x} - 589048,62$$

$$Ts7 = \frac{600 - x}{x}.0,003.2.10^5.1963,4954$$

$$= \frac{706858344}{x} - 1178097,24$$

Hitung jarak garis netral x:

$$Ts7.(½(d\text{-}d')+e)+Ts6.(½(d\text{-}d')\text{-}pkp+e)+Ts5(½(d\text{-}d')\text{-}2.pkp+e)$$

$$- Cs4.e - Cs3.(e+pkp) - Cs2.(e+2.pkp) + Cs1.(e+3.pkp)$$

$$- Cc.(½(\beta.x)\text{-}65,65,744) = 0$$

$$(\frac{706858344}{x} - 1178097,24).534,7256 + (\frac{328885459,9}{x} - 589048,62)$$

$$.443,0589 + (\frac{245436885,7}{x} - 589048,62).351,3922 + 259,7256.$$

$$(55149.7705 - \frac{191440860,4}{x}) - (55149,7705 - \frac{137444717,30}{x}).$$

$$168,0589 - (55149,7705 - \frac{83448574,13}{x}).76,3922 + 710294,464$$

$$.15,2744 - 11169.x.(0,365.x\text{-}65,744) = 0$$

Persamaan diatas menghasilkan persamaan pangkat 3 sebagai berikut ini.

$$4076,685.x^3 + 734294,736.x^2 + 1365131578.x - 6,891312099.2.10^{11} = 0$$

$$x^3 + 180,120548.x^2 + 334863,1493.x - 169042055 = 0$$

Persamaan tersebut diselesaikan dengan Iterasi Newton Rhapson menghasilkan.

$$X = 399,87487 \text{ mm}$$

kontrol x:

$$(399,87487)^3 + 180,120548.(399,87487)^2 + 334863,1493$$

$$. 399.87487 - 169042055 = 0 \text{ ---- ok}$$

Kontrol regangan

$$\varepsilon's1 = \frac{x - d'}{x}.0,003 = \frac{399,87487 - 50}{399,87487}.0,003 = 0,00262 > 0,002$$

$$\varepsilon's2 = \frac{x - (d'+pkp)}{x}.0,003 = \frac{399,87487 - (50 + 91,6667)}{399,87487}. 0,003$$

$$= 0.001937 < 0.002 \text{ baja tulangan belum leleh}$$

$$\varepsilon s1 = \frac{d - x'}{x}.0,003 = \frac{600 - 399,874877}{399,87487}.0,003 = 0,00150 > 0,002$$

Jadi semua regangan yang terjadi sesuai dengan anggapan semula. Gaya dalam dan Pn dapat dihitung.

$$Cc = 11169.x = 11169.399,87487 = 4466202,423 \text{ N}$$

$$Cs1 = 710294,464 \text{ N}$$

$$Cs2 = 551496,7705 - \frac{83448574,13}{399,87487} = 342810,0527 \text{ N}$$

$$Cs3 = 551496,7705 - \frac{137444717,30}{399,87487} = 207777,4532 \text{ N}$$

$$Cs4 = 551496,7705 - \frac{191440860,4}{399,87487} = 72744,8539 \text{ N}$$

$$Ts5 = \frac{245436885,7}{399,87487} - 589048,62 = 24735,60134 \text{ N}$$

$$Ts6 = \frac{328885459,90}{399,87487} - 589048,62 = 233422,3193 \text{ N}$$

$$Ts7 = \frac{70685344}{399,87487} - 1178097,24 = 589601,6005 \text{ N}$$

$$Pn = Cc + Cs1 + Cs2 + Cs3 + Cs4 + Ts5 + Ts6 + Ts7$$

$$= 4466202,423 + 710294,464 + 342810,0527 + 207777,4532 + 72744,8539 + 24735,60134 + 233422,3193 + 589601,6005$$

$$= 4952069,725 \text{ N}$$

$$Pn.e = 4466202,423.(325-\tfrac{1}{2}(0,73.399,87487) + 710294,464.(275) + 342810,0527.(183,333) + 207777,4532.(91,6667) + 72744,8539.(0) + 24735,60134.(91,6667) + 233422,3193 .(183,333) + 589601,6005.(275)$$

$$Pn.e = 1284081897 \text{ Nmm}$$

$$e = \frac{1284081897}{4952069,275} = 259,3021 \text{ mm} \approx 259,7256 \text{ mm}$$

Jadi Kapasitas tampang kolom K14 adalah:

$$Pu = \varphi.Pn = 0,65.\ 4952069,725 = \mathbf{3218845,321} \text{ N}$$

$$Mu = \varphi.Mn = 0,65.\ 1284081897 = \mathbf{834653233,20} \text{ Nmm}$$

5.5 Kekuatan Baut

Baut yang digunakan pada sambungan ini dalah baut A325 dengan ∅ 20 mm.Data yang didapat dari analisis struktur adalah gaya lintang = 19301,98 N dan momen = 54749277,65 Nmm pada ujung balok susulan.

1. Baut dianggap sebagai sambungan yang menahan geser, maka baut A 325 ∅ 20 mm mempunyai tarikan minimum Tb=141KN

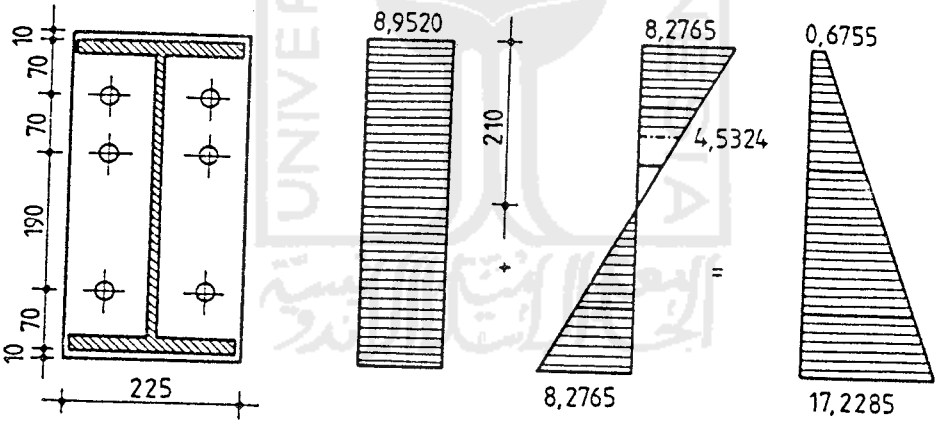
$$P/A = \frac{6.141.1000}{225.420} = 8{,}952\ N/mm^2$$

$$fv = \frac{19301{,}98}{6.(0{,}25.\pi.20.20)} = 10{,}240\ N/mm^2$$

$$s = \frac{b.h^2}{6} = \frac{225.420^2}{6} = 6615000\ mm^2$$

ft (tegangan tarik) = fc (tegangan desak)

$$ft = fc = M/s = \frac{54749277{,}65}{6625000} = 8{,}2765\ N/mm^2$$



Gambar 5.5.1 Diagram Tegangan Baut

$$T = \frac{(10 + 70 + \frac{70}{2}).8{,}2765}{210} = 4{,}5324\ N/mm^2$$

Gaya tarik yang ditahan baut atas:

$$Tm = \frac{8,2765 + 4,5324}{2} \cdot \frac{115.225}{2} = 82857,3717 \text{ N/mm}^2$$

$$F'v = C4.\left(1 - \frac{fb.Ab}{Tb}\right)$$

$$= 121.\left(1 - \frac{82857,3717}{141000}\right) = 49,8954 \text{ N/mm}^2$$

$$fv = 10,240 \text{ N/mm}^2 < F'v = 49,8954 \text{ N/mm}^2$$

Untuk satu baut atas :

$$\text{Tarikan akhir} = Tb - \left(\frac{0,6755 + 5,2079}{2}\right).\left(115.\frac{225}{2}\right)$$

$$= 141000 - 38058,0435$$

$$= 102941,9565 \text{ N}$$

$$ft = \frac{102941,9565}{0,25.\pi.20^2} = \frac{102941,9565}{314,1593}$$

$$= 327,6477 \text{ N/mm}^2$$

$$Ft = c1 - c2.fv$$

$$= 380 - 1,4 \,.\, 10,240$$

$$= 365,664 \text{ N/mm}^2$$

cek persamaan interaksi: $\left(\frac{fv}{Fv}\right)^2 + \left(\frac{ft}{Ft}\right)^2 \leq 1,00$

$$\left(\frac{10,240}{49,8954}\right)^2 + \left(\frac{327,6744}{365,664}\right)^2 \leq 1,00$$

$$0,8451 < 1,00$$

jadi sambungan memenuhi dan mampu menahan beban yang bekerja.

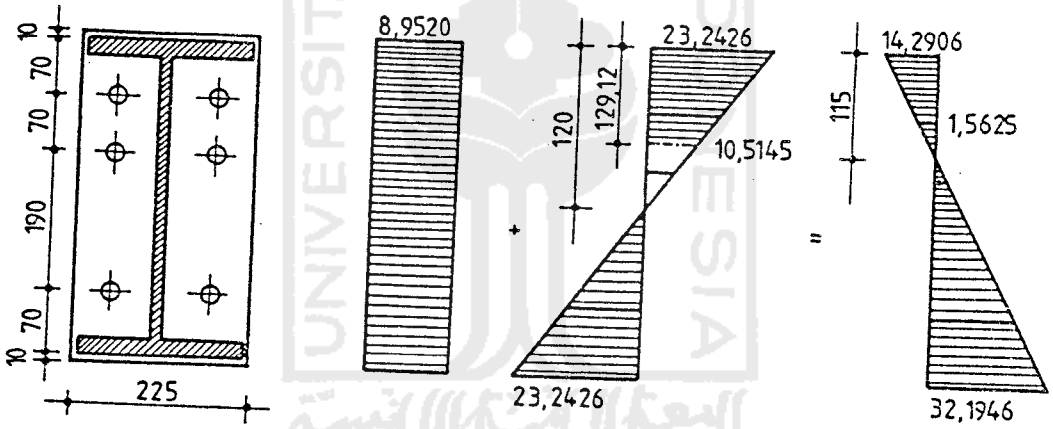
2. Perhitungan keuatan baut untuk M = 153750000 Nmm; V = 131700 N

P/A = 8,952 N/mm^2

$$fv = \frac{131700}{6.0{,}25.\ \pi.20^2} = 69{,}8690 \text{ N/mm}^2 < 120 \text{ N/mm}^2 \text{ (AISC)}$$

s = 6615000 mm^3

$$ft = fc = M/s = \frac{153750000}{6615000} = 23{,}2426 \text{ N/mm}^2$$



Gambar 5.5.2 Diagram Tegangan Tampang

gaya tarikan yang ditahan baut atas keadaan akhir untuk satu baut:

$$T = Tb - \left(\frac{1{,}5625 + 14{,}2906}{2}\right).(115.225/2)$$

= 141000 - 102549,741

= 38450,2594 N

$$ft = \frac{38450,2594}{0,25.\ \pi.20^2} = 122,3909\ N/mm^2$$

$$Ft = c1 - c2.fv$$

$$= 380 - 1,4.69,8690$$

$$= 282,1834\ N/mm^2 > 122,3909\ N/mm^2$$

$$\left(\frac{fv}{Fv}\right)^2 + \left(\frac{ft}{Ft}\right)^2 \leq 1,00$$

$$\left(\frac{69,8690}{120}\right)^2 + \left(\frac{122,3909}{282,1834}\right)^2 \leq 1,00$$

$$0,5271 < 1,00$$

3. Perhitungan dengan asumsi tanpa tarikan awal:

$M = 153750000$ Nmm

$V = 131700$ N

Baut A 325 $\varnothing$ 20 mm

gaya geser baut :

$$Rn = \frac{V}{n} = \frac{131700}{6} = 21950\ N$$

Tegangan geser:

$$fv = \frac{Rv}{Av} = \frac{21950}{0,25.\ \pi.20^2} =$$

$$= 69,8690\ N/mm^2 < 120\ N/mm^2\ (AISC)$$

Tegangan tarik untuk baut paling atas dengan pendekatan luasan efektif:

$$a = \left(\frac{A}{p}\right).m = \left(\frac{314,159}{115}\right).2 = 5,4636 \text{ mm}$$

$$be = 2.b = 2.\left(\frac{225 - 8}{2}\right) = 217 \text{ mm}$$

$$\frac{c1}{c} = \frac{\sqrt{a}}{\sqrt{be}} = \frac{\sqrt{5,4636}}{\sqrt{217}} = 0,1587$$

h = 420 mm maka:

c1 = 0,1587.c

h = c1 + c

420 = c + 0,1587.c

$$c = \frac{420}{1,1587} = 362,4829 \text{ mm}$$

c1 = 420 - 362,4829 = 57,5171 mm.

$$I = \frac{a.c^3}{3} + \frac{be.c1^3}{3}$$

$$= \frac{5,4636.\ (262,4829)^3}{3} + \frac{217.\ (57,5171)^3}{3}$$

$$= 86803585,16 \text{ mm}^4$$

"Section modulus" tampang untuk baut teratas:

$$S = \frac{I}{c - 80} = \frac{86803585,16}{362,4829 - 80} = 307287,9284 \text{ mm}^3$$

maka: $ft = \frac{M}{s} = \frac{153750000}{307287,9284} = 500,3451 \text{ N/mm}^2 > 303 \text{ N/mm}^2$ tidak memenuhi

Jika data baut menggunakan spesifikasi baut F.10.t dengan tegangan tarik minimum

$$= 84{,}6 \text{ kg.f/mm}^2 = 846 \text{ N/mm}^2$$

maka ft < Ft -------- 500,3451 N/mm^2 < 846 N/mm^2

Anggapan gaya tarik awal diabaikan:

menghitung letak garis netral:

$$b.\frac{y^2}{2} = 2.0{,}25.\pi.20^2 . [(80-y)+(270-y)+(340-y)]$$

$$225.\frac{y^2}{2} = 2.314{,}159.[690 - 3.y]$$

$$112{,}5.y^2 = 433539{,}7862 - 1884{,}9556.y$$

$$y^2 + 16{,}7552 - 3853{,}6870 = 0$$

$$y = 54{,}2632 \text{ mm}$$

kontrol:

Momen dari luasan bagian tekan $= 225.\frac{54{,}2632^2}{2}$

$= 331256{,}0117 \text{ mm}^3$

Momen dari luasan bagian tarik

$= 2.0{,}25.\pi.20^2.[(80-54{,}2632)+(270-54{,}2632)+(340-54{,}2632)$

$= 331256{,}0117 \text{ mm}^3$ --------- ok!

Momen Inersia:

$$I = \frac{225.(54{,}2632)^3}{12} + \frac{225.(54{,}2632)^2}{2} + 2.314{,}159.(25{,}7368)^3$$
$$+2.314{,}159.(215{,}7368)^2 + 2.314{,}159.(258{,}7368)^2$$

$= 84286104{,}21 \ mm^4$

Gaya geser tiap baut $= \frac{131700}{6} = 21950 \ N$

Tegangan geser $fv = \frac{21950}{0{,}25.\pi.20^2} = \frac{21950}{314{,}159}$

$= 69{,}8690 \ N/mm^2 < 120 \ N/mm^2$ (AISC)

Gaya tarik baut paling atas:

$ft = \frac{M.c}{I} = \frac{153750000.285{,}7368}{84246104{,}21}$

$= 521{,}2251 \ N/mm^2 < 846 \ N/mm^2$ (baut F.10.t)

Persamaan interaksi:

$$\left(\frac{fv}{Fv}\right)^2 + \left(\frac{ft}{Ft}\right)^2 \leq 1{,}0$$

$$\left(\frac{69{,}8690}{120}\right)^2 + \left(\frac{521{,}2251}{846}\right)^2 \leq 1{,}0$$

$0{,}7186 \leq 1{,}0$

5.6 Balok Anak B-21 Sebagai Balok T

Kemampuan balok yang lebih maksimal dapat dilihat dengan menganalisa balok tersebut sebagai balok tampang T. Hal ini didasarkan pada anggapan bahwa balok tersebut pada kenyataannya tidak bekerja sendiri, tetapi menjadi bersama-sama dengan pelat dalam mendukung beban yang bekerja. Perhitungan analisis balok anak sebagai balok tampang T adalah sebagai berikut ini.

Panjang balok = 8236 mm

Tebal slab = 130 mm

Jarak balok dari as ke as

- bentang sebelah kanan = 5575 mm
- bentang sebelah kiri = 1240 mm

Perhitungan analisis menggunakan bentang sebelah kiri 1240 mm

1.) Lebar efektif pelat

- $be = \frac{L}{4} = \frac{8236}{4} = 2059$ mm
- be = 16.ts + bw
  = 16.130 + 250
  = 2330 mm
- be = 1240 mm

dipakai yang terkecil jadi be = 1240 mm.

2.) Kontrol luasan tulangan

Cc = Ts ; dengan a = tebal slab 130 mm

$0{,}85.f'c.be.a = Fy.As$

$$As = \frac{0{,}85.35.1240.130}{400} = 11989{,}25\ mm^2 > As\ tersedia$$

garis netral jatuh pada sayap

$$a = \frac{Fy.\ As}{0{,}85.\ be.\ f'c}$$

$$= \frac{400.2\ 0{,}25.\pi\ 22^2}{0{,}85\ .1240.\ 35}$$

$$= 8{,}2436\ mm$$

$$x = \frac{8{,}2436}{0{,}73} = 11{,}2926\ mm$$

cek tulangan A's sebagai tulangan tarik

$$\varepsilon s2 = \frac{d'-x}{x}.0{,}003 = \frac{48-11{,}2926}{11{,}2926}.0{,}003$$

$= 0{,}00975 > 0{,}002$, baja sudah leleh

3.) Kontrol kapasitas tampangdalam kesetimbangan gaya

$Cc = 0{,}85.f'c.a.be$

$= 0{,}85.35.8{,}2436.1240$

$= 304106{,}404\ N$

$fs1 = fs2 = fy$

$Ts1 = Ts2 = As.fy$

$= 2.\varnothing\ 22.400$

$= 760{,}2654.400$

$= 304106,1689$ N

$Cc = Ts1 + Ts2$

$= 304106,1689 + 304169,1689$

$= 608212,3377$ N ; tidak seimbang

Jadi tulangan atas harus diperhitungkan untuk mengimbangi tegangan desak beton. Tulangan atas masuk serat tarik

$d' = 48$ mm > $x = 11,2926$ mm.

Untuk mencapai keseimbangan gaya dalam tulangan As1 dianggap sudah leleh

$$\frac{\varepsilon s2 + 0,003}{d'} = \frac{0,003}{x}$$

$$\varepsilon s2.x + 0,003.x = d'.0,003$$

$$\varepsilon s2 = \frac{d'.0,003 - 0,003.x}{x} = \frac{48 - x}{x}.0,003$$

$$fs = \varepsilon s2 \,.\, 2.10^5$$

Kontrol keseimbangan:

$$Cc - Ts2 = Ts1$$

$$0,85.f'c.\beta.x.be - As'.fs = As.fy$$

$$0,85.35.1240.0,73.x - 760,2654.\left(\frac{48 - x}{x}.0,003\right).2.10^5$$

$$= 760,2645.400$$

$$26929,7.x - 162053084,4 .\left(\frac{48 - x}{x}.0,003\right) = 304106,1689$$

$$26929,7.x + 152053,0844 - \frac{21895644,16}{x} = 0$$

$$x^2 + 5,6463.x - 813,0668 = 0$$

$$x = 25,83059 \text{ mm}$$

cek gaya dalam:

$$0,85.f'c.\beta.x.be - As'.fs = As.fy$$

$$0,85.35.1240.0,73.25,830594 - 760,2654.\left(\frac{48 - 25,830594}{25,830594}.0,003\right).2.10^5$$

$$= 760,2645.400$$

$$695610,1363 - 391503,9674 = 304106,1689$$

$$304106,1689 = 304106,1689 \text{ ------ok}$$

Kontrol $\varepsilon s2$

$$\varepsilon s2 = \frac{48 - x}{x}.0,003$$

$$= \frac{48 - 25,83059}{25,83059}.0,003$$

$$= 0,00257 > 0,002$$

jadi anggapan tulangan tarik sudah leleh memenuhi

$$fs1 = fs2 = fy$$

$$Cc = Ts1 + Ts2$$

$$0,85.f'c.be.a = (A's + As).fy$$

$$a = \frac{(760,2654 + 760,2654).400}{0,85.35.1240} = 16,4872 \text{ mm}$$

Cc = 0,85.35.1240.16,4872 = 608212,3377 N

Ts1 = Ts2 = 304106,1689 N

4.) kapasitas tampang

Mn = Cc.(d-½.a) - Ts.(d-d')

= 608212,3377.(552-½.16,4872)-304106,1689.(552-48)

= 177449846 Nmm

Mu = φ .Mn = 0,8. 177449846 = **141959876,80 Nmm**

5.7 Pembahasan

Dari hasil perbandingan analisis tampang elemen dengan hasil analisis struktur portal, dapat diketahui kondisi elemen-elemen struktur setelah mengalami perubahan pembebanan. Perbandingan analisis tampang elemen yang berdekatan (berhubungan langsung dengan balok susulan) dengan analisis struktur dapat dilihat dalam tabel berikut ini.

Tabel 1 Perbandingan Kapasitas Tampang Balok dengan Momen Hasil Analisis Strukutur

Balok	Momen Analisis Struktur (Nmm)	Kapasitas Momen Elemen (Nmm)	Keterangan
Balok induk B-1 (tumpuan)	286470000	426203937,2	Aman
Balok induk B-1 (lapangan)	167150000	317424997,4	Aman
Balok induk B-37	55081150,2	194475201,1	Aman
Balok induk B-8 (tumpuan)	67209065,28	194470333,7	Aman
Balok induk B-8 (lapangan)	29970971,63	131184639,9	Aman
Balok Anak B-21	206620000	141959876	Tidak Aman

Tabel 2 Perbandingan Kapasitas Tampang Kolom dengan Aksial dan Momen Hasil Analisis Strukutur

Kolom	Analisis Struktur		Kapasitas Elemen		Keterangan
	Aksial (N)	Momen(Nmm)	Aksial (N)	Momen (Nmm)	
K 11	400418,1	112990000	1967823	55280827,1	Aman
K 14	563039,9	155960000	3218845	834653233,2	Aman

Dari tabel diatas dapat diketahui balok anak tidak aman, maka untuk menjamin kestabilan struktur harus dihitung beban maksimal yang dapat ditahan oleh balok anak tersebut. Perhitungan tersebut dilakukan dengan memasukkan momen kapasitas balok anak tampang T ke dalam persamaan Clapeyron sebagai berikut ini.

Momen kapasitas tampang:

$MA = MB = 141959876,80\ N$

$\alpha A = \beta A$

$$\frac{MA.\ell}{3.EI} + \frac{MB.\ell}{6.EI} = \frac{q.(\ell)^3}{24.EI} + \frac{P.a.(\ell'^2 - a^2)}{6.EI.\ell}$$

$$8.MA.\ell + 4.MB.\ell = q.8236^3 + \frac{4..88329,45.3636(8236^2 - 3636^2)}{8236}$$

$$12.MA.\ell = q.8236^3 + \frac{4..88329,45.3636(8236^2 - 3636^2)}{8236}$$

$$12.141959876,80.8236 = q.8236^3 + \frac{4..88329,45.3636(8236^2 - 3636^2)}{8236}$$

$$q = \frac{1{,}403017854.10^{13} - 8{,}518336142.10^{12}}{8236^3}$$

$$= 9{,}86615 \text{ N/mm}$$

$$\alpha B = \beta B$$

$$\frac{MA.\ell}{6.EI} + \frac{MB.\ell}{3.EI} = \frac{q.(\ell)^3}{24.EI} + \frac{P.b.(\ell^{2\,2} - b^2)}{6.EI.\ell}$$

$$4.MA.\ell + 8.MB.\ell = q.8236^3 + \frac{4..88329{,}45.4600\,(8236^2 - 4600^2)}{8236}$$

$$12.MA.\ell = q.8236^3 + \frac{4..88329{,}45.4600(8236^2 - 4600^2)}{8236}$$

$$12.141959876{,}80.8236 = q.8236^3 + \frac{4..88329{,}45.4600(8236^2 - 4600^2)}{8236}$$

$$q = \frac{1{,}403017854.10^{13} - 9{,}210021488.10^{12}}{8236^3}$$

$$= 8{,}62804 \text{ N/mm}$$

q diambil yang terkecil. Maka beban kerja (beban hidup) yang diijinkan pada balok anak tersebut adalah sebagai berikut ini.

q ijin = q - q berat sndiri

= 8,62804 - 3,384

= 5,24404 N/mm

Untuk pembebanan permeter persegi

M maks = $1{,}8078 .10^{10}$ .q (hitungan pembebanan B-21)

$$qu = \frac{141959881{,}80}{1{,}8078.\ 10^{10}} = 0{,}007826 \text{ N/mm}^2$$

$= 7{,}826 \ \text{KN/mm}^2$

setelah dikurangi berat sendiri pelat, menjadi:

$$ql = \frac{7{,}826 - (3{,}12.12)}{1{,}6} = 2{,}5512 \ \text{Kn/m}^2$$

$$= 255{,}12 \ \text{kg/m}^2$$

Jadi beban pada pelat yang masih mampu ditahan oleh balok anak pada kondisi tersebut adalah **255,12 kg/m²**

Pembatasan beban yang bekerja pada pelat sebenarnya kurang efisien sebab jenis berat mobil yang keluar dan masuk lantai parkir apartemen tidak mungkin diawasi satu persatu. Solusi lain yang dapat diambil untuk memecahkan masalah tertinggalnya balok induk adalah dengan membuat portal struktur tambahan di bawah pelat lantai. Hal ini dapat digunakan mengingat pelat lantai seluruhnya bertulangan rangkap maka timbulnya momen negatif akibat tumpuan pada portal tersebut dapat ditahan oleh tulangan pelat bagian atas. Apabila solusi yang digunakan adalah dengan memberi portal struktur dibawah pelat maka beban yang bekerja pada pelat dapat seperti yang telah direncanakan