BAB IV

PERHITUNGAN PENULANGAN *ABUTMENT*

4.1 Perhitungan Penulangan *Abutment*

Diketahui perencanaan penulangan:

Mutu beton K-350

Kuat tekan beton (f'c)= 29 Mpa = 350 kg/cm^2

Mutu baja (fy) = 400 Mpa = 4000 kg/cm^2

Berat jenis beton = 2500 kg/m^3

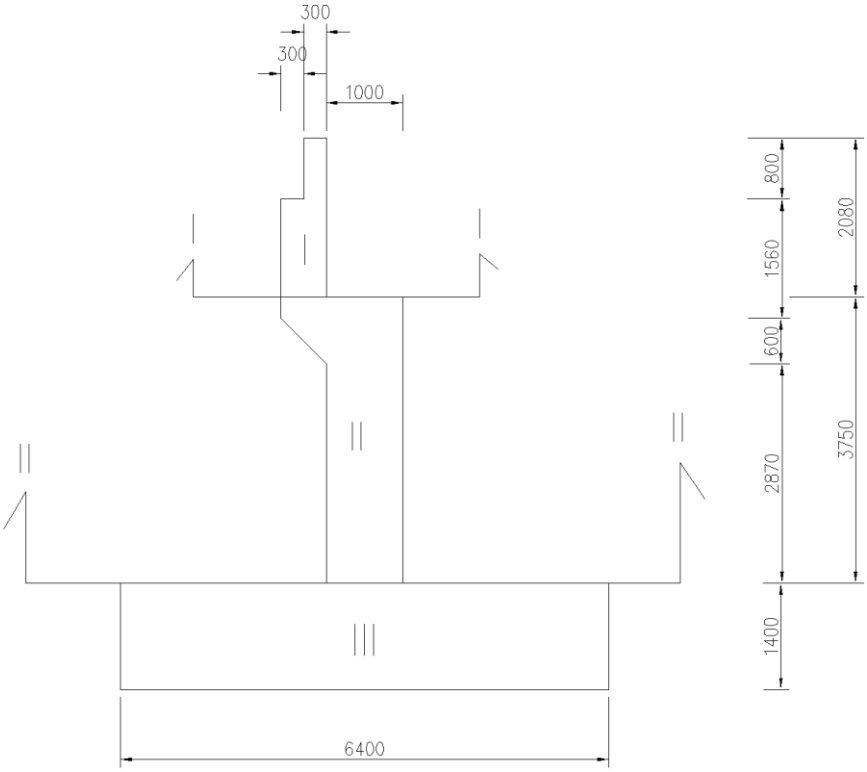
Tebal selimut beton (p) *Abutment* = 50 mm

Tebal selimut beton *Footing* = 70 mm

Penulangan ditinjau pada titik-titik kritis pada *abutment* berdasarkan SK SNI T-15 Tahun 1991. Beban diperhitungkan sebagai beban berfaktor dari suatu kombinasi pembebanan menurut SK SNI T-15 ayat 3.3.2 butir 4:

Mu = 1,2 Mmati + 1,6 Mhidup

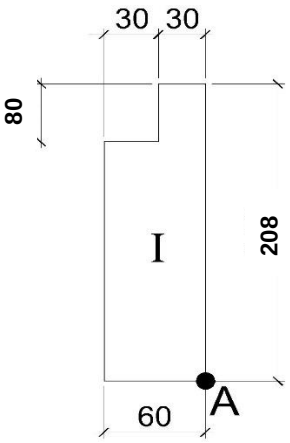
Vu = 1,2 Vmati + 1,6 Vhidup



Gambar 4.1 Potongan Struktur Perhitungan Penulangan *Abutment*

4.2 Perhitungan Penulangan Pot 1-1

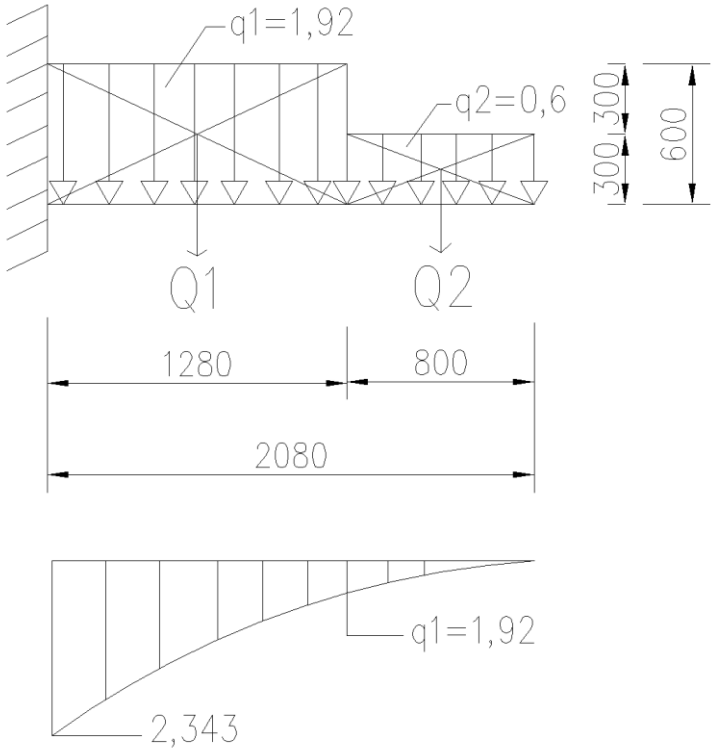
4.2.1 Analisa Pembebanan



Gambar 4.2 Potongan I–I

a. Beban Mati (D)

1) Akibat Berat *Abutment*



Gambar 4.3 Gaya Akibat Berat *Abutment* Pot 1-1

(q1) mati = 1,28 x 0,6 x 2,5 = 1,92 t/m

(q2) mati = 0,8 x 0,3 x 2,5 = 0,6 t/m

Q1 = q1 x L

= 1,92 x 1,28

= 2,458 T

Q2 = q2 x L

= 0,6 x 0,8

= 0,48 T

M_{D1} = (Q2 x 1,68) + (Q1 x 0,625)

= (0,48 x 1,68) + (2,458 x 0,625)

= 2,343 Tm'

M_{D2} = Q2 x 0,5 x L2

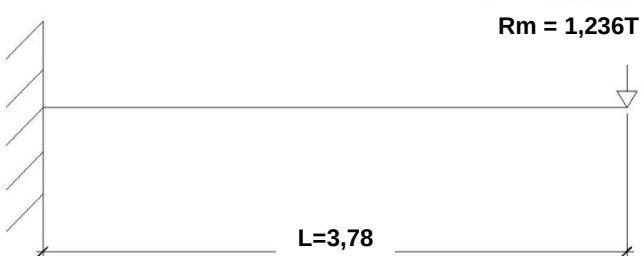
= 0,48 x 0,5 x 0,8

= **0,192 Tm'**

MD_{Max} = 2,343 Tm'

b. Beban Hidup (L)

1) Akibat Rem



Gambar 4.4 Gaya Akibat Rem

L = (Tinggi Girder + Tebal Plat Lantai + Tinggi Titik Tangkap Gaya Rem)

= (1,7 + 0,28 + 1,8)

= 3,78 m

Rm = 21,998 : 17,8

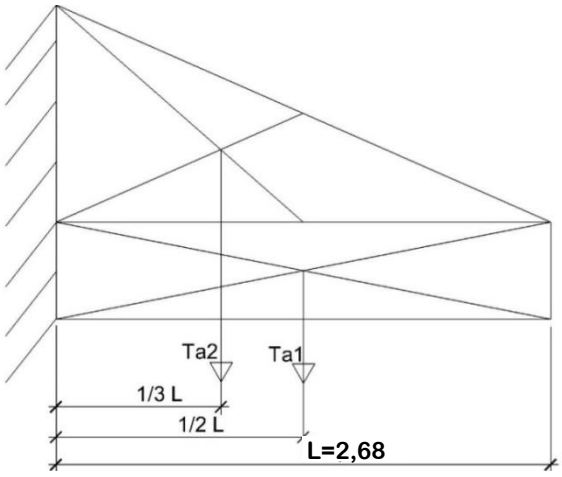
= 1,236T

M_L = Rm . L

= 1,236 x 3,78

= 4,672 Tm'

c. Tekanan Tanah (H)



Gambar 4.5 Gaya Akibat Tekanan Tanah

γ = 1,710 T/m^3

φ = 35°

Ka = $\tan^2 (45^\circ - \varphi_1^\circ / 2)$

= $\tan^2 (45^\circ - 35^\circ / 2)$

= 0,271

q = 1,2 t/m

a1 = (0,6 x γ x Ka)

= (0,6 x 1,710 x 0,271)

= 0,278 t/m

b = (0,6 + 2,08) x γ x Ka

= (0,6 + 2,08) x 1,710 x 0,271

= 1,242 t/m

Ta_1 = a1 x H

= 0,278 x 2,68

= 0,745 T

Ta_2 = 0,5 x (b – a1) H

= 0,5 x (1,242 – 0,278) x 2,68

= 1,292 T

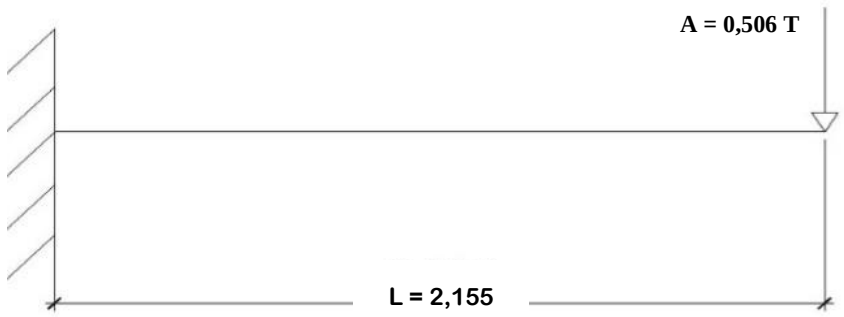
M_H = Ta_1 . 0,5 . L + Ta_2 . 1/3 . L

= 0,745 x 0,5 x 2,68 + 1,292 x 1/3 x 2,68

= 0,998 + 1,154

= 2,152 Tm'

d. Beban Angin (W)



Gambar 4.6 Gaya Angin Pot I-I

L = Titik Tangkap (Z) pada Beban Angin

A = $\frac{18,019 \text{ x } 0,5}{17,8}$

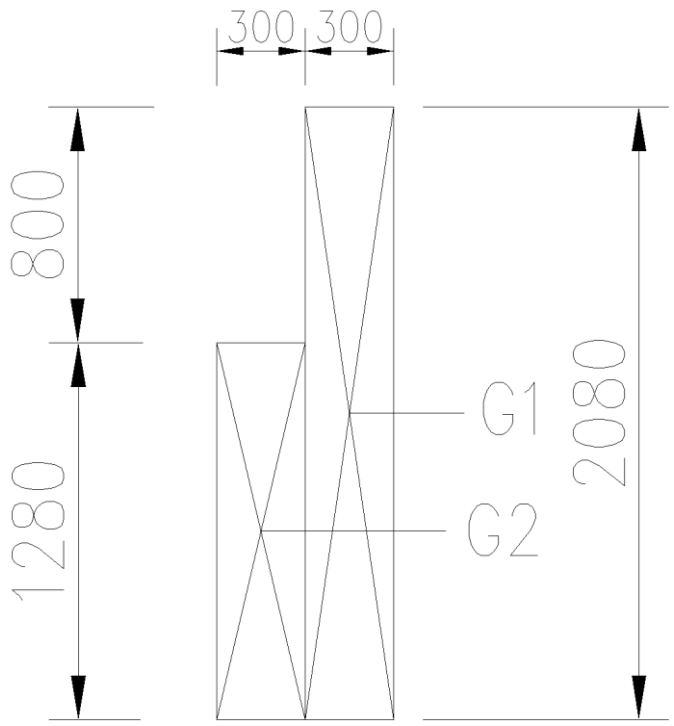
= 0,506 T

M_W = A x Z

= 0,506 x 2,155

= 1,090 Tm

d. Gaya Gempa (E)



Gambar 4.7 Gaya Gempa Pot I-I

Koefisien Gempa = 0,20

Tabel 4.1 Gaya dan Momen Akibat Gempa Pot I-I

No	Gh (T) Volume x γ_c x G	X (m)	Gh . X (Tm)
G1	0,3 x 2,08 x 2,5 x 0,2 = 0,312	1,04	0,324
G2	0,3 x 1,28 x 2,5 x 0,2 = 0,192	0,64	0,123
	∑ Gh = 0,504		**0,447**

d. Momen Ultimate

- Kombinasi 1

Mu = 1,2 M_D + 1,6 M_L + 1,6 M_H

= 1,2 x 2,343 + 1,6 x 4,672 + 1,6 x 2,152

= 13,73 Tm

- Kombinasi 2

Mu = 1,2 M_D + 1,0 M_L + 1,6 M_W

= 1,2 x 2,343 + 1,0 x 4,672 + 1,6 x 1,090

= 9,228 Tm

- Kombinasi 3

Mu = 1,2 M_D + 1,0 M_L + 1,0 M_E

= 1,2 x 2,343 + 1,0 x 4,672 + 1,0 x 0,447

= 7,931Tm

Jadi Mu max = **13,73 Tm**

4.2.2 Perhitungan Penulangan

M_u = 13,73 Tm = 137,3 kNm

f'c = 29 Mpa

fy = 400 Mpa

- Tulangan Utama

Tebal selimut beton (p) = 50 mm

Tebal potongan (h) = 600 mm

D Tul. Pokok = 19 mm

D Tul. Sengkang = 19 mm

Tebal efektif:

deff = h – p – Ø sengkang - 0,5 Ø pokok

= 600 – 50 – 19 - 0,5 x19

= 521,5 mm = 0,5215 m

$$k = \frac{Mu}{\phi \,.\, b \,.\, d^2}$$

$$= \frac{137,3}{0,8 \text{ x } 1,00 \text{ x } 0,5215^2}$$

= 631,062 kNm^2

Dari tabel A–29 pada buku Struktur Beton Bertulang (Istimawan Dipohusodo), sesuai dengan SK SNI T–15-1991–03 didapatkan:

ρ_{min} = 0,0035

ρ_{max} = 0,0244

Berdasarkan hasil dari tabel A–29 dengan nilai k = 631,062 kNm^2, maka didapatkan nilai ρ = 0,0035. Sehingga:

As = ρ_{min} . b . d

= 0,0035 x 1000 x 521,5

= 1825,25 mm^2

Dari tabel A-5 SK SNI T-15-1991-03 didapat **D19-150 (As = 1890,2 mm^2)**

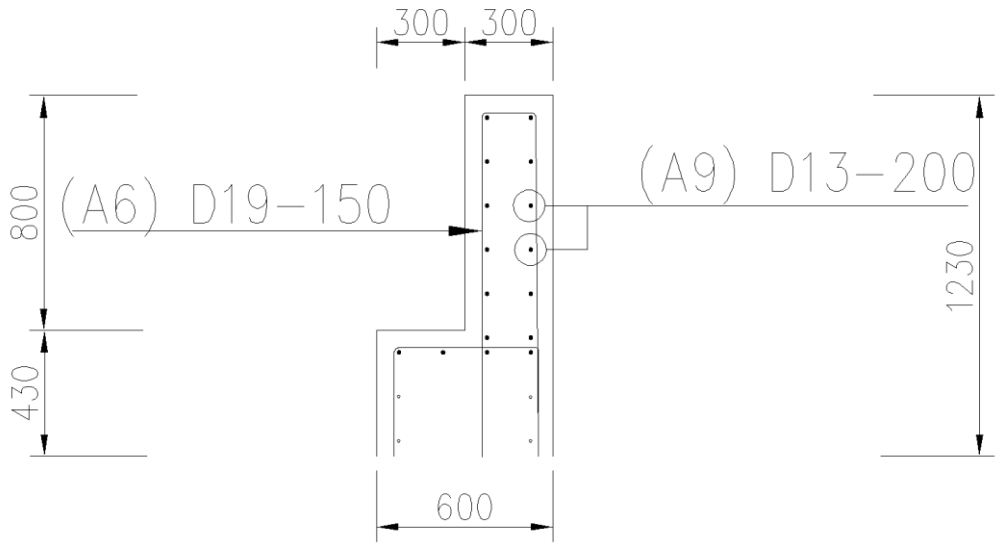
- Tulangan Bagi

As' = 25% x As

= 25% x 1825,25 mm^2

= 456,313 mm^2

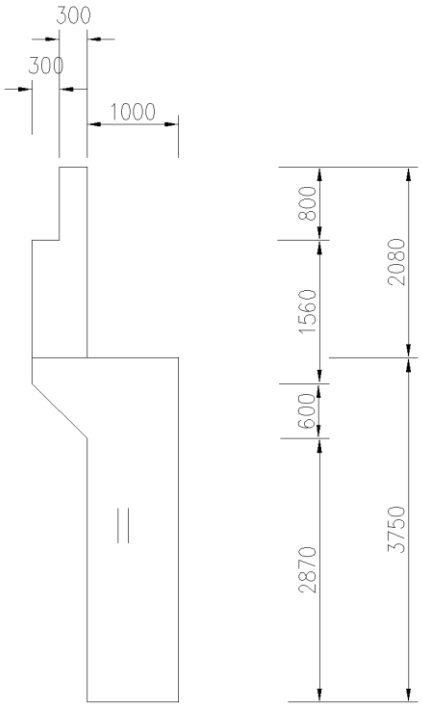
Dari tabel A-5 SK SNI T-15-1991-03 didapat **D13-200 (As = 663,7 mm^2)**



Gambar 4.8 Detai Tulangan Bagian I

4.3 Perhitungan Penulangan Pot II-II

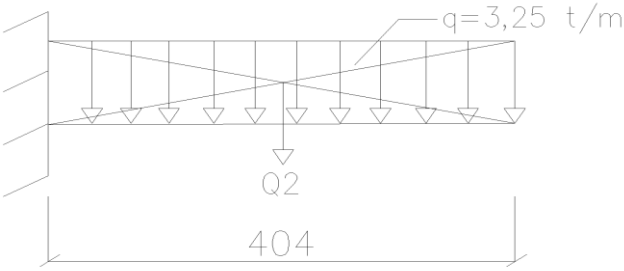
4.3.1 Analisa Pembebanan



Gambar 4.9 Potongan II–II

a. Beban Mati (D)

1) Berat Sendiri *Abutment*



Gambar 4.10 Gaya Akibat Berat *Abutment* Pot II-II

q = ($\frac{1,6+1,0}{2}$) x 1,0 x 2,5 = 3.25 t/m

Q Pot II- II = q x L

= 3.25 x 3,75

= 12,188 T

M_{D1} = Q2 x 1,875

= 12,188 x 1,875

= 22,853 Tm

2) Beban Mati (M) (struktur atas)

Gambar 4.11 Gaya Akibat Beban Mati Pot II-II

M = 367,35 : 8 = 45,919 T

e = 0,1 x 1,3 = 0,13 m

M_{D2} = 45,919 x 0,13

= 5,969 Tm

Total M_D = M_{D1} + M_{D2}

= 22,853 + 5,969

= **28,822Tm**

b. Beban Hidup (L)

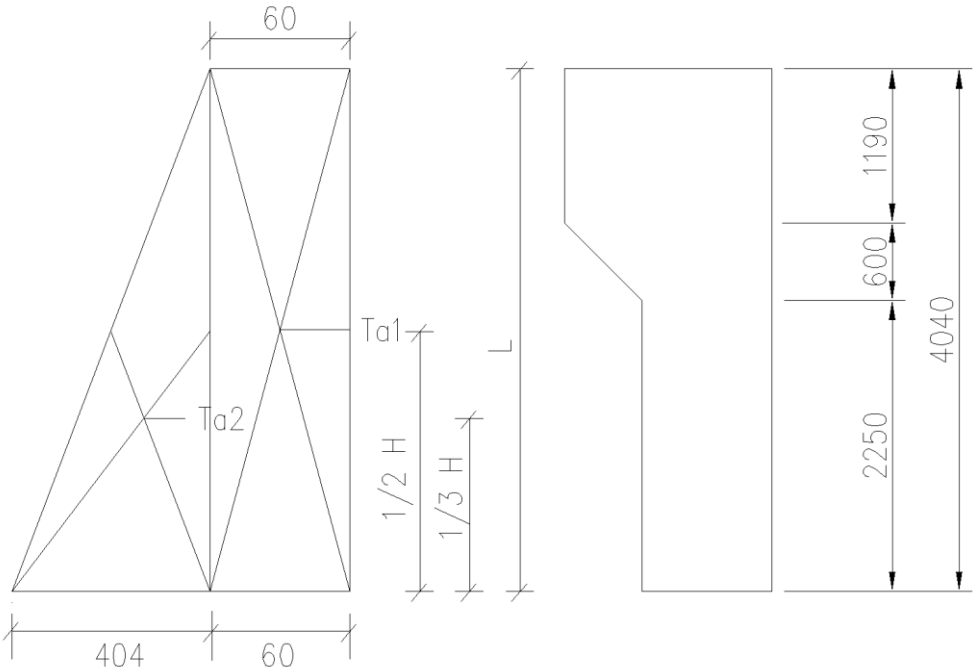
Gambar 4.12 Beban Hidup + Koef Kejut (H+K)

M (H+K) = 228,306 : 8 = 28,538 T

M_L = 28,538 x 0,13

= 3,71 Tm

c. Gaya Tekanan Tanah (H)



Gambar 4.13 Gaya Akibat Ta Pot II-II

Diketahui :

γ = 1,710 T/m^3

φ = 35°

Ka = 0,271

a1 = 0,278 t/m

b = 1,170 t/m

b1 = (0,6 + 5,83) x γ x Ka

= (0,6 + 5,83) x 1,710 x 0,271

= 2,979 t/m

Ta_1 = (a1 . H) + ((b - a1) . H)

= (0,278 x 3,75) + ((1,170 – 0,278) x 3,75)

= 1,042 + 3,345

= 4,387 T

Ta_2 = (3,75 x γ x Ka) x (0,5 x 3,75)

= (1,737) x (1,675)

= 2,909 T

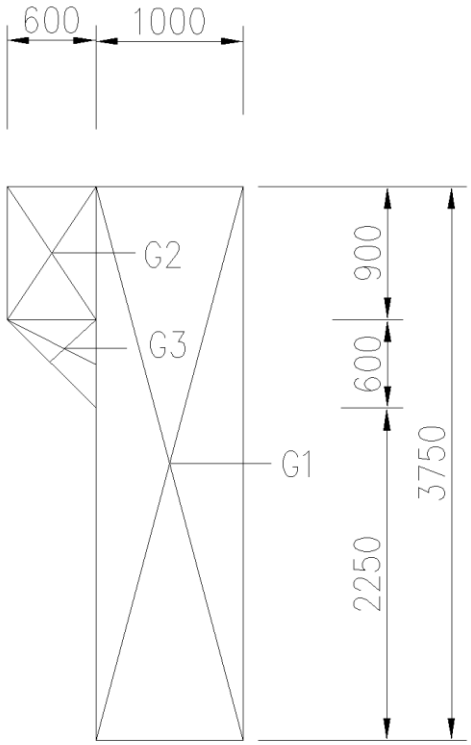
M_H = Ta_1 . 0,5 . L + Ta_2 . 1/3 . L

= 4,387 x 0,5 x 3,75 + 2,909 x 1/3 x 3,75

= 8,225 + 3,636

= 11,861 Tm’

d. Gaya Gempa (E)



Gambar 4.14 Gaya Akibat Gempa Pot II-II

Koefisien Gempa = 0,20

Tabel 4.2 Gaya dan Momen Akibat Gempa Pot II-II

No	Gh (T) Volume x γ_c x G	X (m)	Gh.X (Tm)
G1	1,0 x 3,75 x 2,5 x 0,20 = 1,875	1,875	3,515
G2	0,9 x 0,6 x 2,5 x 0,20 = 0,27	3,3	0,891
G3	(1/2 x 0,6 x 0,6) x 2,5 x 0,20 = 0,09	2,65	0,238
	∑ MGh		4,644

M_E = 4,644 Tm

e. Momen Ultimate

- Kombinasi 1

Mu = 1,2 M_D + 1,6 M_L + 1,6 M_H

= 1,2 x 28,822 + 1,6 x 3,71 + 1,6 x 11,861

= 59,5 Tm

- Kombinasi 2

Mu = 1,2 M_D + 1,0 M_L + 1,0 M_E

= 1,2 x 28,822 + 1,0 x 3,71 + 1,0 x 4,644

= 42,940 Tm

Jadi Mu max = **59,5 Tm**

4.3.2 Perhitungan Penulangan

M_u = 59,5 Tm = 595 kNm

f'c = 29 Mpa

fy = 400 Mpa

- Tulangan Utama

Tebal selimut beton (p) = 50 mm

Tebal potongan (h) = 1000 mm

D Tul. Pokok = 25 mm

D Tul. Sengkang = 19 mm

P'u = M_W (Beban Girder dan Bangunan Atas) + M_D (Beban Mati) + M_L (Beban Hidup) + M_H (Tekanan Tanah)

= 367,35 + 28,822 + 3,71 + 11,81

= 411,09 T = 4110,9 KN

= 4110900 N

Agr = h . b

= 1000 x 1000

= 1000000 mm^2

$$\frac{P'u}{\theta \cdot Agr \cdot 0{,}85 \cdot f'c} = \frac{4110900}{0{,}8 \text{ x } 1000000 \text{ x } 0{,}85 \text{ x}29}$$

= 0,2

Nilai ø tetap 0,8

$$e_t = \frac{Mu}{P'u}$$

$$= \frac{595}{4110{,}9}$$

= 0,145 m = 145 mm

$\frac{\text{et}}{\text{h}}$ = $\frac{145}{1000}$

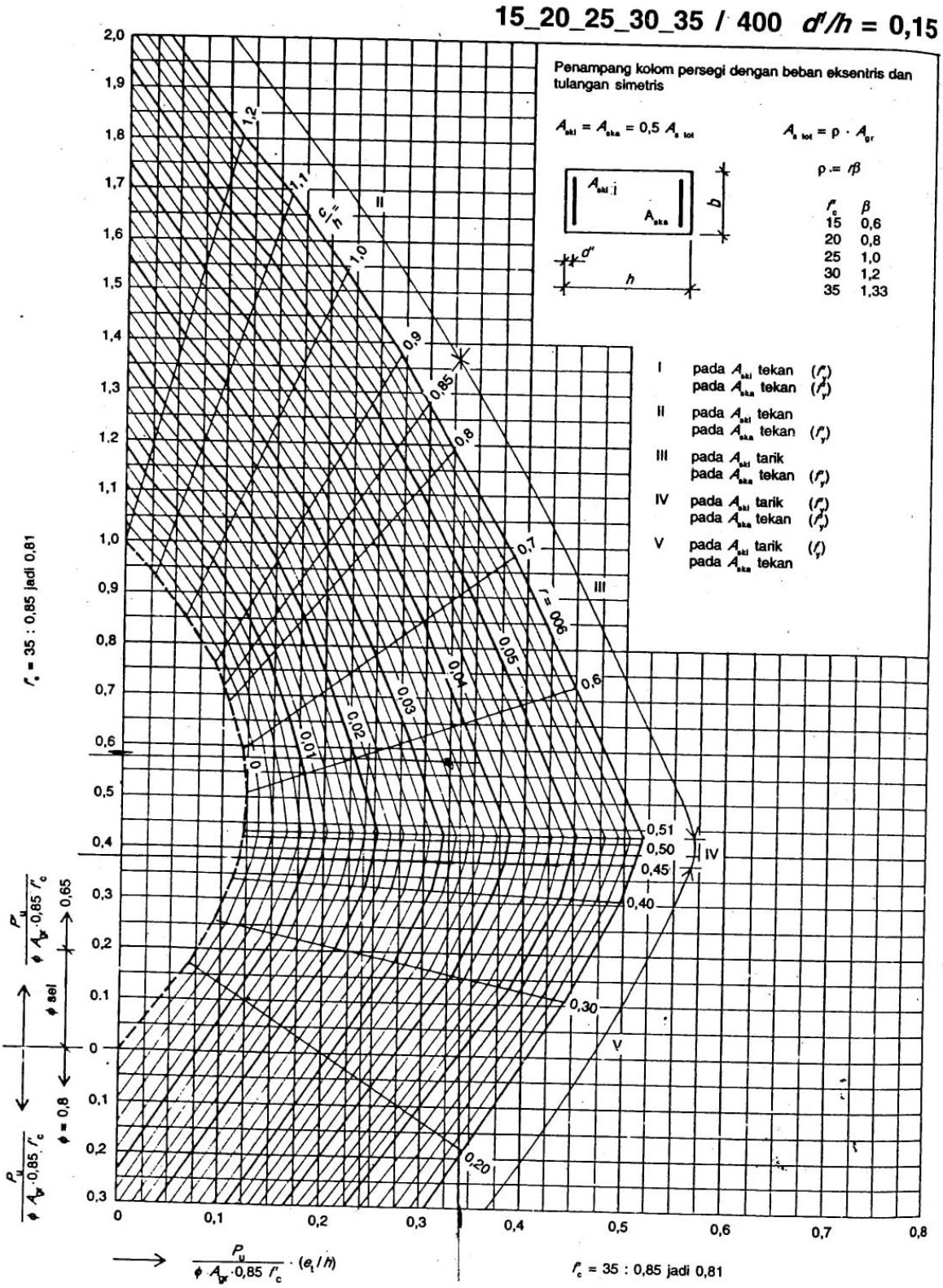
= 0,145

$\left(\frac{P'u}{\theta\ .\ Agr\ .0{,}85\ .f'c}\right)\ .\left(\frac{et}{h}\right)$ = 0,2x 0,145

= 0,03

Dianggap $\frac{\text{d}'}{\text{h}}$ = $\frac{65}{1000}$

= ≈0,07



Gambar 4.15 Grafik Untuk Kolom Dengan Tulangan Pada Dua Sisi Kolom

(Sumber: Buku Dasar-dasar Perencanaan Beton Bertulang)

Menurut grafik pada Gambar 4.15 Grafik Untuk Kolom Dengan Tulangan Pada Dua Sisi Kolom didapatkan:

r = 0,0145

β = 1,2

ρ = r. β

= 0,0145 . 1,2

= 0,0174

As total = ρ . Agr

= 0,0145 . 1000000

= 14500 mm^2

Dari tabel A-4 SK SNI T-15-1991-03 didapat **30D25 (As = 14727 mm^2)**

Jarak antar tulangan: $\frac{1000 - 2\ x\ 50}{7}$ = **150 mm**

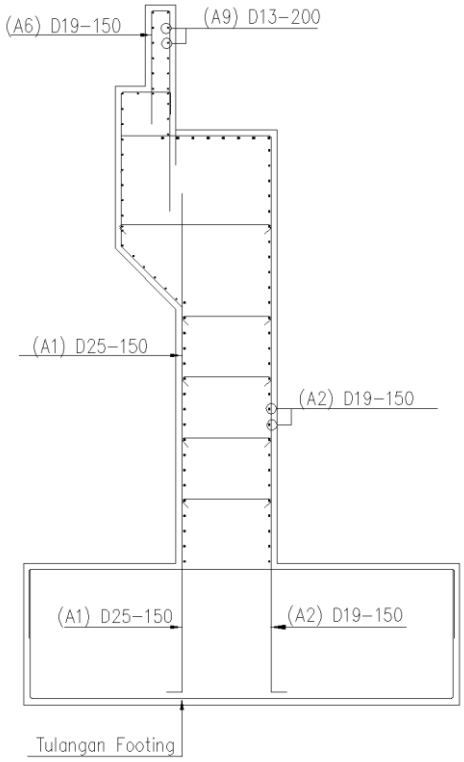
- Tulangan Bagi

As' = 25% x As

= 25% x 14500 mm^2

= 3625 mm^2

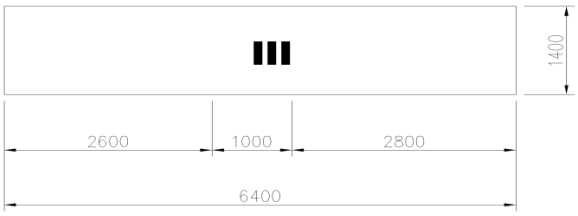
Dari tabel A-4 SK SNI T-15-1991-03 didapat **13D19 (As = 3685,5 mm^2)** jarak antar tulangan 150 mm.



Gambar 4.16 Detail Tulangan Bagian II-II

4.4 Perhitungan Penulangan Pot III-III

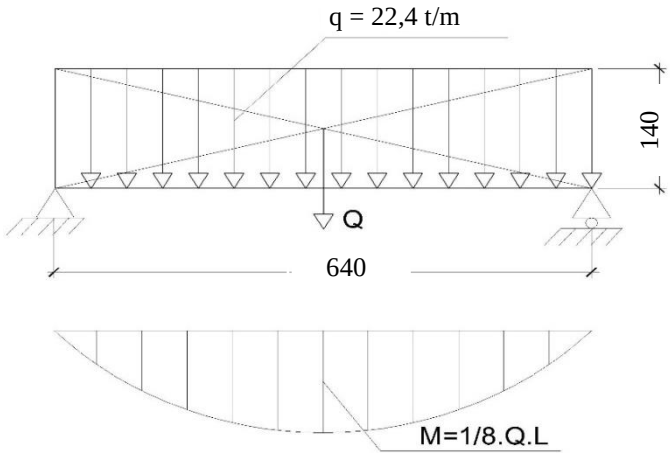
4.4.1 Analisa Pembebanan



Gambar 4.17 Potongan III-III

a. Beban Mati (D)

1) Akibat Berat *Abutment*



Gambar 4.18 Gaya Akibat Berat *Abutment* Pot III-III

(q) mati = 6,4 x 1,4 x 2,5 = 22,4 t/m

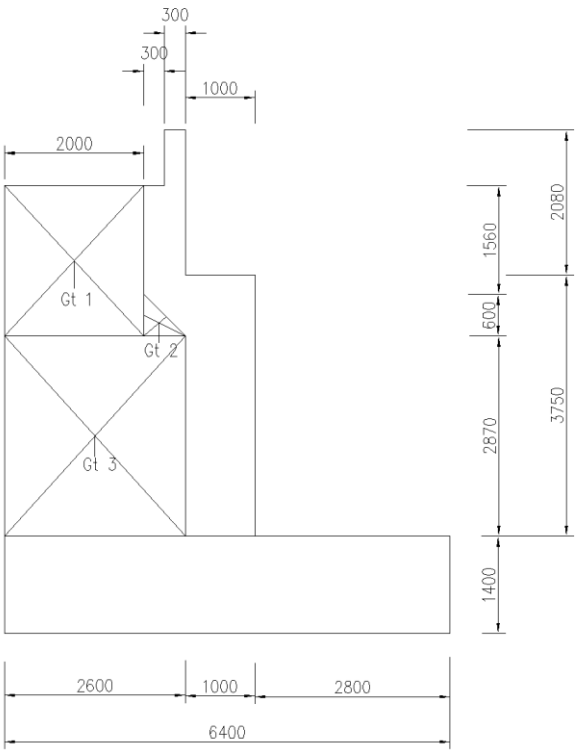
Q = q x L

= 22,4 x 6,4 = 143,36 T

M_{D1} = $\frac{1}{8}$ x Q x L

= $\frac{1}{8}$ x 143,36 x 6,4 **= 114.688 Tm'**

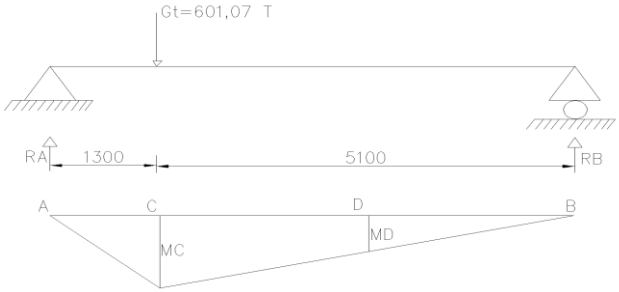
2) Akibat Berat Tanah Isian



Gambar 4.19 Gaya Tanah Isian

Tabel 4.3 Berat Tanah Isian

	V x γ_t	Berat (Ton)
Gt_1	(2.0x 2.32 x 17,8) x 2	165.184
Gt_2	($^1/_2$ x 0.6 x 0.6 x 17.8) x 2	6.408
Gt_3	(4.64 x 2.6 x 17.8) x 2	429.478
	∑Gt	601.07



Gambar 4.20 Momen Tanah Isian

$R_A \rightarrow \sum M_B = 0$

R_A x 6,4 – G_t x 5,1 = 0

$R_A = \frac{601.07\ x\ 5,1}{6,4}$

$R_A =$ 478,978 t

$R_B = G_t - R_A$

= 601,07 – 478,978

= 122,092 t

$M_C = R_A$ x 0.75

= 478,978 x 0.75

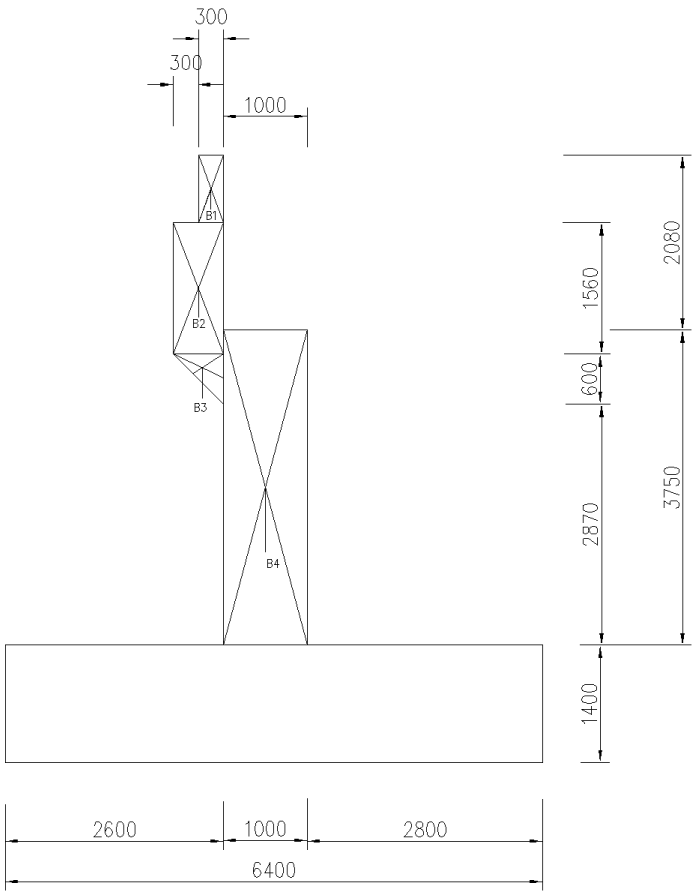
= 359,233 t

$\frac{M_D}{M_C} = \frac{3.2}{5.1}$

$M_D = \frac{359,233\ x\ 3,2}{5,1}$

$M_D =$ 225,401 Tm

3) Akibat Berat *Abutment* Terpusat (Gc)



Gambar 4.21 Beban Mati *Abutment* di Atas *Footing*

Tabel 4.4 Berat Sendiri *Abutment* di Atas *Footing*

	$V_1 \cdot \gamma_c$	Berat (Ton)
B1	(0.3 x 0.8 x 17,8) x 2.5	10,68
B2	(0.6 x 1.72 x 17,8) x 2.5	45,924
B3	(½ x 0.6 x 0.6x 17,8) x 2.5	8,01
B4	(5,68 x 1.0 x 17,8) x 2.5	252,76
	∑ Gc =	**317,374**

Total berat *abutment* di atas *footing* $= \frac{317,374}{17,8}$

= 17,83 T

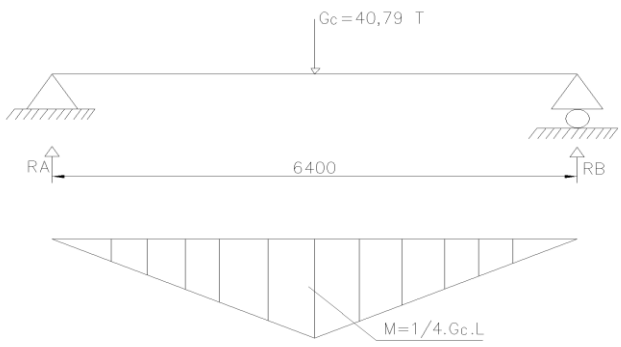
Beban mati struktur atas

M = $\left(\frac{367,35}{8}\right)$ x 0.5

= 22,960 T

G_c total = 17,83 + 22,960

= 40,79 T



Gambar 4.22 Gaya Akibat Berat *Abutment*

M_{D3} = $\frac{1}{4}$ x Gc x L

= $\frac{1}{4}$ x 40,79 x 6,4

= 65,264 Tm'

Total M_D = M_{D1} + M_{D2} + M_{D3}

= 114,688 + 225,401 + 65,264

= 405,353 Tm

b. Momen Ultimate

Mu = 1,2 M_D

= 1,2 x 405,353

= **486,424 Tm**

4.4.2 Perhitungan Penulangan

M_u = 486,424 Tm = 4864,24 kNm

f'c = 29 Mpa

fy = 400 Mpa

- Tulangan Utama

Tebal selimut beton (p) = 70 mm

Tebal potongan (h) = 1400 mm

D Tul. Pokok = 25 mm

D Tul. Sengkang = 19 mm

Tebal efektif:

deff = h – p – Ø sengkang - 0,5 Ø pokok

= 1400 – 70 – 19 - 0,5 x 25

= 1298.5 mm = 1,2985 m

$$k = \frac{Mu}{\phi \,.\, b \,.\, d^2}$$

$$= \frac{4864{,}24}{0{,}8 \text{ x } 1{,}00 \text{ x } 1{,}2985^2}$$

= 3606.128 kNm^2

Dari tabel A–29 pada buku Struktur Beton Bertulang (Istimawan Dipohusodo), sesuai dengan SK SNI T–15-1991–03 didapatkan:

ρ_{min} = 0,0035

ρ_{max} = 0,0244

Berdasarkan hasil dari tabel A–29 dengan nilai k = 3606,128 kNm^2, maka didapatkan nilai ρ = 0,0035. Sehingga:

As = ρ_{min} . b . d

= 0,0035 x 1000 x 1298.5

= 4544.75 mm^2

Dari tabel A-5 SK SNI T-15-1991-03 didapat **D25-150 (As = 4908,7 mm^2)**

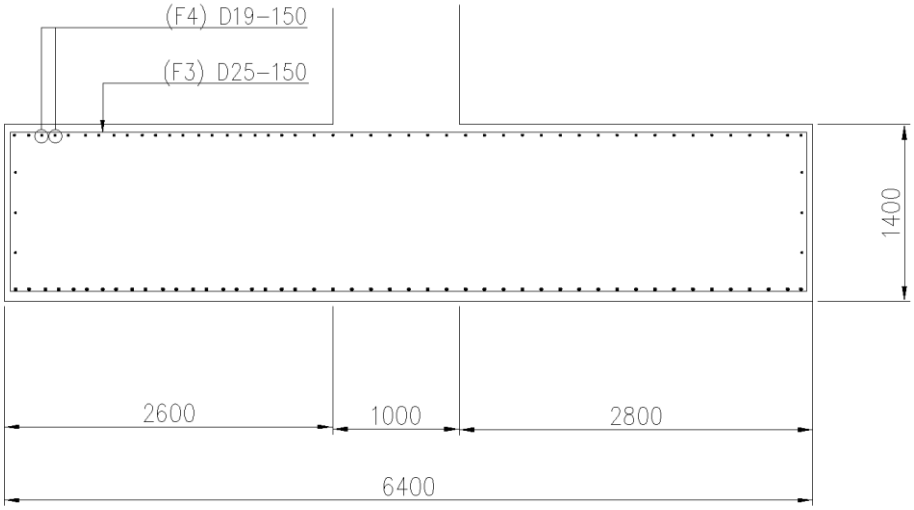
- Tulangan Bagi

As' = 25% x As

= 25% x 4544.75 mm^2

= 1136.188 mm^2

Dari tabel A-5 SK SNI T-15-1991-03 didapat **D16-150 (As = 1340,4 mm^2)**



Gambar 4.23 Detail Tulangan *Footing*