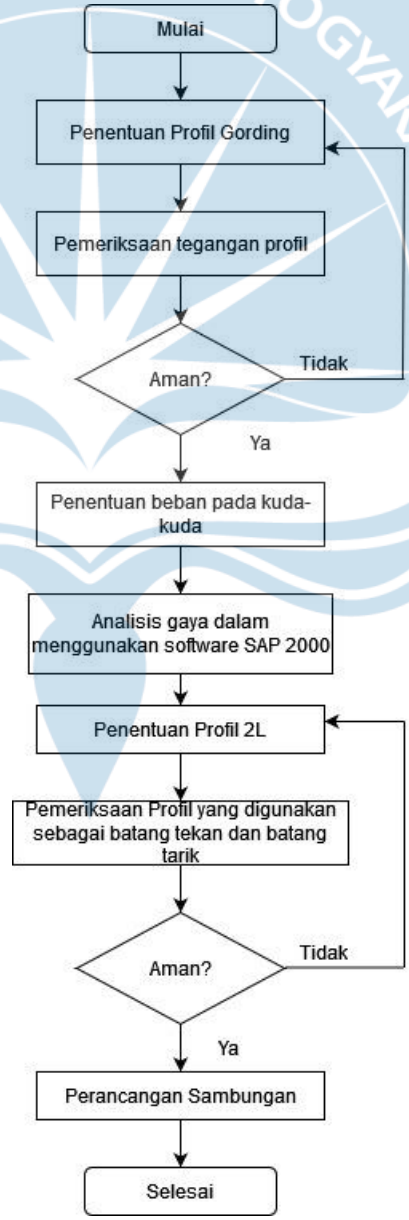
BAB II

PERANCANGAN STRUKTUR ATAS

2.1. Metode Perancangan

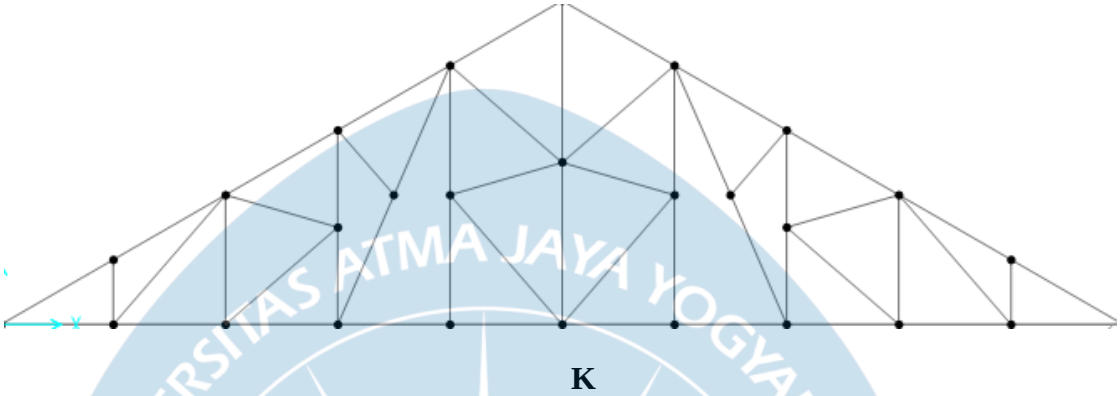
Untuk menentukan keamanan pada atap maka diperlukan perancangan atap dengan baik mulai dari mengecek keamanan profil gording, menentukan beban kuda-kuda, penentuan dan pemeriksaan profil pada batang tekan dan tarik hingga merancang sambungan yang akan dipakai. Untuk selengkapnya dapat dilihat *flowchart* pada gambar 2.1



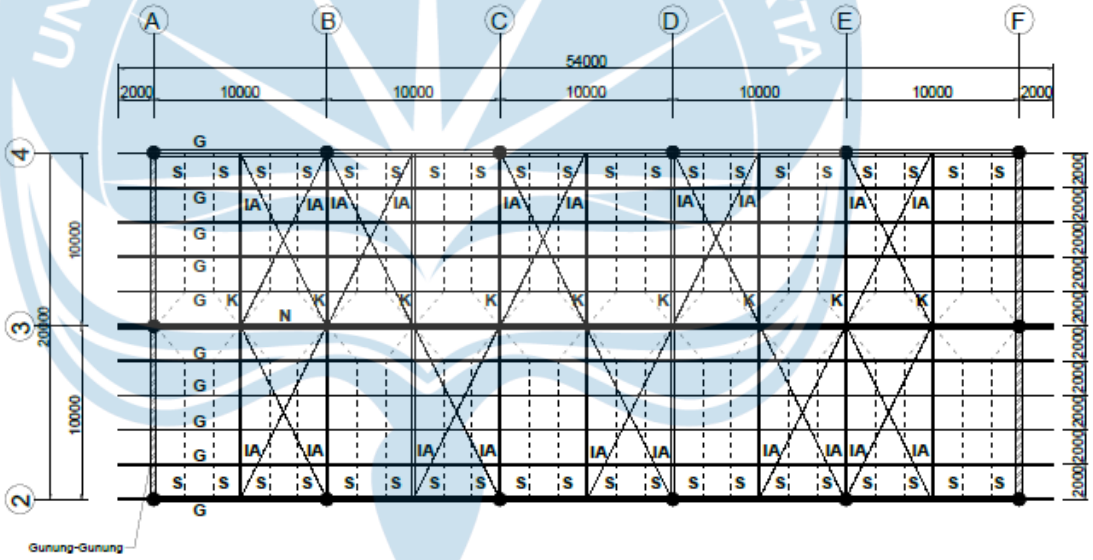
Gambar 2.1 *Flowchart* Perancangan Atap

2.1.1. Perencanaan Gording

Berikut merupakan gambar dari pemodelan kuda-kuda atap menggunakan yang diinputkan melalui software SAP 2000 pada 2.2dan gambar denah rencana atap pada gambar 2.3



Gambar 2.2 Pemodelan kuda-kuda atap menggunakan SAP 2000



Gambar 2.3 Gambar Denah Rencana Atap

Beban Gording

Berat sendiri = 10 kg / m' = 0,1 kN/m'

Berat Atap $= \frac{2}{\cos 30} \times 0{,}4$ = 0,924 kN/m'

Berat Plafond = 2 × 0,18 = 0,36 kN/m' +

Dead Load (D) rencana gording q = 1,384 kN/m'

Beban Hidup (L) diambil sebesar 1,0 kN

$$M_{3,D} = \frac{1}{8} \times 1{,}384 \times \cos 30 \times 5^2 = 3{,}746\ k\text{Nm}'$$

4

$$M_{3,L} = \frac{1}{4} \times 1 \times \cos 30 \times 5 = 1{,}082 \text{ kNm'}$$

$$M_{2,D} = \frac{1}{8} \text{ x } 1{,}384 \text{ x } \sin 30 \left(\frac{5}{3}\right)^2 = 0{,}240 \text{ kNm'}$$

$$M_{2,L} = \frac{1}{4} \times 1 \times \sin 30 \times \frac{5}{3} = 0{,}347 \text{ kNm'}$$

$M_{3,U}$ = 1,4 × 3,746 = 5,244 kNm'

$M_{3,U}$ = 1,2 × 3,746 + 1,6 × 1,082 = 6,226 kNm'

Dipilih $M_{3,U}$ = 6,226 kNm'

$M_{2,U}$ = 1,4 × 0,240 = 0,336 kNm'

$M_{2,U}$ = 1,2 × 0,240 + 1,6 × 0,347 = 0,843 kNm'

Dipilih $M_{2,U}$ = 0,843 kNm'

Cek Tegangan Pada Profil C

$f_b = \frac{M_{3,U}}{\emptyset W_3} + \frac{M_{2,U}}{\emptyset W_2} \leq F_y$ dengan nilai $\emptyset = 0{,}9$ (tabel 6.4-2 SNI 03-1729-2002)

Dipilih Profil C 150 x 65 x 20 dengan tebal 2,5mm

Dengan Data-data:

I_x = 2.670.000 mm^4

I_y = 440.000 mm^4

W_3 = Zx = 35.600 mm^3

W_2 = Zy = 10.000 mm^3

$f_b = \frac{6{,}226}{0{,}9\ x\ 35600} + \frac{0{,}843}{0{,}9\ x\ 10000} = 287{,}986\ MPa \geq 240$ MPa (Tidak Aman)

Cari profil lain

Dipilih Profil C 150 x 65 x 20 dengan tebal 3,2 mm

Dengan Data-data:

I_x = 3.320.000 mm^4

I_y = 540.000 mm^4

W_3 = Zx = 44.200 mm^3

W_2 = Zy = 12.200 mm^3

$$f_b = \frac{6{,}226}{0{,}9\ x\ 44200} + \frac{0{,}843}{0{,}9\ x\ 12200} = 233{,}287\ MPa\ \leq 240\ \text{MPa}$$

Karena 233,287 MPa ≤ 240 MPa maka tegangan profil C 150 x 65 x 20 dengan tebal 3,2 mm aman

Cek Defleksi Gording

$$\delta_2 = \frac{5}{384} \times \frac{1{,}384\ x \cos 30\ x\ 5000^4}{200.000\ x\ 3.320.000} + \frac{1}{48} \times \frac{1\ x\ cos\ 30\ x\ 5000^3}{200.000\ x\ 3.320.000}$$

=14,693 mm

$$\delta_3 = \frac{5}{384} \times \frac{1{,}384\ x\ \sin 30}{200.000\ x\ 540000} \times (\frac{5000}{3})^4 + \frac{1}{48} \times \frac{1\ \text{x}\ \sin 30}{200.000\ x\ 540000} \times (\frac{5000}{3})^3$$

= 0,644 mm

$$\delta = \sqrt{14{,}693^{\,2} + 0{,}644^2}\ \leq \frac{1}{240} L$$

= 14,707 ≤ 20,833

Karena defleksi gording 14,707 mm < 20,833 maka defleksi gording aman

Rencana Sag-Rod

Gaya Sag-Rod

- $F_{t,D} = n(\frac{L}{3} \times q \times \sin\alpha)$

  $F_{t,D} = 5(\frac{5}{3} \times 1{,}384 \times \sin 30)$ = 5,77 kN

- $F_{t,L} = \frac{n}{2} \times P \times \sin\alpha$

  $F_{t,L} = \frac{5}{2} \times 1 \times \sin 30$ = 1,25 kN

Kombinasi Pembebanan

- $F_{t,U} = 1{,}4F_{t,D}$

  = 1,4 x 5,77 = 8,078 kN

- $F_{t,U} = 1{,}2F_{t,D} + 1{,}6F_{t,L}$

  $= 1{,}4\ x\ 5{,}77\ +\ 1{,}6\ x\ 1{,}25 = 10{,}078$ kN (Dipilih yang terbesar)

Luas Batang Sag-rod yang dibutuhkan

$$A_{sr} = \frac{F_t . 10^3}{\emptyset F_y}\ mm^2$$

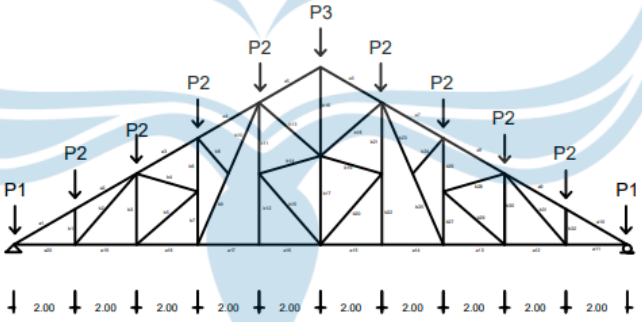
$$= \frac{10{,}078\ .10^3}{0{,}9\ x\ 240}\ mm^2$$

$$= 46{,}66\ mm^2$$

Pakai P10 = 78,540 mm²

2.1.2. Rencana Beban Kuda-kuda

pada gambar 2.4 merupakan rencana beban mati pada kuda kuda.



Gambar 2.4 Rencana beban mati

Beban Mati

Beban P1:

- Berat sendiri kuda-kuda $= \frac{2}{2} \times 0{,}5$ = 0,5 kN
- Berat gording = 5 x 0,0751 = 0,376 kN
- Berat atap $= \frac{(\frac{2}{2}+2)}{\cos 30} \times 5 \times 0{,}4$ = 6,928 kN
- Berat plafond $= (\frac{2}{2} + 2) \times 5 \times 0{,}2$ = 3 kN +

  10,804 kN

Beban P2:

- Berat sendiri kuda-kuda = $2 \times 0{,}5$ = 1 kN
- Berat gording = 5 x 0,0751 = 0,375 kN
- Berat atap = $\frac{2}{\cos 30} \times 5 \times 0{,}4$ = 4,619 kN
- Berat plafond = $2 \times 5 \times 0{,}2$ = 2 kN +

7,994 kN

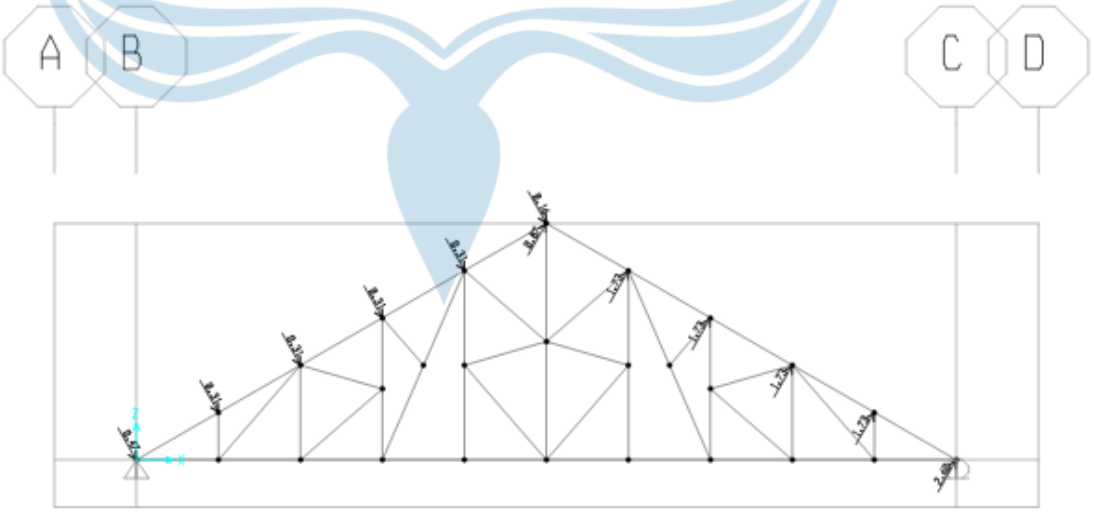
Beban P3:

- Berat sendiri kuda-kuda = $2 \times 0{,}5$ = 1 kN
- Berat gording = 2 x 5 x 0,0751 = 0,751 kN
- Berat atap = $\frac{2}{\cos 30} \times 5 \times 0{,}4$ = 4,619 kN
- Berat plafond = $2 \times 5 \times 0{,}2$ = 2 kN +

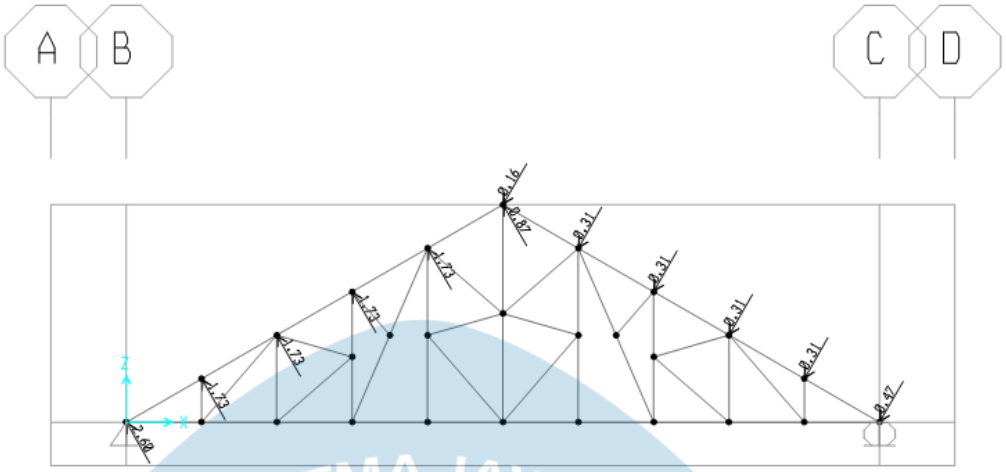
8,37 kN

Beban Hidup

Beban hidup (*L*) diambil sesuai ketentuan dalam Peraturan Pembeban, dalam hal ini diambil sebesar 1,0 kN pada setiap joint. Pada gambar 2.5 merupakan rencana beban angin dari kiri ke kanan pada atap dan dari kanan ke kiri pada atap.



(a) Beban angin dari kiri ke kanan pada atap



Gambar 2.5 Rencana beban angin

(b) Beban angin dari kanan ke kiri pada atap

h = (10+5,8)/2 =7,9 m

α = 30°

h/L = 0,329

C_{ti} = 0,1088 (Interpolasi) efek angin tiup

C_{is} = −0,6 efek angin hisap

Beban $W_1 = \frac{(\frac{a}{2}+b)}{\cos\alpha} \times C_{ti} \times L \times Q_w$

$= \frac{(\frac{2}{2}+2)}{\cos 30} \times 0{,}1088 \times 5 \times 0{,}25$ = 0,471 kN

Beban $W_2 = \frac{a}{\cos\alpha} \times C_{ti} \times L \times Q_w$

$= \frac{2}{\cos 30} \times 0{,}1088 \times 5 \times 0{,}25$ = 0,314 kN

Beban $W_3 = \frac{1}{2}\frac{a}{\cos\alpha} \times C_{ti} \times L \times Q_w$

$= \frac{1}{2}\frac{2}{\cos 30} \times 0{,}1088 \times 5 \times 0{,}25$ = 0,157 kN

Beban $W_4 = \frac{1}{2}\frac{a}{\cos\alpha} \times C_{is} \times L \times Q_w$

$$=\frac{1}{2}\frac{2}{\cos 30}\times -0{,}6\times 5\times 0{,}25 \qquad = \text{-0,866 kN}$$

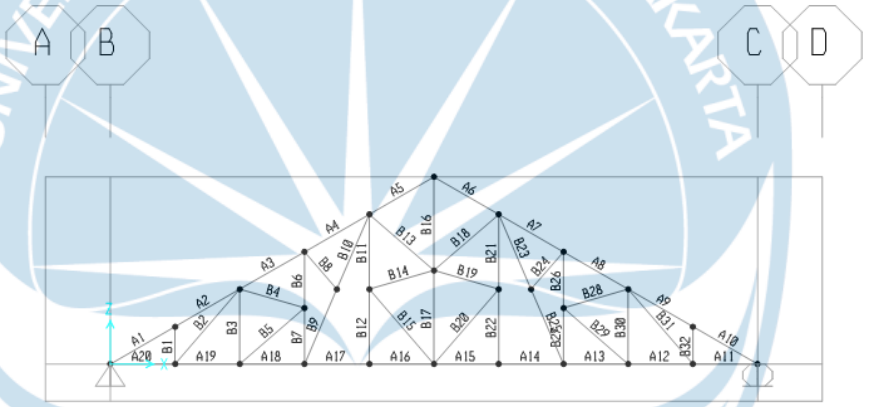
Beban $W_5 = \frac{a}{\cos\alpha}\times C_{is}\times L\times Q_w$

$$=\frac{2}{\cos 30}\times -0{,}6\times 5\times 0{,}25 \qquad = \text{-1,732 kN}$$

Beban $W_6 = \frac{(\frac{a}{2}+b)}{\cos\alpha}\times C_{is}\times L\times Q_w$

$$=\frac{(\frac{2}{2}+2)}{\cos 30}\times -0{,}6\times 5\times 0{,}25 \qquad = \text{-2,598 kN}$$

Berikut merupakan rencana gaya batang pada kuda kuda atap dapat dilihat pada tabel 2.1. untuk mengetahui nomor pada setiap batang kuda kuda atap dapat dilihat pada gambar 2.6



Gambar 2.6 Nomor batang pada kuda-kuda

Tabel 2.1 Rencana Gaya-gaya Batang pada Kuda-kuda Atap

No Batang (1)	Panjang (m) (2)	Beban DL (kN) (3)	Beban LL (KN) (4)	Beban Angin Kiri Wiki (KN) (5)	Beban Angin Kanan Wiki (KN) (6)	1,4 DL (7)	1,2DL + 1,6 LL (8)	1,2DL + 1,3 Wki + 0,5 LL (9)	1,2DL + 1,3 Wka + 0,5 LL (10)	Gaya rencana (kN) (11)
A1	2,3	-81,68	-8,97	-1,54	4,99	-114,35	-112,38	-104,50	-96,02	-114,35
A2	2,3	-81,56	-8,96	-1,71	4,98	-114,19	-112,21	-104,58	-95,88	-114,19
A3	2,3	-64,40	-7,00	-1,18	5,00	-90,16	-88,48	-82,31	-74,28	-90,16
A4	2,3	-64,37	-6,99	-1,36	5,00	-90,12	-88,43	-82,50	-74,24	-90,12
A5	2,3	-35,60	-3,84	-0,61	3,86	-49,84	-48,85	-45,28	-39,63	-49,84
A6	2,3	-35,60	-3,84	-0,70	3,35	-49,84	-48,85	-45,54	-40,28	-49,84
A7	2,3	-64,37	-6,99	-0,91	7,48	-90,12	-88,43	-81,92	-71,01	-90,12
A8	2,3	-64,40	-7,00	-0,91	6,50	-90,16	-88,48	-103,53	-72,33	-103,53
A9	2,3	-81,56	-8,96	-0,90	9,45	-114,19	-112,21	-103,39	-90,07	-114,35
A10	2,3	-81,68	-8,97	-0,90	8,48	-114,35	-112,38	-103,68	-91,48	-114,35
A11	2	70,68	7,77	0,78	-6,04	98,95	97,25	89,72	80,85	98,95
A12	2	63,45	6,94	0,79	-4,34	88,83	87,24	80,63	73,96	99,83

Tabel 2.1 Rencana Gaya-gaya Batang pada Kuda-kuda Atap

No Batang (1)	Panjang (m) (2)	Beban DL (kN) (3)	Beban LL (KN) (4)	Beban Angin Kiri Wiki (KN) (5)	Beban Angin Kanan Wiki (KN) (6)	1,4 DL (7)	1,2DL + 1,6 LL (8)	1,2DL + 1,3 Wki + 0,5 LL (9)	1,2DL + 1,3 Wka + 0,5 LL (10)	Gaya rencana (kN) (11)
A13	2	55,72	6,06	0,79	-2,60	78,01	76,56	70,91	66,51	78,01
A14	2	47,97	5,20	0,79	-0,88	67,16	65,89	61,19	59,03	67,16
A15	2	47,97	5,20	0,79	-0,87	67,16	65,89	61,19	59,03	67,16
A16	2	47,97	5,20	1,10	0,86	67,16	65,89	61,60	61,29	67,16
A17	2	47,97	5,20	1,10	0,86	67,16	65,89	61,60	61,29	67,16
A18	2	55,72	6,06	1,41	0,86	78,01	76,56	71,73	71,01	78,01
A19	2	63,45	6,94	1,73	0,86	88,83	87,24	81,86	80,73	88,83
A20	2	70,68	7,77	2,04	0,87	98,95	97,25	91,35	89,83	98,95
B1	1,1	-8,16	-0,98	-0,36	-0,008	-11,43	-11,36	-10,75	-10,30	-11,43
B2	3	11,07	1,27	0,47	0,02	15,50	15,31	14,33	13,95	15,50
B3	2,3	-6,23	-0,74	-0,27	-0,005	-8,72	-8,66	-8,20	-7,85	-8,72
B4	2	-8,06	-0,91	-0,33	0,005	-11,28	-11,13	-10,50	-10,12	-11,28
B5	2,6	10,26	1,15	0,42	-0,001	14,36	14,16	13,43	12,89	14,36
B6	1,7	-8,36	-0,98	-0,36	-0,002	-11,70	-11,60	-10,98	-10,52	-11,70
B7	1,7	-17,53	-1,99	-0,72	-0,0009	-24,54	-24,21	22,96	-22,03	-24,54
B8	1,5	0,09	-0,006	-0,002	0,0001	0,13	0,1	0,11	0,11	0,13
B9	2,5	19,45	2,16	0,78	0,003	27,23	26,79	25,47	24,66	27,23
B10	2,5	19,65	2,16	0,78	0,005	27,51	27,03	25,43	24,42	27,51
B11	2,3	2,79	0,21	-0,19	-1,44	3,91	3,69	3,21	1,59	3,01
B12	2,3	0,46	0,008	0,002	-0,002	0,64	0,56	0,66	0,55	0,66
B13	2,6	-22,75	-2,48	-0,65	1,31	-31,85	-31,27	-29,39	-26,83	-31,85
B14	2	-1,48	-0,15	0,14	1,04	-2,08	-2,02	-1,67	-0,51	-2,08
B15	3	2,20	0,22	-0,20	-1,52	3,08	2,99	2,48	0,78	3,08
B16	2,8	26,87	2,83	0,52	-2,85	37,62	36,77	34,33	29,96	37,62
B17	2,8	-2,79	-0,33	-0,05	0,3	3,90	-3,87	-3,58	-3,13	3,90
B18	2,6	-22,75	-2,48	-0,24	3,61	-31,85	31,27	-28,85	-23,85	-31,85
B19	2	-1,48	-0,15	-0,19	-0,77	-2,08	2,02	-2,10	-2,85	-2.85
B20	3	2,20	0,22	0,28	1,13	3,08	2,99	3,11	4,42	4,42
B21	2,3	2,79	0,21	0,26	1,05	3,91	3,69	3,79	4,83	4,83
B22	2,3	0,46	0,008	0,00009	-0,02	0,64	0,56	0,55	0,53	0,64
B23	2,5	19,65	2,16	-0,0005	-4,32	27,51	27,03	24,66	19,04	27,51
B24	1,5	0,09	-0,004	0,000004	0,01	0,13	0,10	0,11	0,13	-0,13
B25	2,5	19,48	2,16	-0,0003	-4,31	27,23	26,79	24,42	18,81	27,23
B26	1,7	-8,23	-0,98	0,0003	1,96	-11,70	-11,60	-10,52	-7,97	-11,70
B27	1,7	-17,53	-1,99	-0,000006	3,97	-24,54	-24,21	22,03	-16,87	-24,54
B28	2	-8,06	-0,91	0,0006	1,81	-11,28	-11,13	-10,13	-7,77	-11,13
B29	2,6	10,26	1,15	0,0007	-2,30	14,36	14,16	12,89	9,90	14,16
B30	2,3	-6,23	-0,74	0,0007	1,49	-8,72	-8,66	-7,85	-5,91	-8,66
B31	3	11,07	1,26	-0,004	-2,57	15,50	15,31	13,92	10,58	15,31
B32	1,1	-8,16	-0,98	0,001	1,97	-11,43	-11,36	-10,28	7,72	-11,36

2.1.3. Penentuan Profil Kuda-Kuda

A. Profil L 60x60x6-10 (batang eksterior)

Gaya Rencana Batang Tekan (-) = 114,35 kN

Gaya Rencana Batang Tarik (+) = 98,95 kN

A= 691 mm^2

Ix=Iy = 227900 mm^4

Cx=Cy = 17 mm

Tp= 10 mm

Properti Profil gabungan 2L

A = 2 x 691 = 1382 mm^2

I_{xg} = 2 x 227900 = 455800 mm^4

$I_{yg} = (2 \times Iy) + (2 \times Ag \times (Cy + \frac{Tp}{2})^2)$ = 1124688 mm4

$r_{xg} = \sqrt{\frac{Ixg}{A\ Profil}} = \sqrt{\frac{455800}{1382}}$ = 18.162 mm

$r_{yg} = \sqrt{\frac{Iyg}{A\ Profil}} = \sqrt{\frac{1124688}{1382}}$ = 28. 53 mm

digunakan nilai yang terkecil yaitu 18.162 mm

1. Analisis Batang Tekan

$$\frac{KL}{r} = \frac{1 \times 2300}{18.162} = 126.64$$

$$4.71\sqrt{\frac{E}{fy}} = 4.71\sqrt{\frac{200000}{240}} = 135.97$$

Karena nilai $\frac{KL}{r} < 4.71\sqrt{\frac{E}{Fy}}$ maka digunakan persamaan pertama dengan

$$F_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2}$$

Fe = 123.06 MPa

Fcr = 106.102 MPa

ΦPn = 0.9 x 106.102 x 1382

= 131969.667 N

= 131.969 >114.35 kN (Pu)….aman

2. Analisis Batang Tarik

Syarat:

$$\frac{L}{imin} = \frac{3000}{18.162} = 165.18 < 240\ (aman)$$

ΦPn = 0.9 x 240 x 1382

= 298512 N

= 298.512 kN > 98.95 kN ….aman

B. Profil L 50x50x5 (batang interior)

Gaya tekan max = -31,85 kN

Gaya tarik max = 37,62 kN

A= 480,2 mm^2

I_x=I_y = 111000 mm^4

C_x=C_y = 14,1 mm

Tp= 10 mm

Properti Profil gabungan 2L

A = 2 x 480,2 = 960,4 mm^2

I_{xg} = 2 x 111000 = 222000 mm^4

$I_{yg} = (2 \times Iy) + (2 \times Ag \times (Cy + \frac{Tp}{2})^2)$ = 572363,5 mm^4

$r_{xg} = \sqrt{\frac{Ixg}{A\ Profil}} = \sqrt{\frac{222000}{960,4}}$ = 15,2037 mm

$r_{yg} = \sqrt{\frac{Iyg}{A\ Profil}} = \sqrt{\frac{572363,5}{960,4}}$ = 24,4124 mm

digunakan nilai yang terkecil yaitu 15,2037 mm

1. **Analisis Batang Tekan**

$$\frac{KL}{r} = \frac{1 \times 2600}{15{,}2037} = 171{,}0106$$

$$4.71\sqrt{\frac{E}{Fy}} = 4.71\sqrt{\frac{200000}{240}} = 135.97$$

Karena nilai $\frac{KL}{r} > 4.71\sqrt{\frac{E}{fy}}$ maka digunakan persamaan kedua dengan

$$F_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2}$$

Fe = 67,4969 MPa

Fcr = 59,1948 MPa

ΦPn = 0.9 x 59,1948 x 960,4

= 51165,61 N

= 51,1656 > 31,85 kN (Pu)….aman

2. **Analisis Batang Tarik**

Syarat:

$$\frac{L}{imin} = \frac{2800}{15{,}2037} = 184{,}1652 < 240\ (aman)$$

ΦPn = 0.9 x 240 x 960,4

= 207446,4 N

= 207,446 kN > 37,62 kN ….aman

2.1.4. Rencana Sambungan Elemen Kuda-Kuda

1. **Kegagalan Geser**

Diketahui:

Φf = 0.75

R1 = 0.4 (ulir pada seluruh bagian baut)

fub = 565 MPa

Ab = 0.25 x π x 12^2 = 113.0973 mm^2

Vd = Φf x r1 x fub x Ab

= 0.75 x 0.4 x 565 x 113.0973

= 19170 N = 19.17 kN

2. Kegagalan Tumpu

Φf = 0.9

Db = 12 mm

tp = 10 mm

fu = 565 MPa

Rd = 2.4 x Φf x db x tp x fu

= 2.4 x 0.75 x 12 x 10 x 565

= 122040 N = 122,04 kN

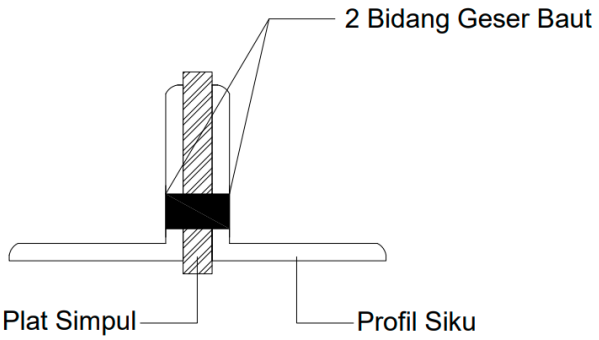
Digunakan nilai yang terkecil antara 2 Vd dan Rd, maka:

$$nb = \frac{114.35}{2 \times 19,17} = 2,9825 \approx 3 \; buah \; baut$$

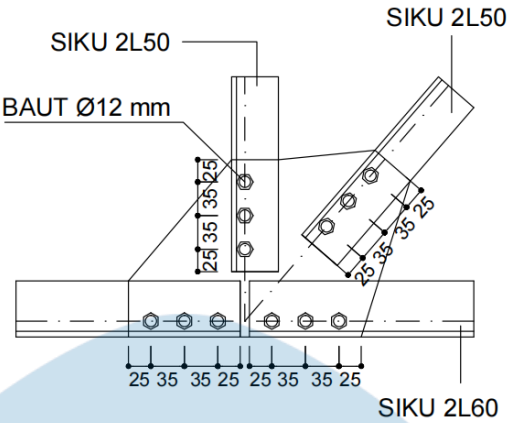
Jarak baut ke tepi = 2 x 12 mm = 24 mm

Jarak antar baut = 3 x 12 = 36 mm

Setelah melakukan perhitungan,Berikutnya digambarkan penampang geser baut dan detail sambungan baut kuda kuda siku pada gambar 2.7 dan gambar gambar 2.8.



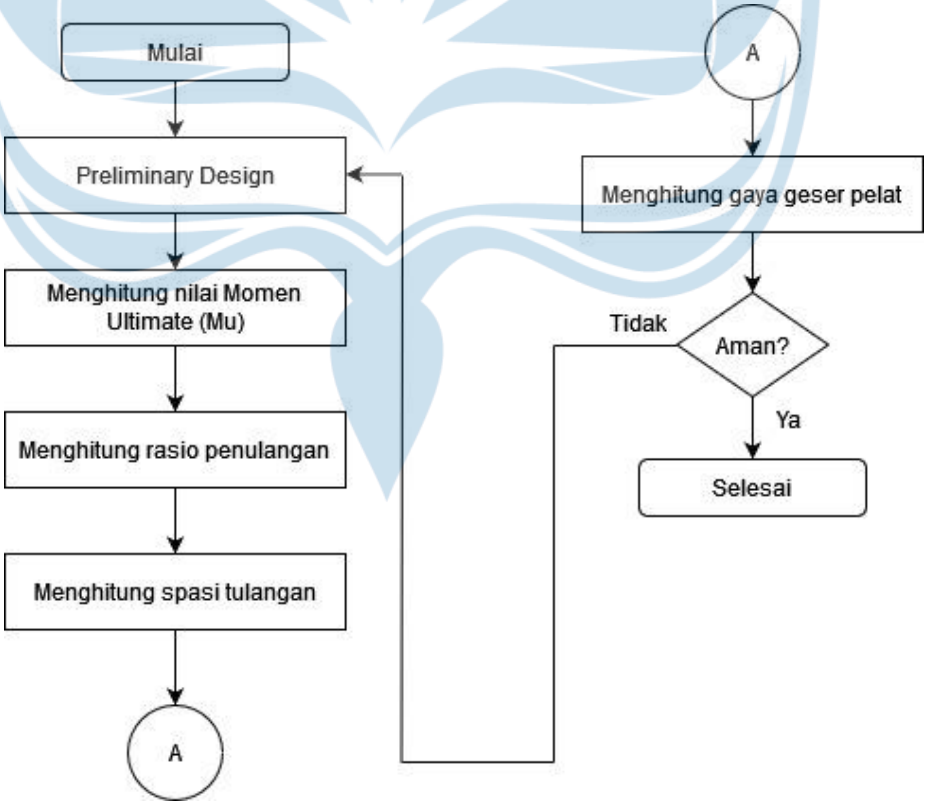
Gambar 2.7 Penampang Geser Baut



Gambar 2.8 Detail Sambungan Baut Kuda-Kuda Siku

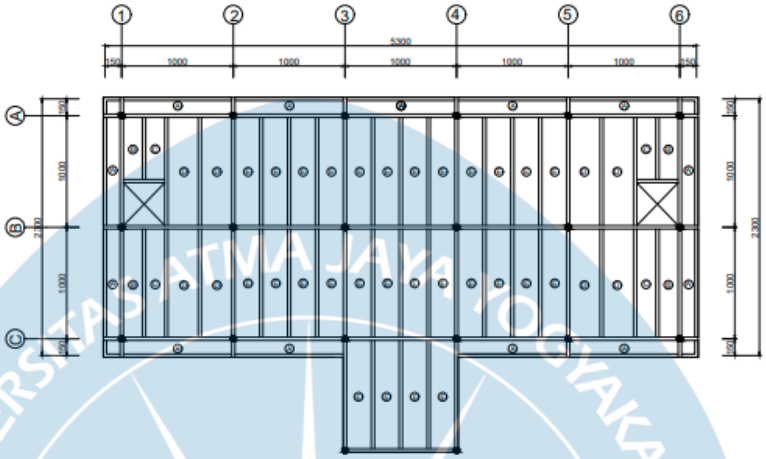
2.1.5. Rencana Pelat Lantai

Setelah melakukan perancangan atap, selanjutnya dilakukan perancangan pelat lantai. Untuk serangkaian urutan pekerjaan yang dilaksanakan selengkapnya dapat dilihat pada gambar 2.9 mengenai perancangan pelat lantai



Gambar 2.9 *Flowchart* Perancangan Pelat Lantai

Berikut merupakan gambar denah rencana pada pelat lantai serta tabel pembebanan pada pelat lantai. Tipe plat pada denah disesuaikan dengan ukuran pelat lantainya.



Gambar 2.10 Denah Rencana Pelat

Tabel 2.2 Pembebanan Pada Pelat Lantai

Fungsi Plat	Macam Pembebanan	Tebal	B. Vol	B. Mati, D	B.Hidup, L	Wu = 1.2D + 1.6 L
		mm	kN/m^3	kN/m^2	kN/m^2	kN/m^2
Lantai	1. Beban sendiri	120	24	2,88		
	2. Beban Pasir	50	14	0,7		
	3. beban spesi	40	22	0,88		
	4. Beban Keramik (granit)	10	24	0,24		
	5. Beban Plafon	-	-	0,18		
			Total	4,88	4,79	16,092

1. Rencana Penulangan Pelat Lantai

Penentuan tebal pelat (SNI 2847:2019 pasal 7.3.1.1)

Pelat lantai 1 ujung menerus = $\frac{L}{24} = \frac{2500}{24}$ = 104,1667 mm

Pelat lantai 2 ujung menerus = $\frac{L}{28} = \frac{2500}{28}$ = 89,2857 mm

Maka diambil tebal pelat sebesar 120 mm

A. Pelat lantai A (Pelat 1 Arah)

Ly = 10 m

Lx = 1.5 m

Mu^{-} = ½ x q x L^2

Mu^{-} = ½ x 16.092 x 1.5^2

Mu^{-} = 18,1035 kNm

= 18,1035 x 10^6 Nmm

Selimut beton (ts) = 20 mm

fy = 280 MPa

f'c = 25 MPa

Tebal Pelat (ht) = 120 mm

b = 1000 mm

β1 = 0,85 (karena f'c = 25 MPa)

ds = 20 + $\frac{12}{2}$ = 26 mm

d = 120 – 26 = 94 mm

1. Perhitungan Tulangan Pokok

$$k = \frac{Mn}{bd^2} = \frac{Mu(-)}{\Phi bd^2}$$

$$= \frac{18{,}1035 \text{ x } 10^6}{0{,}9 \; x \; 1000 \; x \; 94^2} = 2{,}27648$$

$$\rho = \frac{0{,}85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85 \; f'c}}\right)$$

$= \frac{0,85x25}{280}\left(1 - \sqrt{1 - \frac{2(2,227648)}{0,85x25}}\right)$

= 0,00861981

$$\rho\text{maks} = 0,429 \times \frac{0,85 \times f'c \times \beta_1}{fy}$$

$$= 0,429 \times \frac{0,85 \times 25 \times 0,85}{280}$$

= 0,027674 $\rho \leq \rho$maks …(OK!)

As min = 0,002 x b x h (SNI 2847:2019 Pasal 7.6.1.1)

As min = 0,002 x 1000 x 120 = 240 mm^2

As = ρ x b x d

= 0,00861981x 1000 x 94 = 810,262 mm^2

As ≥ As min …(digunakan nilai As)

Hitung Spasi Maksimum tulangan

S maks = 3xh

= 3 x 120 = 360 mm

atau 450 mm

Hitung spasi tulangan

- $s = \frac{\frac{1}{4} \times \pi \times 12^2 \times 1000}{810,262} = 139,5812\ mm$
- Diambil 100 mm
- s < smaks…maka digunakan d12-100

2. Perhitungan Tulangan Bagi

As = 0,002 x b x h

= 0,002 x 1000 x 120

= 240 mm

Hitung Spasi Maksimum tulangan

S maks = 5xh

= 5 x 120 = 600 mm

atau 450 mm

Hitung spasi tulangan

- $s = \frac{\frac{1}{4} \times \pi \times 8^2 \times 1000}{240} = 209{,}4395\ mm$
- Diambil 200 mm
- s < smaks…maka digunakan d8-200
-

3. Perhitungan Geser

$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$Vc = 0{,}17 \times 1 \times \sqrt{25} \times 1000 \times 94$

= 79900 N

ΦVc = 0,75 x 79900

= 59925 N → 59,925 KN

ΦVc > Vu …(Aman!)

B. Pelat lantai B (pelat 1 arah)

Ly = 5,86 m

Lx = 2 m

$Mu_1^- = \frac{1}{24}$ x q x L^2

Mu_1^- = $\frac{1}{24}$ x 16,092 x 2^2

= 2,682 kNm

Mu_2^- = $\frac{1}{10}$ x q x L^2

Mu_2^- = $\frac{1}{10}$ x 16,092 x 2^2

= 6,4368 kNm

Mu^- use = 6,4368 kNm

Mu^+ = 4,5977 kNm

Vu_1 = 1.15 x $\frac{wu \times ln}{2}$

= 1.15 x $\frac{16,092 \times 2}{2}$

= 18,5058 kN

Vu_2 = $\frac{wu \times ln}{2}$

= $\frac{16,092 \times 2}{2}$

= 16,092 kN

Vu use = 18,5058 kN

ds = 20 + $\frac{10}{2}$ = 25 mm

d = 120 – 25 = 95 mm

1. Tulangan Tumpuan

$$k = \frac{Mn}{bd^2} = \frac{Mu(-)}{\Phi bd^2}$$

$$= \frac{6,4368 \text{ x } 10^6}{0,9 \, x \, 1000 \, x \, 95^2} = 0,792465$$

$$\rho = \frac{0,85 x F'c}{Fy}\left(1 - \sqrt{1 - \frac{2k}{0,85 \, F'c}}\right)$$

$= \frac{0,85x25}{280}\left(1 - \sqrt{1 - \frac{2(0,792465)}{0,85x25}}\right)$

= 0,0028851

$$\rho maks = 0,429 \times \frac{0,85 \times f'c \times \beta_1}{fy}$$

$$= 0,429 \times \frac{0,85 \times 25 \times 0,85}{280}$$

= 0,027674 $\rho \leq \rho maks$ …(OK!)

As min = 0,002 x b x h (SNI 2847:2019 Pasal 7.6.1.1)

As min = 0,002 x 1000 x 120 = 240 mm^2

As = ρ x b x d

= 0,0028851 x 1000 x 95 = 274,0818 mm^2

As ≥ As min …(digunakan nilai As)

Hitung Spasi Maksimum tulangan

S maks = 3xh

= 3 x 120 = 360 mm

atau 450 mm

Hitung spasi tulangan

- $s = \frac{\frac{1}{4} \times \pi \times 10^2 \times 1000}{274,0818} = 286,5561\ mm$
- Diambil 250 mm
- s < smaks…maka digunakan d10-250

2. Tulangan Lapangan

$$k = \frac{Mn}{bd^2} = \frac{Mu(+)}{\Phi bd^2}$$

$$= \frac{4{,}5977 \text{ x } 10^6}{0{,}9\ x\ 1000\ x\ 95^2} = 0{,}56605$$

$$\rho = \frac{0{,}85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\ f'c}}\right)$$

$$= \frac{0{,}85x25}{280}\left(1 - \sqrt{1 - \frac{2(0{,}56605)}{0{,}85x25}}\right)$$

= 0,0020493

$$\rho\text{maks} = 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy} \text{ S}$$

$$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{280}$$

= 0,027674 $\rho \leq \rho$maks …(OK!)

As min = 0,002 x b x h (SNI 2847:2019 Pasal 7.6.1.1)

As min = 0,002 x 1000 x 120 = 240 mm^2

As = ρ x b x d

= 0,0020493 x 1000 x 95 = 194,6799 mm^2

As < As min …(digunakan nilai As min)

Hitung Spasi Maksimum tulangan

S maks = 3xh

= 3 x 120 = 360 mm

atau 450 mm

Hitung spasi tulangan

- $s = \frac{\frac{1}{4} \times \pi \times 10^2 \times 1000}{240} = 327{,}2492\ mm$
- Diambil 300 mm
- s < smaks…maka digunakan d10-300

3. Perhitungan Tulangan Bagi

As = 0,002 x b x h

= 0,002 x 1000 x 120

= 240 mm

Hitung Spasi Maksimum tulangan

S maks = 5xh

= 5 x 120 = 600 mm

atau 450 mm

Hitung spasi tulangan

- $s = \frac{\frac{1}{4} \times \pi \times 8^2 \times 1000}{240} = 209{,}4395\ mm$
- Diambil 200 mm
- s < smaks…maka digunakan d8-200

4. Perhitungan Geser

$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$Vc = 0{,}17 \times 1 \times \sqrt{25} \times 1000 \times 95$

= 80750 N

ΦVc = 0,75 x 80750

= 60562,5 N → 60,5625 KN

ΦVc > Vu …(Aman!)

C. Pelat lantai C (pelat 1 arah)

Ly = 5,86 m

Lx = 2 m

$Mu^{-} = \frac{1}{11}$ x q x L^2

$= \frac{1}{11}$ x 16,092 x 2^2

= 5,85164 kNm

Mu^{+} = 6,4368 kNm

Vu $= \frac{wu \times ln}{2}$

$= \frac{16,092 \times 2}{2}$

= 16,092 kN

ds = 20 + $\frac{10}{2}$ = 25 mm

d = 120 – 25 = 95 mm

1. Tulangan Tumpuan

$$k = \frac{Mn}{bd^2} = \frac{Mu(-)}{\Phi bd^2}$$

$$= \frac{5,85164 \text{ x } 10^6}{0,9\ x\ 1000\ x\ 95^2} = 0,720423$$

$$\rho = \frac{0,85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0,85\ f'c}}\right)$$

$$= \frac{0,85x25}{280}\left(1 - \sqrt{1 - \frac{2(0,720423)}{0,85x25}}\right)$$

= 0,0026181

$$\rho\text{maks} = 0,429\ \times\ \frac{0,85\ \times\ f'c\ \times\ \beta_1}{fy}$$

$$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{280}$$

$= 0{,}027674 \quad \rho \leq \rho$maks …(OK!)

As min = 0,002 x b x h (SNI 2847:2019 Pasal 7.6.1.1)

As min = 0,002 x 1000 x 120 = 240 mm^2

As = ρ x b x d

= 0,0026181 x 1000 x 95 = 248,7193 mm^2

As ≥ As min …(digunakan nilai As)

Hitung Spasi Maksimum tulangan

S maks = 3xh

= 3 x 120 = 360 mm

atau 450 mm

Hitung spasi tulangan

- $s = \frac{\frac{1}{4} \times \pi \times 10^2 \times 1000}{248{,}7193} = 315{,}7769\ mm$
- Diambil 300 mm
- s < smaks…maka digunakana d10-300

2. Tulangan Lapangan

$$k = \frac{Mn}{bd^2} = \frac{Mu(+)}{\Phi bd^2}$$

$$= \frac{4{,}023 \text{ x } 10^6}{0{,}9\ x\ 1000\ x\ 94^2} = 0{,}495291$$

$$\rho = \frac{0{,}85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\ f'c}}\right)$$

$= \frac{0,85x25}{280}\left(1 - \sqrt{1 - \frac{2(0,495291)}{0,85x25}}\right)$

= 0,00179

$\rho maks = 0,429 \times \frac{0,85 \times f'c \times \beta_1}{fy}$ S

$= 0,429 \times \frac{0,85 \times 25 \times 0,85}{280}$

= 0,027674 $\rho \leq \rho maks$ …(OK!)

As min = 0,002 x b x h (SNI 2847:2019 Pasal 7.6.1.1)

As min = 0,002 x 1000 x 120 = 240 mm^2

As = ρ x b x d

= 0,00179 x 1000 x 95 = 170,0505 mm^2

As < As min …(digunakan nilai As min)

Hitung Spasi Maksimum tulangan

S maks = 3xh

= 3 x 120 = 360 mm

atau 450 mm

Hitung spasi tulangan

- $s = \frac{\frac{1}{4} \times \pi \times 10^2 \times 1000}{240} = 327,2492\ mm$
- Diambil 300 mm
- s < smaks…maka digunakan d10-300

3. Perhitungan Tulangan Bagi

As = 0,002 x b x h

= 0,002 x 1000 x 120

= 240 mm

Hitung Spasi Maksimum tulangan

S maks = 5xh

= 5 x 120 = 600 mm

atau 450 mm

Hitung spasi tulangan

- $s = \frac{\frac{1}{4} \times \pi \times 8^2 \times 1000}{240} = 209{,}4395\ mm$
- Diambil 200 mm
- s < smaks…maka digunakan d8-200

4. Perhitungan Geser

$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$Vc = 0{,}17 \times 1 \times \sqrt{25} \times 1000 \times 95$

= 80750 N

ΦVc = 0,75 x 80750

= 60562,5 N → 60,5625 KN

ΦVc > Vu …(Aman!)

D. Pelat lantai D (pelat 1 arah)

Ly = 10 m

Lx = 3 m

$Mu^- = \frac{1}{11}$ x q x L^2

= $\frac{1}{11}$ x 16,092 x 3^2

= 13,1662 kNm

Mu^{+} = 9,05175 kNm

Vu = $\frac{wu \times ln}{2}$

= $\frac{16,092 \times 3}{2}$

= 24,138 kN

ds = 20 + $\frac{10}{2}$ = 25 mm

d = 120 – 25 = 95 mm

1. Tulangan Tumpuan

$$k = \frac{Mn}{bd^2} = \frac{Mu(-)}{\Phi bd^2}$$

$$= \frac{13,1662 \text{ x } 10^6}{0,9 \; x \; 1000 \; x \; 95^2} = 1,620952$$

$$\rho = \frac{0,85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0,85 \; f'c}}\right)$$

$$= \frac{0,85x25}{280}\left(1 - \sqrt{1 - \frac{2(1,620952)}{0,85x25}}\right)$$

= 0,006029

$$\rho\text{maks} = 0,429 \times \frac{0,85 \times f'c \times \beta_1}{fy}$$

$$= 0,429 \times \frac{0,85 \times 25 \times 0,85}{280}$$

= 0,027674 $\quad \rho \leq \rho$maks …(OK!)

As min = 0,002 x b x h (SNI 2847:2019 Pasal 7.6.1.1)

As min = 0,002 x 1000 x 120 = 240 mm^2

As = ρ x b x d

= 0,006029 x 1000 x 95 = 572,7125 mm^2

As ≥ As min …(digunakan nilai As)

Hitung Spasi Maksimum tulangan

S maks = 3xh

= 3 x 120 = 360 mm

atau 450 mm

Hitung spasi tulangan

- $s = \frac{\frac{1}{4}\times\pi\times10^2\times1000}{572,7125} = 137,1365\ mm$
- Diambil 100 mm
- s < smaks…maka digunakan d10-100

2. Tulangan Lapangan

$$k = \frac{Mn}{bd^2} = \frac{Mu(+)}{\Phi bd^2}$$

$$= \frac{9,05175 \text{ x } 10^6}{0,9\ x\ 1000\ x\ 95^2} = 1,114404$$

$$\rho = \frac{0,85xf'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0,85\ f'c}}\right)$$

$$= \frac{0,85x25}{280}\left(1 - \sqrt{1 - \frac{2(1,114404)}{0,85x25}}\right)$$

= 0,0040902

$$\rho\text{maks} = 0,429 \times \frac{0,85 \times f'c \times \beta_1}{fy} \text{ S}$$

$$= 0,429 \times \frac{0,85 \times 25 \times 0,85}{280}$$

= 0,027674 $\rho \leq \rho$maks …(OK!)

As min = 0,002 x b x h (SNI 2847:2019 Pasal 7.6.1.1)

As min = 0,002 x 1000 x 120 = 240 mm^2

As = ρ x b x d

= 0,0040902 x 1000 x 94 = 388,57254 mm^2

As < As min …(digunakan nilai As min)

Hitung Spasi Maksimum tulangan

S maks = 3xh

= 3 x 120 = 360 mm

atau 450 mm

Hitung spasi tulangan

- $s = \frac{\frac{1}{4}\times\pi\times10^2\times1000}{388,57254} = 202,12395\ mm$
- Diambil 200 mm
- s < smaks…maka digunakan d10-200

3. Perhitungan Tulangan Bagi

As = 0,002 x b x h

= 0,002 x 1000 x 120

= 240 mm

Hitung Spasi Maksimum tulangan

S maks = 5xh

= 5 x 120 = 600 mm

atau 450 mm

Hitung spasi tulangan

- $s = \frac{\frac{1}{4}\times\pi\times8^2\times1000}{240} = 209,4395\ mm$
- Diambil 200 mm

- s < smaks…maka digunakan d8-200

4. perhitungan Geser

$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$Vc = 0{,}17 \times 1 \times \sqrt{25} \times 1000 \times 95$

= 80750 N

ΦVc = 0,75 x 80750

= 60562,5 N → 60,5625 KN

ΦVc > Vu …(Aman!)

E. Pelat Lantai E (pelat 1 arah)

Ly = 10 m

Lx = 2,5 m

$Mu^- = \frac{1}{11}$ x q x L^2

$= \frac{1}{11}$ x 16,092 x $2{,}5^2$

= 9,143182 kNm

Mu^+ = 6,285938 kNm

Vu = $\frac{wu \times ln}{2}$

$= \frac{16{,}092 \times 2{,}5}{2}$

= 20,115 kN

ds = 20 + $\frac{10}{2}$ = 25 mm

d = 120 – 25 = 95 mm

1. Tulangan Tumpuan

$$k = \frac{Mn}{bd^2} = \frac{Mu(-)}{\Phi bd^2}$$

$$= \frac{9{,}143182 \text{ x } 10^6}{0{,}9\ x\ 1000\ x\ 95^2} = 1{,}12566$$

$$\rho = \frac{0{,}85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\ f'c}}\right)$$

$$= \frac{0{,}85 x 25}{280}\left(1 - \sqrt{1 - \frac{2(1{,}12566)}{0{,}85 x 25}}\right)$$

= 0,0041327

$$\rho\text{maks} = 0{,}429\ \times\ \frac{0{,}85\ \times\ f'c\ \times\ \beta_1}{fy}$$

$$= 0{,}429\ \times\ \frac{0{,}85\ \times 25\ \times\ 0{,}85}{280}$$

= 0,027674 $\quad \rho \leq \rho$maks …(OK!)

As min = 0,002 x b x h (SNI 2847:2019 Pasal 7.6.1.1)

As min = 0,002 x 1000 x 120 = 240 mm^2

As = ρ x b x d

= 0,0041327 x 1000 x 95 = 392,6105 mm^2

As ≥ As min …(digunakan nilai As)

Hitung Spasi Maksimum tulangan

S maks = 3xh

= 3 x 120 = 360 mm

atau 450 mm

Hitung spasi tulangan

- $s = \frac{\frac{1}{4} \times \pi \times 10^2 \times 1000}{392{,}6105} = 200{,}04512\ mm$
- Diambil 200 mm

- s < smaks…maka digunakan d10-200

2. Tulangan Lapangan

$$k = \frac{Mn}{bd^2} = \frac{Mu(+)}{\Phi bd^2}$$

$$= \frac{6{,}2859375 \text{ x } 10^6}{0{,}9\ x\ 1000\ x\ 95^2} = 0{,}773892$$

$$\rho = \frac{0{,}85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\ f'c}}\right)$$

$$= \frac{0{,}85x25}{280}\left(1 - \sqrt{1 - \frac{2(0{,}773892)}{0{,}85x25}}\right)$$

$$= 0{,}002816$$

$$\rho\text{maks} = 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy} \text{ S}$$

$$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{280}$$

$$= 0{,}027674 \quad \rho \leq \rho\text{maks} \ldots\text{(OK!)}$$

As min = 0,002 x b x h (SNI 2847:2019 Pasal 7.6.1.1)

As min = 0,002 x 1000 x 120 = 240 mm^2

As = ρ x b x d

= 0,002816 x 1000 x 94 = 267,53417 mm^2

As < As min …(digunakan nilai As min)

Hitung Spasi Maksimum tulangan

S maks = 3xh

= 3 x 120 = 360 mm

atau 450 mm

Hitung spasi tulangan

- $s = \frac{\frac{1}{4} \times \pi \times 10^2 \times 1000}{267{,}53417} = 293{,}5693\ mm$
- Diambil 250 mm
- s < smaks…maka digunakan d10-250

3. Perhitungan Tulangan Bagi

As = 0,002 x b x h

= 0,002 x 1000 x 120

= 240 mm

Hitung Spasi Maksimum tulangan

S maks = 5xh

= 5 x 120 = 600 mm

atau 450 mm

Hitung spasi tulangan

- $s = \frac{\frac{1}{4} \times \pi \times 8^2 \times 1000}{240} = 209{,}4395\ mm$
- Diambil 200 mm
- s < smaks…maka digunakan d8-200

4. Perhitungan Geser

$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$Vc = 0{,}17 \times 1 \times \sqrt{25} \times 1000 \times 95$

= 80750 N

ΦVc = 0,75 x 80750

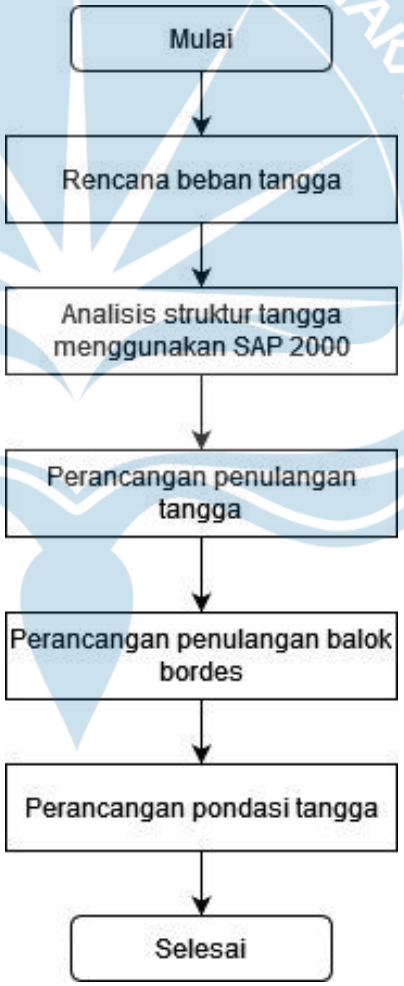
= 60562,5 N → 60,5625 KN

ΦVc > Vu …(Aman!)

Untuk memudahkan pelaksanaan, diputuskan menggunakan 1 jenis pelat. Detail penulangan terdapat pada Lampiran B.1.

2.2. Perencanaan Tangga Dan Pelat

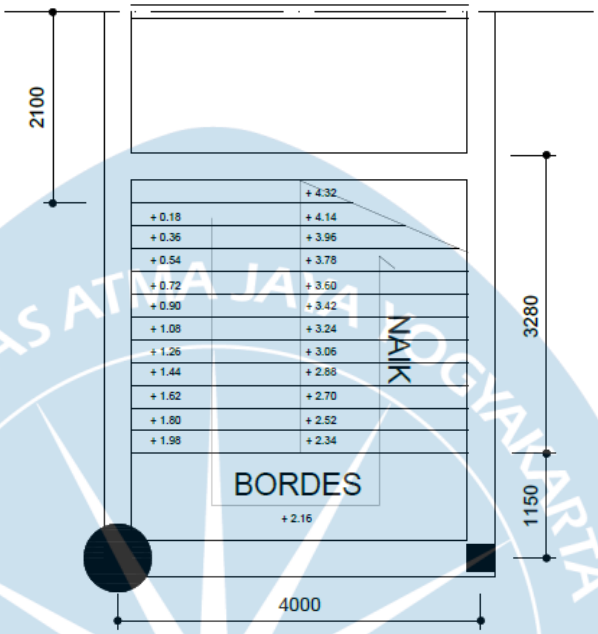
Setelah melakukan perhitungan pada pelat, selanjutnya dilakukan perhitungan pada tangga. Dimulai dari memperkirakan rencana beban tangga, menganalisis melalui software, merancang penulangan pada tangga dan bordes. Pada gambar 2.11 dibawah merupakan *flowchart* dari perancangan tangga.



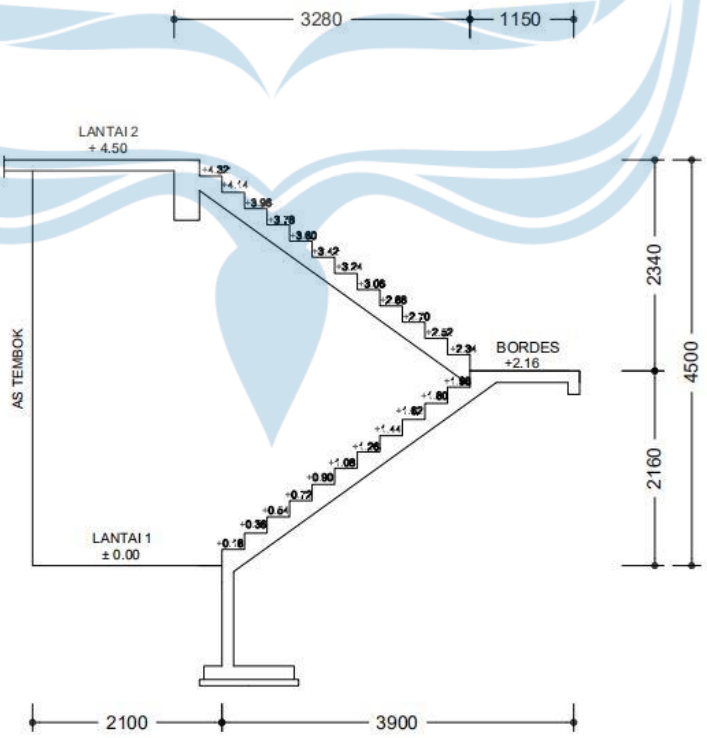
Gambar 2.11 *Flowchart* Perancangan Tangga

2.2.1. Denah Ruang Tangga

Berikut merupakan denah rencana tangga pada gambar 2.12 dan gambar tangga pada gambar 2.13.



Gambar 2.12 Denah rencana tangga



Gambar 2.13 Tangga

Rencana Tangga

a. Menentukan lebar bordes

Lebar bordes = 1150 mm

b. Jumlah anak tangga (n_{tg})

(O) yang besarnya antara 150mm sampai 200mm,

h_{lt} = Tinggi lantai

O = Optrade (naik)

O = 180 mm

$n_{tg} = \frac{h_{lt}}{O}$

$n_{tg} = \frac{4500}{180}$ = 25 anak tangga

c. Antrade (A)

A = 250 mm (Dari rencana gambar arsitek)

Lebar tangga (L_{tg}) = $\left(\frac{1}{2} \text{ x } \frac{h_{lt}}{O}\right)$ A

= $\left(\frac{1}{2} \text{ x } \frac{4500}{180}\right)$ 250 = 3125 mm

d. Sudut kemiringan tangga

$\alpha = tan^{-1}\left(\frac{O}{A}\right)$

$= tan^{-1}\left(\frac{180}{250}\right)$ = 35, 75 °

Kesimpulan :

Lebar Bordes = 1150 m

Jumlah anak tangga = 25 anak tangga

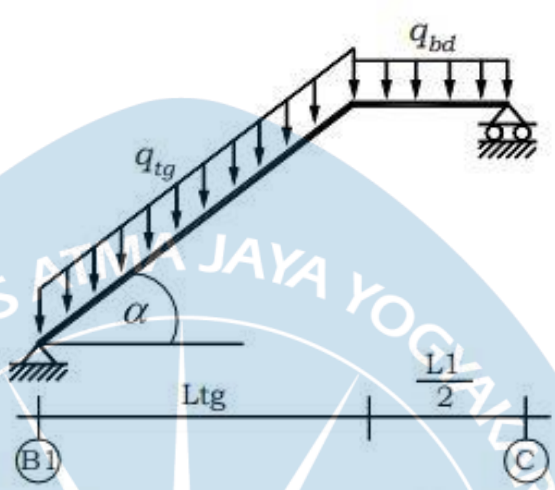
Optrade (naik) = 180 mm

Antrade(datar) = 250 mm

Sudut kemiringan tangga = 35, 75 °

2.2.2. Rencana Beban Tangga

Sesuai panduan praktik perancanaan bangunan gedung maka digunakan sesuai gambar 2.14 mengenai rencana beban tangga.



Gambar 2.14 Rencana beban tangga

Sumber : Panduan Praktik Perancangan Bangunan Gedung (Haryanto Yoso Wigroho)

Diketahui :

Tebal plat tangga (h_{tg})= 130 mm = 0,13 m

α = 35, 75 °

1. Beban Mati
   a. Beban q_{tg} :

   - berat sendiri tangga = $\frac{0,13}{cos\ 35,75}$ x 24 = 3,844 kN/m²

   - berat anak tanga = $\frac{1}{2} x$ 0,18 x 24 = 2,16 kN/m²

   - berat ubin & spesi = 0,05 x 21 = 1,05 kN/m²

   - berat railling (diperkirakan) = 1,00 kN/m²

   Beban q_{tg} = 8,054 kN/m²

b. Beban qbd :

- berat sendiri tangga = 0,13 x 24 = 3,12 kN/m²

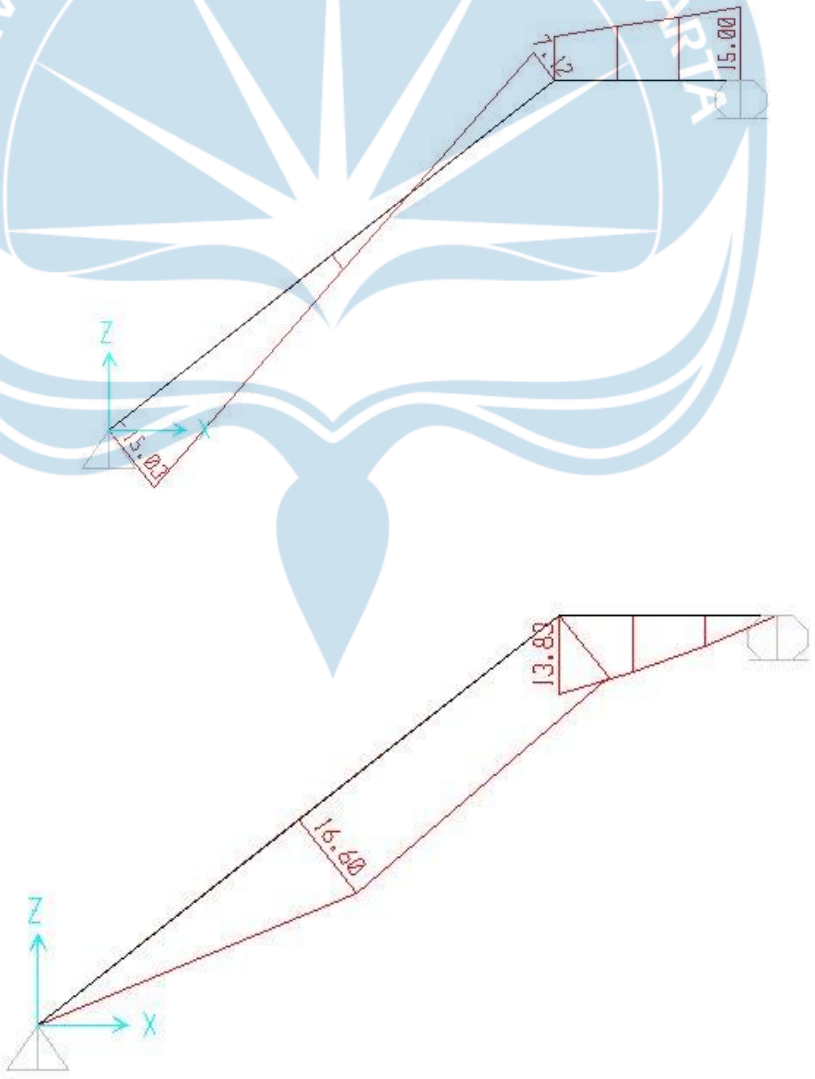
- berat ubin & spesi = 0,05 x 21 = 1,05 kN/m²

- berat railling (diperkirakan) = 1,00 kN/m²

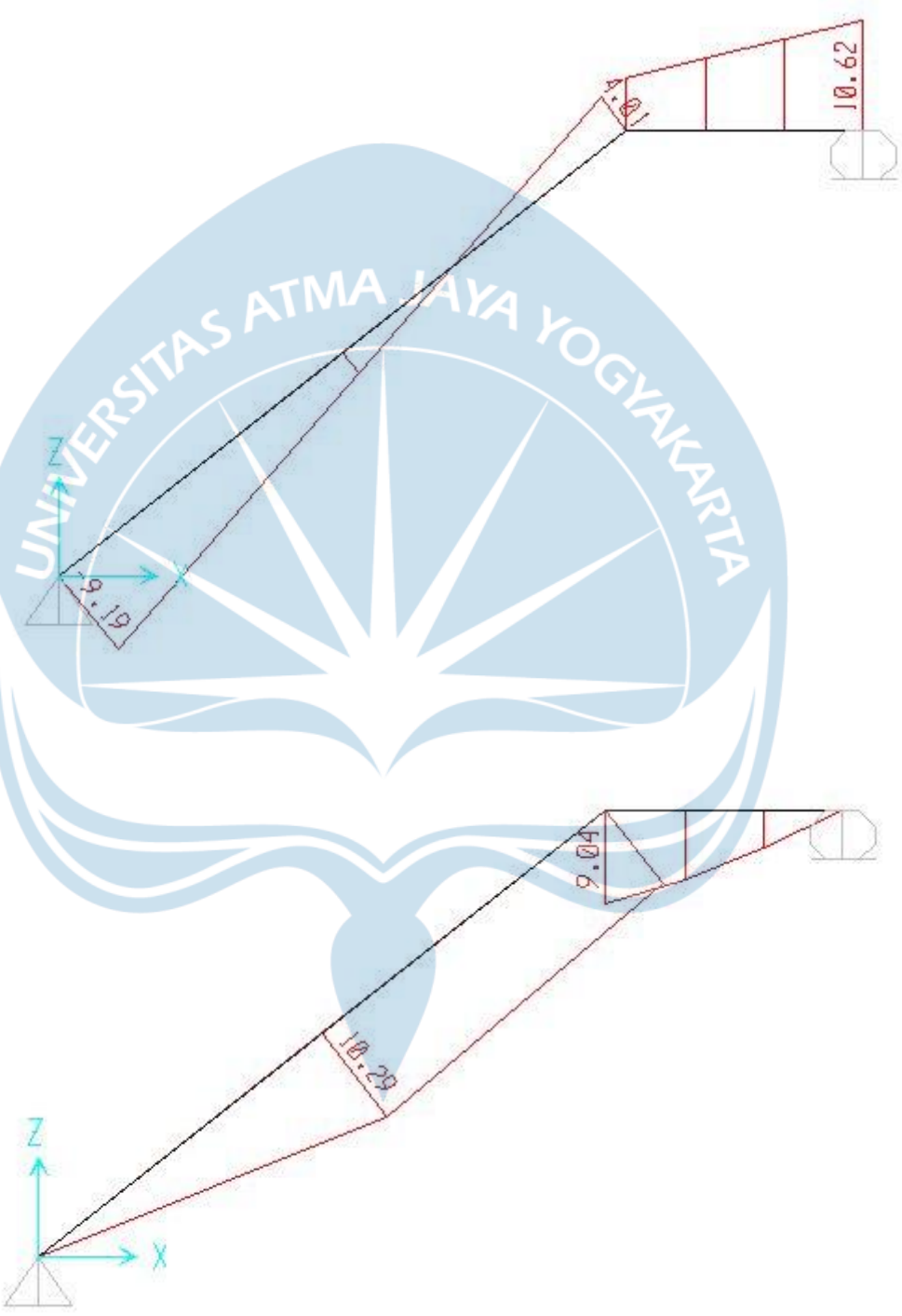
Beban qbd = 5,17 kN/ m²

2. Beban hidup bangunan kantor: 4,8 kN/ m²

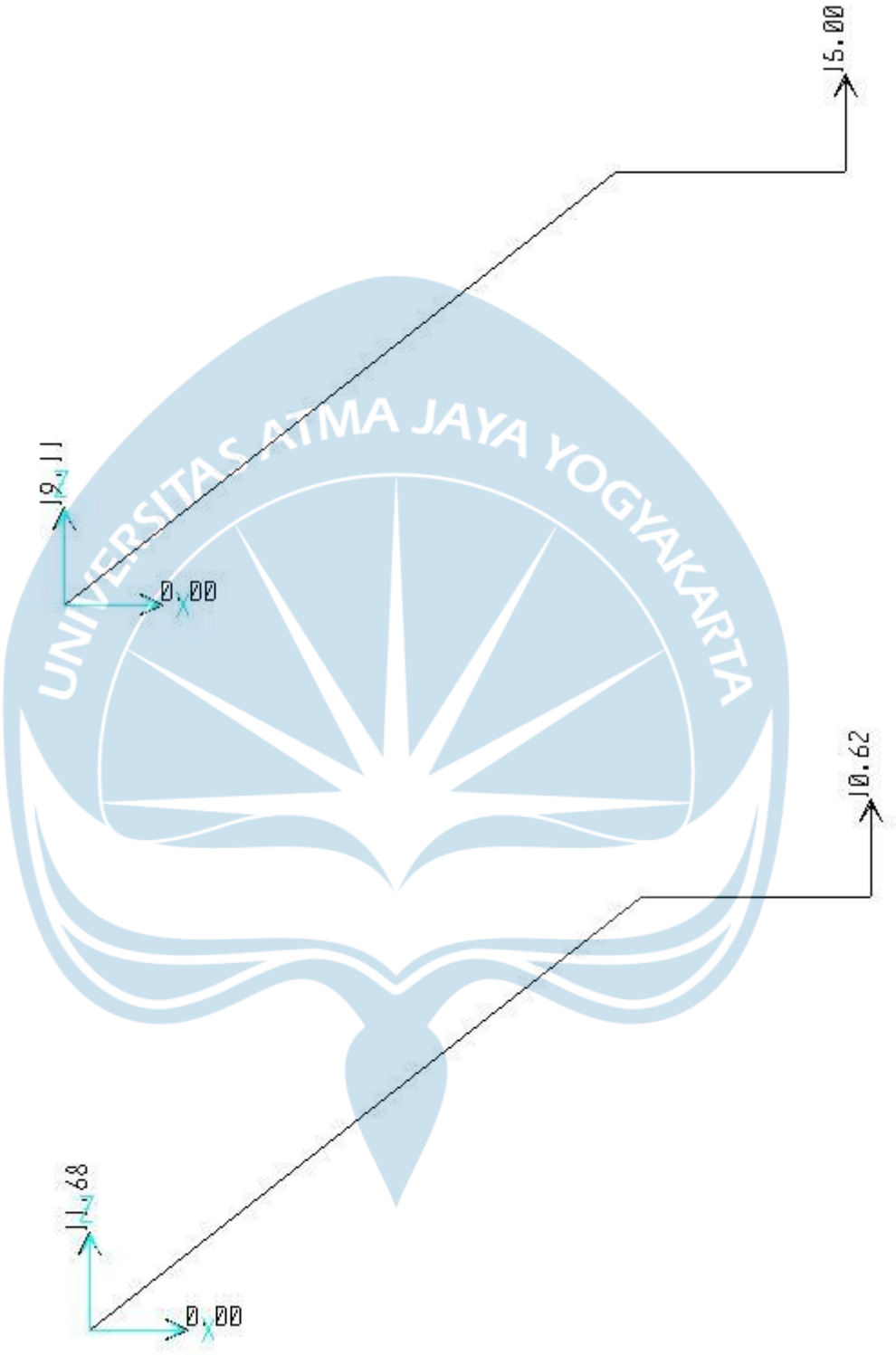
Pada gambar dibawah merupakan shear force diagram yang diakibatkan pembebanan pada daerah tangga. Nilai-nilai ini didapat melalui software SAP 2000.



Gambar 2.15 SFD dan BMD akibat Dead Load



Gambar 2.16 SFD dan BMD akibat Live Load



Gambar 2.17 Reaksi Tumpuan Tangga

2.2.3. Rencana Penulangan Tangga

- Momen akibat DL (MDL) = 16,60 kNm
- Momen akibat LL (MLL) = 10,29 kNm
- Mu = 1,4 MDL = 1,4 x 16,60 = 23,24 kNm
- Mu = 1,2 MDL+ 1,6MLL = 1,2(16,60) + 1,6(10,29) = 36,384 kNm

Dipakai Mur = 36,384 kNm

- Geser akibat DL (VDL) = 15,03 kN
- Geser akibat LL (VLL) = 9,19 kN
- Vu = 1,4 VDL = 1,4 x 15,03 = 21.042 kN
- Vu = 1,2 VDL+ 1,6VLL = 1,2(15,03) + 1,6(9,19) = 32,74 kN

Dipakai Vur = 32,74 kN

1. Rencana Penulangan Tumpuan Tangga

Mu^- (Momen negatif) = 0,5 x Mur = 0,5 x 36,384 = 18,192 kNm

Direncanakan :

- Tulangan Pokok (D13)

As =¼ x π x D2 = =¼ x π x 13X13 = 132, 732 mm²

- Tulangan Susut (P8)

As = ¼ x π x P 2 = =¼ x π x 8x8 = 50,265 mm²

fy tulangan pokok = 420 MPa

fy tulangan susut = 280 MPa

f'c = 25 MPa ; b = 1000 mm ; h = 130 mm ; β = 0,85

selimut beton (ti) = 20 mm

Faktor Reduksi (Ø) = 0,9

ds = h-(ti+(½ x D)) = 130 – (20 +13/2) = 103,5 mm

$k = \frac{Mux}{\emptyset.b.ds^2} = \frac{18{,}192\ x\ 10^6}{0{,}9.1000.103{,}5^2} = 1{,}887$ MPa

ρ perlu = $\frac{0,85}{fy}$. f'c$\left(1-\sqrt{1-\frac{2k}{0,85.f'c}}\right)$

= $\frac{0,85}{420}$. 25$\left(1-\sqrt{1-\frac{2.1,887}{0,85.25}}\right)$

= $4,71 . 10^{-3}$

ρ min = $\frac{1,4}{fy} = \frac{1,4}{420} = 3,33 . 10^{-3}$

ρ max = 0,75 . $\left(\frac{0,85.f'c.\beta}{fy}\right)\left(\frac{600}{600+fy}\right)$

= 0,75 . $\left(\frac{0,85.25.0,85}{420}\right)\left(\frac{600}{600+420}\right)$

= 0,019

Maka, ρ min < ρ perlu < ρ max >>> OK!

As perlu = ρ perlu x b x ds = $4,71. 10^{-3}$· 1000 ·103,5 = 487,485 mm²

As min = ρ min x b x ds = $3,33 . 10^{-3}$· 1000 ·103,5 = 344,655 mm²

As perlu ≥ As min

Spasi = $\frac{As\ tulangan}{As\ perlu} . b$

= $\frac{132,732}{487,485} . 1000$ = 272,280 ≈ 250 mm

- Maka digunakan Tulangan Utama D13-250

Cek terhadap geser

Vc = 0,17 · λ· $\sqrt{f'c}$ · b · ds

= 0,17 · 1 · $\sqrt{25}$ · 1000 · 103,5 = 104,975 kN

ØVc = 0,75· Vc

= 0,75 . 104,975 = 78,731 kN

Vur = 32,74 kN

Karena ØVc ≥ Vur (Aman)

Tulangan Susut

As min = 0,002 x b x ds

= 0,002 x 1000 x 103,5 = 207 mm²

As tulangan =0,25 x π x P² = 0,25 x π x 8² = 50,265 mm²

Spasi = $\frac{As\ Tulangan}{As\ min}$. b

= $\frac{50,265}{207}$. 1000 = 242,826 ≈ 200 mm

As = As tulangan . $\frac{b}{s}$

= 50,265 . $\frac{1000}{200}$ = 251,327 mm²

As >As min >>> Ok (Aman)

Maka digunakan Tulangan Susut P8-200

2. Rencana Penulangan Lapangan Tangga

Mu^+ (Momen positif) = 0,8 x Mur = 0,8 x 36,384 = 29,107 kNm

Direncanakan:

Tulangan Utama (D13)

f'c =25 MPa ; fy =420 MPa ; selimut beton = 20 mm ; b = 1000 mm ; Ø =0,9

ds = h-(ti+(½ x D)) = 130 – (20 +13/2) = 103,5 mm

k = $\frac{Mux}{\emptyset.b.ds^2}$ = $\frac{29,107\ x\ 10^6}{0,9.1000.103,5^2}$ = 3,019 MPa

ρ perlu = $\frac{0,85}{fy}$. f'c$\left(1-\sqrt{1-\frac{2k}{0,85.f'c}}\right)$

= $\frac{0,85}{420}$. 25$\left(1-\sqrt{1-\frac{2.3,019}{0,85.25}}\right)$

= 7,79 . 10^{-3}

ρ min = $\frac{1,4}{fy}$ = $\frac{1,4}{420}$ = 3,33 . 10^{-3}

ρ max = 0,75 . $\left(\frac{0,85.f'c.\beta}{fy}\right)\left(\frac{600}{600+fy}\right)$

$= 0{,}75 \cdot \left(\frac{0{,}85.25.0{,}85}{420}\right)\left(\frac{600}{600+420}\right)$

$= 0{,}019$

Maka, ρ min < ρ perlu < ρ max >>> OK!

As perlu = ρ perlu x b x ds = $0{,}0079 \cdot 1000 \cdot 103{,}5 = 817{,}65\ mm^2$

As min = ρ min x b x ds = $3{,}33 \cdot 10^{-3} \cdot 1000 \cdot 103{,}5 = 344{,}655\ mm^2$

Spasi = $\frac{As\ tulangan}{As\ perlu} \cdot b$

$= \frac{132{,}732}{817{,}65} \cdot 1000 = 162{,}33 \approx 150$ mm

- Maka digunakan Tulangan Utama D13-150

Cek terhadap geser

$Vc = 0{,}17 \cdot \lambda \cdot \sqrt{f'c} \cdot b \cdot ds$

$= 0{,}17 \cdot 1 \cdot \sqrt{25} \cdot 1000 \cdot 103{,}5 = 104{,}975$ kN

$\emptyset Vc = 0{,}75 \cdot Vc$

$= 0{,}75 \cdot 104{,}975 = 78{,}731$ kN

Vur = 32,74 kN

Karena ØVc ≥ Vur (Aman)

2.2.4. Perhitungan Balok Bordes Tangga (Dimensi dan Tulangan)

Diketahui:

Panjang bentang (L) = 4000 mm

lebar minimum balok (SNI 2847:2019 pasal 9.3.1.1) adalah:

h minimum = $\frac{4000}{16} = 250\ mm$

maka, diambil nilai h sebesar 350 mm

lebar minimum balok (SNI 2847:2019 pasal 18.6.2.1) adalah:

250 mm atau 0,3h. maka digunakan nilai b sebesar 250 mm

Asumsi desain balok : 250 x 350 mm

Beban balok bordes:

- berat sendiri = (0,25 x 0,35) x 24 = 2,1 kN/m
- Reaksi tangga (DL) = 15,00 kN/m
- Berat dinding = 2,34 x 2,5 kN/m2 = 5,85 kN/m

QDL = 22,95 kN/m

QLL = 10,62 kN/m

Qu = 1,2 DL + 1,6 LL = 1,2(22,95) + 1,6(10,62) = 44,532 kN/m

Mu = 1/8 x qu x $L1^2 = \frac{1}{8} \times 44{,}532 \times 4^2 = 89{,}064$ kNm

Mu^- tumpuan = 0,5 x 89,064 = 44,532 kNm

Mu^+ lapangan = 0,8 x 89,064 = 71,2512 kNm

Vu tumpuan = qu x L1 = 44,532 x 4 = 178,128 kN

Vu lapangan = ½ x qu x L1 = ½ x 44,532 x 4 = 89,064 kN

Spesifikasi balok:

fy = 420 Mpa

f'c = 25 Mpa

Selimut = 40 mm

B1 = 0,85

1. Tulangan tumpuan

ds = 40 + 10 + $\frac{13}{2}$ = 56,5 mm

d = h – ds

= 350 – 56,5 = 293,5 mm

$$k = \frac{Mn}{bd^2} = \frac{Mu(-)}{\Phi bd^2}$$

$$= \frac{44{,}532 \text{ x } 10^6}{0{,}9\ x\ 250\ x\ 293{,}5^2} = 2{,}29759$$

$$\rho = \frac{0{,}85xf'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\ f'c}}\right)$$

$$= \frac{0{,}85x25}{420}\left(1 - \sqrt{1 - \frac{2(2{,}29759)}{0{,}85x25}}\right)$$

= 0,0058033

$$\rho\text{min} = \frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420} = 0{,}0029762\ atau\ \rho\ \text{min} = \frac{1{,}4}{fy} = \frac{1{,}4}{420} = 0{,}00333$$

Digunakan yang besar = ρ min = 0,00333

$$\rho\text{maks} = 0{,}429\ \times\ \frac{0{,}85\ \times\ f'c\ \times\ \beta_1}{fy}$$

$$= 0{,}429\ \times\ \frac{0{,}85\ \times 25\ \times\ 0{,}85}{420}$$

= 0,0184495

$\rho\text{min} \leq \rho \leq \rho\text{maks}$ …(OK!)

As = ρ x b x d

= 0,0058033 x 250 x 293,5 = 425,8159 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n\ = \frac{425{,}8159}{\frac{1}{4} \times \pi \times 13^2} = 3{,}2081 \approx 4\ buah$$

As use = $4 \times \frac{1}{4} \times \pi \times 13^2$ = 530,92916 mm^2

Menghitung spasi tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{250-(2\times40)-(2\times10)-(4\times13)}{4-1}$ 32,667 mm > 25 mm (Aman!)

Analisis kapasitas momen

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

$$a = \frac{530{,}9216 \times 420}{0{,}85 \times 25 \times 250} = 41{,}9746 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{41{,}9746}{0{,}85} = 49{,}3819 \text{ mm}$$

$$\varepsilon t = \frac{(d-c)}{c} \times 0{,}003$$

$$= \frac{(293{,}5 - 49{,}3819)}{49{,}3819} \times 0{,}003$$

$= 0{,}0148 > 0{,}005$, Terkendali Tarik $\Phi = 0{,}9$

$$Mn = 0{,}9\ x\ As\ x\ fy \times \left(d* - \frac{a}{2}\right)$$

$$= 0{,}9 \times 530{,}92916\ x\ 420\ x\ \left(293{,}5 - \frac{41{,}9746}{2}\right)$$

$$= 54690128{,}15\ Nmm = 54{,}69091\ kNm$$

$\Phi\ Mn >$ Mu *Aman*!

Perhitungan Geser

$$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times b \times d$$

$$Vc = 0{,}17 \times 1 \times \sqrt{25} \times 250 \times 293{,}5$$

= 62368,75 N

$$Vs = \frac{Vu}{\Phi} - Vc$$

$$Vs = \frac{178128}{0{,}75} - 62368{,}75 = 175135{,}25\ KN$$

Cek nilai Vs

$$Vs \leq 0{,}66 \times \sqrt{f'c} \times b \times d$$

$$175135{,}25 \leq 242137{,}5 \ldots(\text{OK!})$$

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

$$= 2 \times \tfrac{1}{4} \times \pi \times 10^2 = 157{,}0796\ mm^2$$

$$s = \frac{Av \times fyt \times d}{Vs}$$

$$s = \frac{157{,}0796 \times 280 \times 293.5}{175135{,}25} = 73{,}70763 \text{ mm}$$

Diambil spasi = 50 mm

- Sehingga tulangan Sengkang yang digunakan adalah 2P10-50

2. Tulangan Lapangan

ds = 40 + 10 + $\frac{13}{2}$ = 56,5 mm

d = h – ds

= 350 – 56,5 = 293,5 mm

$$k = \frac{Mn}{bd^2} = \frac{Mu(\mp)}{\Phi bd^2}$$

$$= \frac{71{,}2512 \text{ x } 10^6}{0{,}9\ x\ 250\ x\ 293{,}5^2} = 3{,}67615$$

$$\rho = \frac{0{,}85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\ f'c}}\right)$$

$$= \frac{0{,}85x25}{420}\left(1 - \sqrt{1 - \frac{2(3{,}67615)}{0{,}85x25}}\right)$$

= 0,009678

$\rho\text{min} = \frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420} = 0{,}0029762\ atau\ \rho\ \text{min} = \frac{1{,}4}{fy} = \frac{1{,}4}{420} = 0{,}00333$

Digunakan yang besar = ρ min = 0,00333

$$\rho\text{maks} = 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy}$$

$$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{420}$$

$$= 0{,}0184495$$

$\rho\text{min} \leq \rho \leq \rho\text{maks}$ …(OK!)

As = ρ x b x d

= 0,009678 x 250 x 293,5 = 710,1559 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{710{,}1559}{\frac{1}{4} \times \pi \times 13^2} = 5{,}350288 \approx 6\ buah$$

As use = $6 \times \frac{1}{4} \times \pi \times 13^2$ = 796,3937 mm^2

Menghitung spasi tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n - 1}$$

$= \frac{250-(2\times40)-(2\times10)-(6\times13)}{6-1} = 14{,}4\ mm$ < 25 mm (Tidak OK!)

Dibuat menjadi 2 lapis tulangan, dihitung nilai tinggi efektif yang baru

$ds = \frac{\left(3\times\left(40+10+\frac{13}{2}\right)\right)+\left(3\times\left(40+10+13+25+\frac{13}{2}\right)\right)}{6}$ = 75,5 mm

d = h – ds

= 350 – 75,5 = 274,5 mm

Analisis kapasitas momen

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

a = $\frac{796{,}3937 \times 420}{0{,}85 \times 25 \times 250}$ = 62,96195 mm

c = $\frac{a}{\beta_1}$ =$\frac{62{,}96195}{0{,}85}$ = 74,0729 mm

$$\varepsilon t = \frac{(d-c)}{c} \times 0{,}003$$

$$= \frac{(293{,}5 - 74{,}0729)}{74{,}0729} \times 0{,}003$$

$= 0{,}008887 > 0{,}005$ -> Terkendali Tarik Φ = 0,9

$$\Phi\, Mn = 0{,}9\ x\ As\ x\ fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 796{,}3937\ x\ 420\ x\ \left(274{,}5 - \frac{62{,}96195}{2}\right)$$

$$= 73157677{,}31\ Nmm = 73{,}155768\ kNm$$

Φ *Mn* > Mu *Aman*!

Perhitungan Geser

$$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times b \times d$$

$$Vc = 0{,}17 \times 1 \times \sqrt{25} \times 250 \times 274{,}5$$

= 58331,25 N

$$Vs = \frac{Vu}{\Phi} - Vc$$

$$Vs = \frac{89064}{0{,}75} - 58331{,}25 = 60420{,}75\ kN$$

Cek nilai Vs

$$Vs \leq 0{,}66 \times \sqrt{f'c} \times b \times d$$

$60420{,}75 \leq 226462{,}5$ …(OK!)

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

$$= 2 \times \tfrac{1}{4} \times \pi \times 10^2 = 157{,}0796\ mm^2$$

$$s = \frac{Av \times fyt \times d}{Vs}$$

$$s = \frac{157{,}0796 \times 280 \times 274{,}5}{60420{,}75} = 199{,}8178 \text{ mm}$$

Diambil spasi = 150 mm

- Sehingga tulangan Sengkang yang digunakan adalah 2P10-150

Perhitungan Pondasi (Dimensi dan Tulangan)

γ tanah = 16,3 kN/m^3

σ tanah = 310 kN/m^2

γ beton = 24 kN/m^3

H pondasi = 0,15 m

Btg = 0.15 m

d = 1,5 m

B = 1,2 m (asumsi)

Beban tangga pada pondasi:

-Beban mati tangga (DL)	= 19,11 kN/m
-Beban hidup tangga (LL)	= 11,68 kN/m
-Beban dinding = 0.15 x 1.5 x 25	= 5.4 kN/m
	36.19 kN/m

Direncanakan:

B= 1.2 m

e = 0,5 x $\frac{Mu}{qtg}$ = 0.5 x $\frac{36{,}38}{36{,}19}$ = 0.503 m

$$\bar{\sigma}_{neto} = \bar{\sigma}_{tanah} - (d - h_{pondasi})(\gamma_{tanah}) - h_{pondasi}(\gamma_{beton})$$

σ netto = 310 – (1.5 - 0.15) (16,3) – (0.15 x 24)

= 284,395 kN/m2

Cek tegangan:

σ max = σ min = $\frac{Qtg}{B} = \frac{36,19}{1,2} = 30,1583$ < 284,395 (memenuhi syarat)

Menghitung tegangan terfaktor

-Beban mati tangga (DL) x 1.2 = 19,11 x1,2 = 22,932 kN/m

-Beban hidup tangga (LL) x 1.6 = 11,68 x 1,6 = 18.69 kN/m

-Beban dinding = 0.15 x 1.5 x 24 x 1.2 = 6.48 kN/m

48,1 kN/m

e = 0,5 x $\frac{Mu}{qutg}$ = 0.5 x $\frac{36,38}{48,1}$ = 0.3782 m

$$\overline{\sigma}_{neto} = \overline{\sigma}_{tanah} - (d - h_{pondasi})(\gamma_{tanah}) - h_{pondasi}(\gamma_{beton})$$

σ netto = 310 – (1.5 - 0.15)(16,3) – (0.15 x 24)

= 284,395 kN/m2

Cek tegangan:

σ max = σ min = $\frac{Qtg}{B} = \frac{48,1}{1,2} = 40,0833$ < 284,395 (memenuhi syarat)

Rencana penulangan pelat

Mu = $\frac{1}{2} \times (\frac{\sigma}{2}) \times (\frac{B}{2} + e - \frac{1}{2}btg)^2$

= 8,1742 kNm

Vu = $(\frac{\sigma}{2}) \times (\frac{B}{2} + e - \frac{1}{2}btg)^2$

Vu = 16,3483 kN

Direncanakan tulangan pokok D13

Berikut merupakan hasil dari spesifikasi pelat tangga

Tabel 2.3 Spesifikasi plat tangga

Spesifikasi	Ukuran	Satuan
Selimut	20	mm
f'c	25	Mpa
fy	420	Mpa
h	200	mm
b	1000	mm
Tul.Utama	13	mm
d	173,5	mm
B1	0,85	

3. Periksa Geser

$$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times bw \times d$$

$$Vc = 0{,}17 \times 1 \times \sqrt{25} \times 1000 \times 123{,}5$$

= 104975 N = 104,975 kN

ΦVc = 0,75 x 104,975

= 78,7313 kN

Karena ΦVc > Vu, maka pondasi aman terhadap geser

4. Menghitung Tulangan Utama

$$k = \frac{Mn}{bd^2} = \frac{Mu}{\Phi bd^2} = \frac{8174163}{0{,}9\ x\ 1000\ x\ 123.5^2} = 0{,}5954796$$

$$\rho = \frac{0{,}85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\ f'c}}\right)$$

$$= \frac{0,85x25}{420}\left(1 - \sqrt{1 - \frac{2(0,5954796)}{0,85x25}}\right)$$

ρ = 0,001439

$$\rho\text{maks} = 0,429 \times \frac{0,85 \times f'c \times \beta_1}{fy}$$

$$= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420}$$

= 0,01845

$\rho < \rho\ maks$ -> aman

Menghitung As min (Sni 2847:2019 pasal 7.6.1.1)

$$\text{As min 1} = \frac{0,0018 \times 420}{fy} \times Ag$$

$$= \frac{0,0018 \times 420}{420} \times 1000 \times 123,5$$

= 222,3 mm^2

As min 2 = 0,0014 Ag

= 0,0014 x 1000 x 123,5

= 172,9 mm^2

Nilai As min yang menentukan adalah nilai As min terbesar yaitu 222,3 mm^2

Menghitung nilai As

As = ρ x b x d

= 0,001439 x 1000 x 123,5

= 177,62398 mm^2

Oleh karena nilai As < As min, maka yang digunakan adalah nilai As min

Menghitung nilai spasi minimum (Sni 2847:2019 pasal 7.7.2.3)

Smin 1 = 3 x h =3 x 150 = 450 mm

Smin 2 = 450 mm

Nilai smin yang menentukan adalah yang terkecil yaitu 450 mm

Menghitung nilai Spasi

$$s = \frac{Ast \times b}{As} = \frac{\frac{1}{4} \times \pi \times 13^2 \times 1000}{222{,}3} = 597{,}0863 \text{ mm}$$

Spasi yang digunakan adalah 450 mm

- Maka, digunakan tulanagan D13- 450

5. Menghitung Tulangan Susut

Digunakan tulangan P8 dengan fyt 280 Mpa

d= 150-20-13-(8/2) = 113 mm

As = 0,002 x 1000 x 113 =226 mm^2

$$s = \frac{Ast \times b}{As} = \frac{\frac{1}{4} \times \pi \times 8^2 \times 1000}{226} = 222{,}4136 \text{ mm}$$

- Maka, digunakan tulangan P8-200

2.3. Pemodelan 3D (3 Dimensi)

2.3.1. *Preliminary Design*

- Balok induk

- Bentang B1 = 10 m

  Balok Induk Lantai 2 (Tipe 1) → b x h = 400 x 800 (mm)

- Balok induk

  Bentang B2 = 10 m

  Balok Induk Lantai 2 (Tipe 2) → b x h = 400 x 700 (mm)

- Balok anak

  Bentang BA = 10 m

  Balok Anak → b x h = 300 x 550 (mm)

- Ring Balk

  Bentang RB = 10 m

  Ring Balk → b x h = 300 x 550 (mm)

- Sloof

  Bentang S = 10 m

  Sloof → b x h = 250 x 450 (mm)

- Balok lisplang

  Bentang BL = 10 m

  Balok Lisplang → b x h = 250 x 600 (mm)

- Balok Kantilever

  Bentang BK = 1,5 m

  Balok Kantilever → b x h = 400 x 600 (mm)

- Kolom

  Untuk kolom digunakan ukuran diameter ;K1 = 900mm dan K2 = 750mm

2.3.2. **Beban**

Beban yang dimasukkan ke dalam program Etabs V20 terdiri atas :

- Beban Mati (Super Dead/SD dan Dead Load/DL)
- Beban Mati (Live Load/LL)
- Beban Gempa

Berikut Beban-Beban yang diinputkan :

a. Beban Kuda Kuda

Diperoleh dari SAP 2000, didapat :

- Kuda Kuda K :

  SIDL = 51,51 kN

  LL = 5,5 kN

b. Beban Dinding

Berat volume dinding menggunakan

Dinding → SIDL = 9,625 kN/m

c. Beban Plat

- Lantai 2

  SIDL = 2 kN/m^2

  LL = 4,8 kN/m^2

d. Beban Gempa

Bangunan terletak di Kecamatan Sungai Kunjang, maka beban gempa menggunakan respon spektrum kota Samarinda dengan nilai Ss = 0.1167 g dan S1 = 0.0956 g

2.3.3. **Data Tambahan**

Fungsi Bangunan : Gedung Pengelola

Tanah : Tanah Sedang

Mutu Beton (f'c) : 25 Mpa

Mutu baja sengkang : 280 Mpa

Mutu baja lentur : 420 Mpa

Ec : 4700 $\sqrt{f'c}$ = 23500 MPa

1. Beban DL → Berat sendiri (DL) dan Super Dead (SIDL)
2. Beban LL → Sesuai SNI 1727 : 2013
3. Beban gempa → sesuai SNI 1726 : 2019, dengan memasukkan nilai Ss dan S1

Cek Hasil Analisis :

1. Mode 1 dan 2 harus translasi
2. Rasio Vd/Vs = 100%
3. Dilakukan *run analysis* struktur, dicatat gaya-gaya batang untuk merancang balok, kolom, sloof, dan pondasi.

Tabel 2.4 *Mass Contribution Factor*

Load	*Multiplier*
SIDL	1
LL	0,3

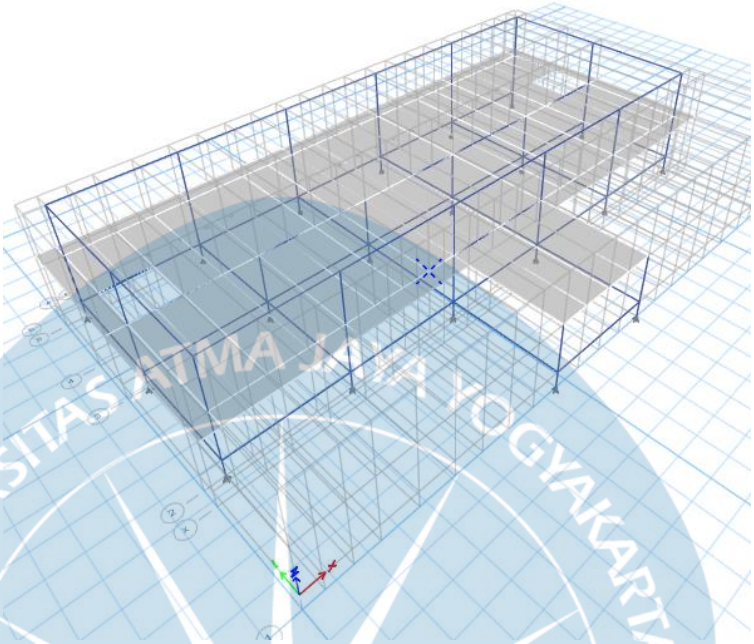
Koefisien respon seismik

Cs = 0,0249

2.3.4. **Pemodelan**

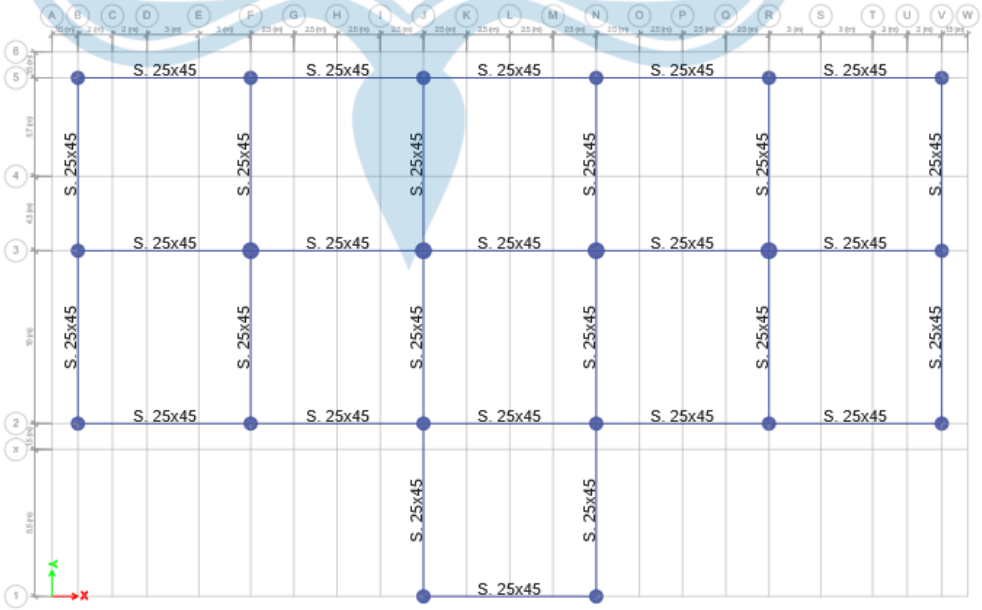
Berdasarkan data-data yang ada, dilakukkan pemodelan pada Etabs V20 sesuai dengan gambar dibawah ini.

1. 3D *View*



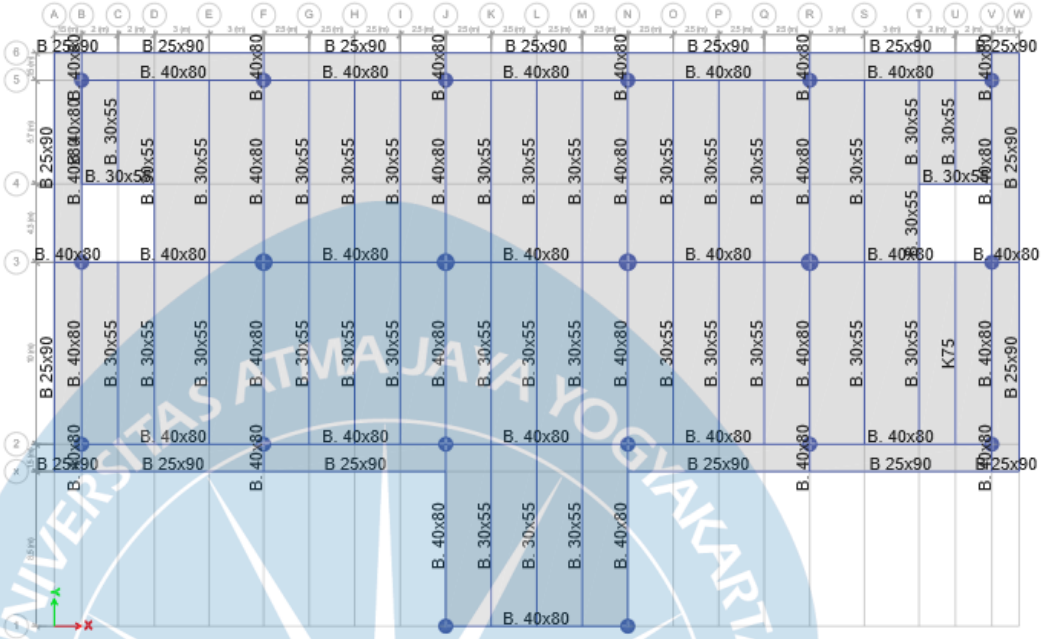
Gambar 2.18 Pemodelan 3D dari Aplikasi Etabs V20

2. Lantai 1 – Elevasi 0,0 m



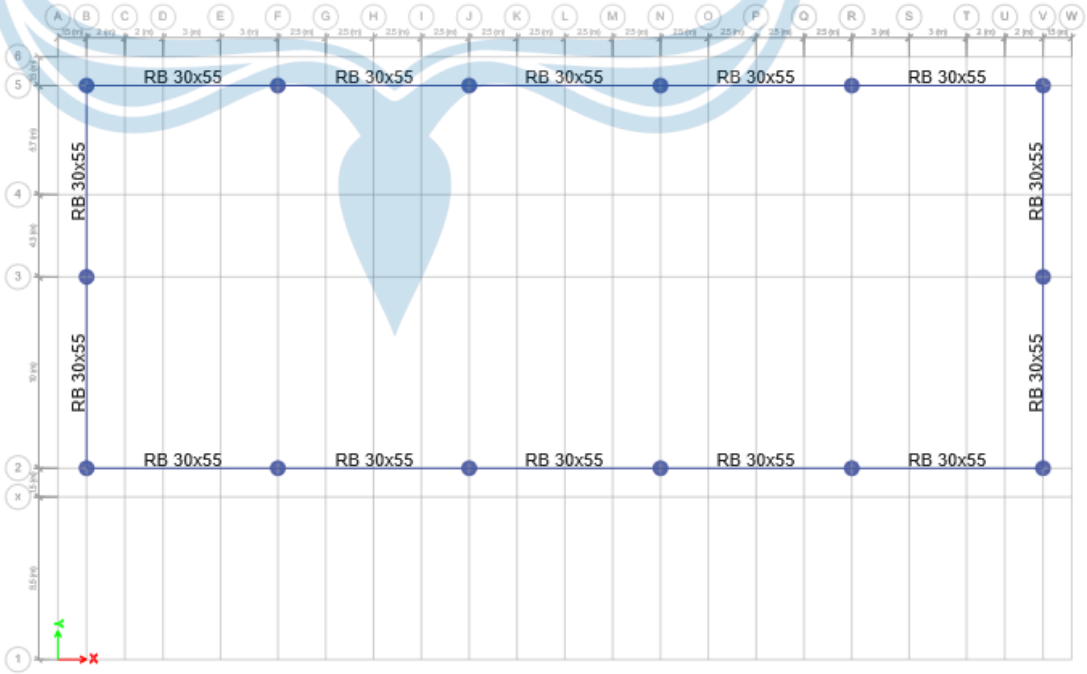
Gambar 2.19 Denah balok lantai 1

3. Lantai 2 – Elevasi 4,5 m



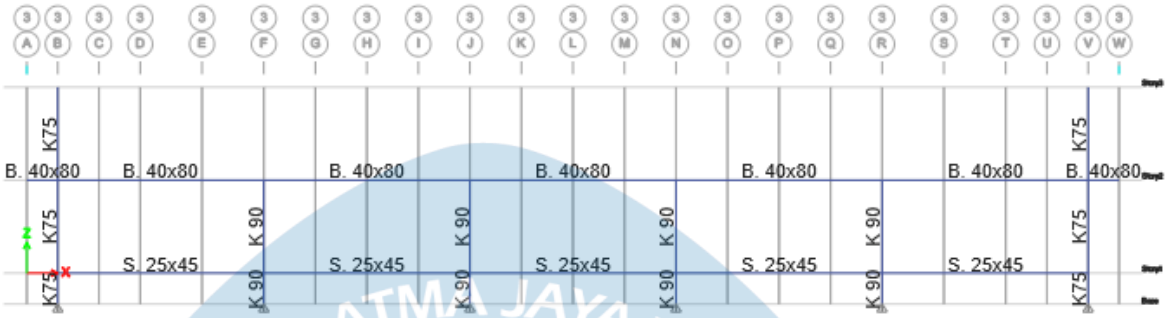
Gambar 2.20 Denah balok lantai 2

4. RING – Elevasi 9 m



Gambar 2.21 Denah ring balk

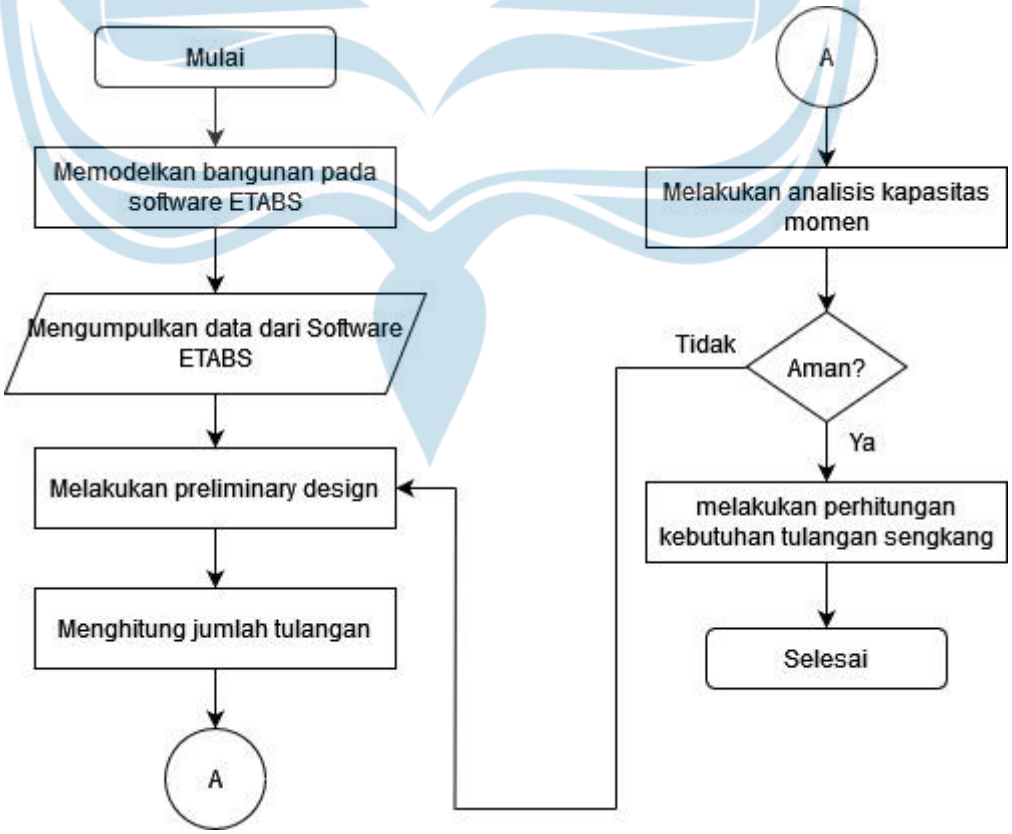
2.4. Perancangan Portal



Gambar 2.22 Portal As -G

2.4.1. Perancangan Balok

Pada perancangan balok, memodelkan bangunan dari software ETABS. Setelah itu dilakukan preliminary design dari data ETABS. Setelah itu dilakukan analisis untuk mengetahui keamanannya. Untuk selengkapnya dapat dilihat *flowchart* pada gambar 2.23



Gambar 2.23 *Flowchart* Perancangan Balok

1. Desain Balok Induk Tipe 1 (400x800) mm

Mutu Baja longitudinal: fy = 420 MPa

Mutu Baja sengkang: fys = 280 MPa

Mutu Beton: f'c = 25 MPa

Ukuran Struktur:

b balok = 400 mm

h balok = 800 mm

selimut beton = 40 mm

diameter tulangan pokok (d.l) = 25 mm

diameter Sengkang (d.s) = 12 mm

A. Pemeriksaan gaya tekan aksial terfaktor (SNI 2847:2019 pasal 18.4.2.6)

Pu = 0 kN-m (dari ETABS)

$$Ag \times \frac{f'c}{10} = (400 \times 800) \times \frac{25}{10}$$

= 800.000 N

= 800 kN > Pu Aman!

B. Desain Tulangan Lentur

- Perencanaan Tulangan Tumpuan Atas

Momen Ultimet (Mu) = 1033,207 kN-m (dari ETABS)

Momen Nominal (Mn) = $\frac{Mu}{\emptyset} = \frac{1033,207}{0,9}$ = 1148,0072 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 12 + (25/2)

= 64,5 mm

Tinggi efektif (d) = h-d'

= 800 – 64,5

= 735,5 mm

Koefisien $(k) = \frac{Mn}{bd^2}$

$$= \frac{1148,0072 \text{ x } 10^6}{400 \; x \; 735,5^2} = 5,30541$$

$$\rho = \frac{0{,}85xf'c}{fy}\left(1-\sqrt{1-\frac{2k}{0{,}85\,f'c}}\right)$$

$$= \frac{0{,}85x25}{420}\left(1-\sqrt{1-\frac{2(5{,}30541)}{0{,}85x25}}\right)$$

= 0,0148

$$\rho\text{maks} = 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy}$$

$$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{420}$$

= 0,0184496

$$\rho\text{min 1} = \frac{\sqrt{f'c}}{4\times fy} = \frac{\sqrt{25}}{4\times 420} = 0{,}002976$$

$$\rho\text{min 2} = \frac{1{,}4}{fy} = \frac{1{,}4}{420} = 0{,}00333$$

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,0148 x 400 x 735,5 = 4352,73316 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{4352{,}73316}{\frac{1}{4}\times\pi\times 25^2} = 8{,}86732 \approx 9\ buah$$

As use = $9\times\frac{1}{4}\times\pi\times 25^2$ = 4417,86467 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{400-(2\times40)-(2\times12)-(9\times25)}{9-1}$ = 8,875 mm < 25 mm (Tidak Memenuhi!)

Oleh karena spasi antar tulangan tidak memenuhi, maka tulangan dibuat 2 baris dengan

baris pertama (n1) = 6 buah (sisi luar)

baris kedua (n2) = 3 buah (sisi dalam)

Analisis kapasitas momen

Tinggi efektif baru (d) = 717,5 mm

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

a = $\frac{4417{,}86467 \times 420}{0{,}85 \times 25 \times 400}$ = 218,29449 mm

c = $\frac{a}{\beta_1}$ = $\frac{218{,}29449}{0{,}85}$ = 256,81705 mm

$$\varepsilon t = \frac{(d - c)}{c} \times 0{,}003$$

$$= \frac{(717{,}5 - 256{,}81705)}{256{,}81705} \times 0{,}003$$

$= 0{,}00538$ > 0,005 Terkendali Tarik $\Phi = 0{,}9$

$$\Phi Mn = 0{,}9\ x\ As\ x\ fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 4417{,}86467 \times 420 \times \left(717{,}5 - \frac{218{,}29449}{2}\right)$$

$$= 1015{,}92041 \times 10^6\ Nmm = 1015{,}92041\ kNm$$

ΦMn < Mu *Tidak Aman*!

Coba menggunakan 10 tulangan

baris pertama (n1) = 6 buah

baris kedua (n2) = 4 buah

As use = $10\times \frac{1}{4}\times \pi \times 25^2$ = 4908,73852 mm^2

Analisis kapasitas momen

Tinggi efektif baru (d) = 713,5 mm

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

a = $\frac{4908{,}73852 \times 420}{0{,}85 \times 25 \times 400}$ = 242,54943 mm

c = $\frac{a}{\beta_1}$ = $\frac{242{,}54943}{0{,}85}$ = 285,35227 mm

$$\varepsilon t = \frac{(d-c)}{c}\times 0{,}003$$

$$= \frac{(713{,}5 - 285{,}35227)}{285{,}35227}\times 0{,}003$$

$$= 0{,}00450546$$

$\Phi = (0{,}75 + (\varepsilon t\text{-}0{,}002)$ x 50

$= (0{,}75 + (0{,}00450546\text{-}0{,}002)$ x 50

Φ = 0,875273

$$\Phi Mn = 0{,}875273\ x\ As\ x\ fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}875273 \times 4908{,}73852 \times 420 \times \left(713{,}9 - \frac{242{,}54943}{2}\right)$$

$$= 1069{,}40667 \times 10^6\ Nmm = 1069{,}40667\ kNm$$

$\Phi\ Mn$ > Mu *Aman*!

Maka digunakan 10D25

- Perencanaan Tulangan Tumpuan Bawah

  Momen Ultimet (Mu) = 781,6672 kN-m (dari ETABS)

Momen Nominal (Mn) $= \frac{Mu}{\emptyset} = \frac{781,6672}{0,9}$ = 868,5191 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 12 + (25/2)

= 64,5 mm

Tinggi efektif (d) = h-d'

= 800 – 64,5

= 735,5 mm

Koefisien $(k) = \frac{Mn}{bd^2}$

$= \frac{868,5191 \text{ x } 10^6}{400 \, x \, 735,5^{\,2}} = 4,01378$

$\rho = \frac{0,85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0,85\, f'c}}\right)$

$= \frac{0,85x25}{420}\left(1 - \sqrt{1 - \frac{2(4,01378)}{0,85x25}}\right)$

= 0,01068

$\rho maks = 0,429 \times \frac{0,85 \times f'c \times \beta_1}{fy}$

$= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420}$

= 0,0184496

ρmin 1 $= \frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420}$ = 0,002976

ρmin 2 = $\frac{1,4}{fy} = \frac{1,4}{420}$ = 0,00333

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,01068 x 400 x 735,5 = 3143,48595 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{3143{,}48595}{\frac{1}{4} \times \pi \times 25^2} = 6{,}40386 \approx 7\ buah$$

As use = $7 \times \frac{1}{4} \times \pi \times 25^2$ = 3436,11696 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n - 1}$$

$= \frac{400-(2\times40)-(2\times12)-(7\times25)}{7-1}$ = 20,17 mm < 25 mm (Tidak Memenuhi!)

Oleh karena spasi antar tulangan tidak memenuhi, maka tulangan dibuat 2 baris dengan

baris pertama (n1) = 1 buah (sisi dalam)

baris kedua (n2) = 6 buah (sisi luar)

Analisis kapasitas momen

Tinggi efektif baru (d) = 728,35714 mm

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

a = $\frac{3436{,}11696 \times 420}{0{,}85 \times 25 \times 400}$ = 169,7846 mm

c = $\frac{a}{\beta_1} = \frac{169{,}7846}{0{,}85}$ = 199,74659 mm

$$\varepsilon t = \frac{(d - c)}{c} \times 0{,}003$$

$$= \frac{(728{,}35714 - 199{,}74659)}{199{,}74659} \times 0{,}003$$

$= 0{,}007939 > 0{,}005$, Terkendali Tarik Φ = 0,9

$$\Phi Mn = 0{,}9\ x\ As\ x\ fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 3436{,}11696 \times 420 \times \left(728{,}35714 - \frac{169{,}7846}{2}\right)$$

$= 835{,}765733 \times 10^6\ Nmm = 835{,}765733\ kNm$

Φ *Mn* > Mu *Aman*!

Maka digunakan 7D25

- Perencanaan Tulangan Lapangan Atas

Momen Ultimet (Mu) = 502,6856 kN-m (dari ETABS)

Momen Nominal (Mn) = $\frac{Mu}{\emptyset} = \frac{502{,}6856}{0{,}9}$ = 558,53956 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 12 + (25/2)

= 64,5 mm

Tinggi efektif (d) = h-d'

= 800 – 66,5

= 735,5 mm

Koefisien $(k) = \frac{Mn}{bd^2}$

$= \frac{558{,}53956 \text{ x } 10^6}{400\ x\ 735{,}5^2} = 2{,}58124$

$\rho = \frac{0{,}85xf'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\ f'c}}\right)$

$= \frac{0{,}85x25}{420}\left(1 - \sqrt{1 - \frac{2(2{,}58124)}{0{,}85x25}}\right)$

= 0,006573

$\rho maks = 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy}$

$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{420}$

= 0,0184496

$\rho min\ 1 = \frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420}$ = 0,002976

$\rho min\ 2 = \frac{1{,}4}{fy} = \frac{1{,}4}{420}$ = 0,00333

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,006573 x 400 x 735,5 = 1933,66979 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{1933{,}66979}{\frac{1}{4} \times \pi \times 25^2} = 3{,}9393 \approx 4\ buah$$

As use = $4 \times \frac{1}{4} \times \pi \times 25^2$ = 1963,49541 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n - 1}$$

$= \frac{400-(2\times40)-(2\times12)-(4\times25)}{4-1}$ = 65,33 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

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

a = $\frac{1963{,}49541 \times 420}{0{,}85 \times 25 \times 400}$ = 97,01977 mm

c = $\frac{a}{\beta_1} = \frac{97{,}01977}{0{,}85} = 114{,}14091$ mm

$$\varepsilon t = \frac{(d - c)}{c} \times 0{,}003$$

$$= \frac{(735{,}5 - 114{,}14091)}{114{,}14091} \times 0{,}003$$

$= 0{,}01633 > 0{,}005$, Terkendali Tarik Φ = 0,9

$$\Phi Mn = 0{,}9 \times As \times fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 1963{,}49541 \times 420 \times \left(735{,}5 - \frac{97{,}01977}{2}\right)$$

$$= 509{,}88493 \times 10^6\ Nmm = 509{,}88493\ kNm$$

Φ *Mn* > Mu *Aman*!

Maka digunakan 4D25

- Perencanaan Tulangan Lapangan Bawah

Momen Ultimet (Mu) = 781,6672 kN-m (dari ETABS)

Momen Nominal (Mn) = $\frac{Mu}{\emptyset} = \frac{781{,}6672}{0{,}9}$ = 868,5191 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 12 + (25/2)

= 64,5 mm

Tinggi efektif (d) = h-d'

= 800 – 66,5

= 735,5 mm

Koefisien $(k) = \frac{Mn}{bd^2}$

$$= \frac{868{,}5191 \text{ x } 10^6}{400\ x\ 735{,}5^2} = 4{,}01378$$

$$\rho = \frac{0{,}85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\ f'c}}\right)$$

$$= \frac{0{,}85x25}{420}\left(1 - \sqrt{1 - \frac{2(4{,}01378)}{0{,}85x25}}\right)$$

= 0,01068

$$\rho maks = 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy}$$

$$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{420}$$

= 0,0184496

$$\rho min\ 1 = \frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420} = 0{,}002976$$

ρmin 2 = $\frac{1,4}{fy} = \frac{1,4}{420}$ = 0,00333

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,01068 x 400 x 735,5 = 3143,48595 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{3143,48595}{\frac{1}{4} \times \pi \times 25^2} = 6,40385 \approx 7\ buah$$

As use = $7 \times \frac{1}{4} \times \pi \times 25^2$ = 3436,11696 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n - 1}$$

$= \frac{400-(2\times40)-(2\times12)-(7\times25)}{7-1}$ = 20,17 mm < 25 mm (Tidak Memenuhi!)

Oleh karena spasi antar tulangan tidak memenuhi, maka tulangan dibuat 2 baris dengan

baris pertama (n1) = 1 buah (sisi dalam)

baris kedua (n2) = 6 buah (sisi luar)

Analisis kapasitas momen

Tinggi efektif baru (d) = 728,35714 mm

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

a = $\frac{3436,11696 \times 420}{0,85 \times 25 \times 400}$ = 169,7846 mm

c = $\frac{a}{\beta_1} = \frac{169,7846}{0,85}$ = 199,74659 mm

$$\varepsilon t = \frac{(d-c)}{c} \times 0{,}003$$

$$= \frac{(728{,}35714 - 199{,}74659)}{199{,}74659} \times 0{,}003$$

$= 0{,}00793922 >$ 0,005 , Terkendali Tarik Φ = 0,9

$$\Phi Mn = 0{,}9 \times As \times fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 3436{,}11696 \times 420 \times \left(728{,}35714 - \frac{169{,}7846}{2}\right)$$

$$= 835{,}76573 \times 10^6\ Nmm = 835{,}76573\ kNm$$

Φ *Mn* > Mu *Aman*!

Maka digunakan 7D25

- Perencanaan Tulangan Transversal

Menghitung nilai Mpr balok

$$\text{Mpr-} = Ast \times 1 \times fy \times \left(d - \tfrac{a}{2}\right)$$

$$= 10 \times \tfrac{1}{4} \times \pi \times 25^2 \times 1 \times 420 \times \left(713{,}9 - \tfrac{242{,}54943}{2}\right)$$

$$= 1221{,}79787 \times 10^6\ Nmm = 1221{,}79787\ kNm$$

$$\text{Mpr+} = Ast \times 1 \times fy \times \left(d - \tfrac{a}{2}\right)$$

$$= 7 \times \tfrac{1}{4} \times \pi \times 25^2 \times x\ 420\ x\ \left(728{,}35714 - \tfrac{169{,}7846}{2}\right)$$

$$= 928{,}628592 \times 10^6\ Nmm = 928{,}628592\ kNm$$

Ln = 9,6 m

Vg = 366,185 kN (dari ETABS)

V_{2E}= 378,8 kN (akibat beban 1,2*D* + 2,0*E* + 1,0*L)*

Vs ways = $\frac{(Mpr-) + (Mpr+)}{Ln} = \frac{1221{,}79787 + 928{,}628592}{9{,}6}$ = 224,00276 kN

Vu1 = Vs ways +Vg

= 224,00276 kN + 366,185 kN

= 590,18776 kN

Vu2 = V_{2E}

= 378,8 kN

Vu use = 590,18776 kN (gunakan nilai tegangan geser yang terbesar)

- Tulangan Transversal Tumpuan

Av = $2 \times \frac{1}{4} \times \pi \times 12^2$ = 226,19467 mm^2

$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times b \times d$

$= 0{,}17 \times 1 \times \sqrt{25} \times 400 \times 713{,}9$

= 242726 N

= 242,726 kN

Vs = $\frac{Vu}{\emptyset} - Vc$

= $\frac{590{,}18776}{0{,}75} - 242{,}726$

= 544,191 kN

Memeriksa batasan dimensi penampang

Vs < $0{,}66 \times \sqrt{f'c} \times bw \times d$

544,191 < $0{,}66 \times \sqrt{25} \times 400 \times 713{,}9$

544,191 < $942{,}348\ kN$ (Aman!)

Spasi = $\frac{Av \times fy \times d}{Vs}$

= $\frac{226{,}19467 \times 280 \times 713{,}9}{544{,}191 \times 10^3}$ = 83,08573 mm

Smaks 1 = $\frac{d}{4} = \frac{716{,}92857}{4}$ =178,475 mm

Smaks 2 = d.l x 8 = 25 x 8 = 200 mm

Smaks 3 = d.s x 24 = 12 x 24 = 288 mm

Smaks 4 = 300 mm

Digunakan spasi terkecil yaitu 83,08573 mm = 50 mm

Maka digunakan tulangan 2d12-50

- Tulangan Transversal Lapangan

Av $= 2 \times \frac{1}{4} \times \pi \times 12^2$ = 226,19467 mm^2

Ve max = Vsways +Vg

= 224,00276 kN + 366,185 kN

= 590,18776 kN

Ve min = Vg - Vsways

= 366,185 kN - 224,00276 kN

= 142,18224 kN

Ve lapangan $= \frac{Ln-2h}{Ln}(Ve\ max - Ve\ min) + Ve\ min$

$= \frac{9,6-2(0,8)}{9,6}(590,18776 - 142,18224) + 142,18224$

= 515,52017 kN

$Vc = 0,17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$= 0,17 \times 1 \times \sqrt{25} \times 400 \times 713,9$

= 242726 N

= 242,726 kN

Vs $= \frac{Vu}{\emptyset} - Vc$

$= \frac{515,52}{0,75} - 242,726$

= 444,634 kN

Spasi $= \frac{Av \times fy \times d}{Vs}$

$= \frac{226,19467 \times 280 \times 713,9}{444,634 \times 10^3}$ = 101,68921 mm

Smaks 1 = $\frac{d}{4} = \frac{716{,}92857}{4}$ = 178,475 mm

Smaks 2 = d.l x 8 = 25 x 8 = 200 mm

Smaks 3 = d.s x 24 = 12 x 24 = 288 mm

Smaks 4 = 300 mm

Digunakan spasi terkecil yaitu 101,68921 mm = 100 mm

Maka digunakan tulangan 2d12-100

2. Balok Induk Tipe 2

Desain Balok Induk Tipe 2 (400x700) mm

Mutu Baja longitudinal:	fy	= 420 MPa
Mutu Baja sengkang:	fys	= 280 MPa
Mutu Beton:	f'c	= 25 MPa
Ukuran Struktur:		
b balok		= 400 mm
h balok		= 700 mm
selimut beton		= 40 mm
diameter tulangan pokok (d.l)		= 25 mm
diameter Sengkang (d.s)		= 12 mm

A. Pemeriksaan Gaya Tekan Aksial Terfaktor (SNI 2847:2019 Pasal 18.4.2.6)

Pu = 0 kN-m (dari ETABS)

$$Ag \times \frac{f'c}{10} = (400 \times 700) \times \frac{25}{10}$$

= 700.000 N

= 700 kN > Pu Aman!

B. Desain Tulangan Lentur

➢ Perencanaan Tulangan Tumpuan Atas

Momen Ultimet (Mu) = 553,0314 kN-m (dari ETABS)

Momen Nominal (Mn) = $\frac{Mu}{\emptyset} = \frac{553,0314}{0,9}$ = 614,479 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 12 + (25/2)

= 64,5 mm

Tinggi efektif (d) = h-d'

= 700 – 64,5

= 635,5 mm

Koefisien $(k) = \frac{Mn}{bd^2}$

$= \frac{614,479 \text{ x } 10^6}{400 \; x \; 635,5^2} = 3,80379$

$\rho = \frac{0,85xF'c}{Fy}\left(1 - \sqrt{1 - \frac{2k}{0,85\,F'c}}\right)$

$= \frac{0,85x25}{420}\left(1 - \sqrt{1 - \frac{2(3,80379)}{0,85x25}}\right)$

= 0,01006

$\rho maks = 0,429 \times \frac{0,85 \times f'c \times \beta_1}{fy}$

$= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420}$

= 0,0184496

ρmin 1 = $\frac{\sqrt{F'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420}$ = 0,002976

ρmin 2 = $\frac{1,4}{fy} = \frac{1,4}{420}$ = 0,00333

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,01006 x 400 x 635,5 = 2556,22569 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{2556,22569}{\frac{1}{4} \times \pi \times 25^2} = 5,2075 \approx 6\ buah$$

As use = $6 \times \frac{1}{4} \times \pi \times 25^2$ = 2945,2431 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n - 1}$$

$= \frac{400-(2\times40)-(2\times12)-(6\times25)}{6-1}$ = 29,2 mm < 25 mm (Memenuhi!)

Analisis kapasitas momen

a = $\frac{As \times fy}{0,85 \times fc \times b}$

a = $\frac{2945,2431 \times 420}{0,85 \times 25 \times 400}$ = 145,52966 mm

c = $\frac{a}{\beta_1}$ = $\frac{145,52966}{0,85}$ = 171,21136 mm

$\varepsilon t = \frac{(d-c)}{c} \times 0,003$

$= \frac{(635,5 - 171,21136)}{171,21136} \times 0,003$

= 0,00813 > 0,005 Terkendali Tarik $\Phi = 0,9$

$\Phi Mn = 0,9\ x\ As\ x\ fy \times \left(d - \frac{a}{2}\right)$

$= 0,9 \times 2945,2431 \times 420 \times \left(635,5 - \frac{145,52966}{2}\right)$

$= 626,49413 \times 10^6\ Nmm = 626,49413\ kNm$

Φ *Mn* > Mu *Aman*!

Maka digunakan 6D25

- Perencanaan Tulangan Tumpuan Bawah

Momen Ultimet (Mu) = 368,9103 kN-m (dari ETABS)

Momen Nominal (Mn) = $\frac{Mu}{\emptyset} = \frac{368,9103}{0,9}$ = 409,90033 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 12 + (25/2)

= 64,5 mm

Tinggi efektif (d) = h-d'

= 700 – 64,5

= 635,5 mm

Koefisien $(k) = \frac{Mn}{bd^2}$

$= \frac{409,90033 \text{ x } 10^6}{400 \; x \; 635,5^{\,2}} = 2,53739$

$\rho = \frac{0,85xfc}{fy}\left(1 - \sqrt{1 - \frac{2k}{0,85\; f'c}}\right)$

$= \frac{0,85x25}{420}\left(1 - \sqrt{1 - \frac{2(2,53739)}{0,85x25}}\right)$

= 0,006453

$\rho maks = 0,429 \times \frac{0,85 \times f'c \times \beta_1}{fy}$

$= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420}$

= 0,0184496

$\rho min\ 1 = \frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420}$ = 0,002976

ρmin 2 = $\frac{1,4}{fy} = \frac{1,4}{420}$ = 0,00333

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,006453 x 400 x 635,5 = 1640,32846 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{1640,32846}{\frac{1}{4} \times \pi \times 25^2} = 3,34165 \approx 4\ buah$$

As use = $4 \times \frac{1}{4} \times \pi \times 25^2$ = 1963,4954 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n - 1}$$

$= \frac{400-(2\times40)-(2\times12)-(4\times25)}{4-1}$ = 65,33 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

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

a = $\frac{1963,4954 \times 420}{0,85 \times 25 \times 400}$ = 97,01978 mm

c = $\frac{a}{\beta_1} = \frac{97,01978}{0,85}$ = 114,14091 mm

$$\varepsilon t = \frac{(d - c)}{c} \times 0,003$$

$= \frac{(635,5 - 114,14091)}{114,14091} \times 0,003$

$= 0,0137 > 0,005$, Terkendali Tarik Φ = 0,9

$$\Phi Mn = 0,9\ x\ As\ x\ fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 1963{,}4954 \times 420 \times \left(635{,}5 - \frac{97{,}01978}{2}\right)$$

$$= 435{,}6648 \times 10^6\ Nmm = 435{,}6648\ kNm$$

$\Phi\ Mn >$ Mu *Aman*!

Maka digunakan 4D25

- Perencanaan Tulangan Lapangan Atas

Momen Ultimet (Mu) = 250,1975 kN-m (dari ETABS)

Momen Nominal (Mn) $= \frac{Mu}{\emptyset} = \frac{250{,}1975}{0{,}9}$ = 277,99722 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 12 + (25/2)

= 64,5 mm

Tinggi efektif (d) = h-d'

= 700 – 64,5

= 635,5 mm

Koefisien (k) $= \frac{Mn}{bd^2}$

$= \frac{277{,}99722 \text{ x } 10^6}{400\ x\ 64{,}5^2} = 1{,}72087$

$$\rho = \frac{0{,}85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\ f'c}}\right)$$

$$= \frac{0{,}85x25}{420}\left(1 - \sqrt{1 - \frac{2(1{,}72087)}{0{,}85x25}}\right)$$

= 0,004278

$$\rho\text{maks} = 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy}$$

$$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{420}$$

= 0,0184496

ρmin 1 = $\frac{\sqrt{f'c}}{4\times fy} = \frac{\sqrt{25}}{4\times 420}$ = 0,002976

ρmin 2 = $\frac{1,4}{fy} = \frac{1,4}{420}$ = 0,00333

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,0184496 x 400 x 635,5 = 1087,51799 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{1087,51799}{\frac{1}{4}\times\pi\times 25^2} = 2,21547 \approx 3\ buah$$

As use = $3 \times \frac{1}{4} \times \pi \times 25^2$ = 1472,6216 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{400-(2\times40)-(2\times12)-(3\times25)}{3-1}$ = 110,5 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

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

a = $\frac{1472,6216\ \times 420}{0,85\times 25\times 400}$ = 72,76483 mm

c = $\frac{a}{\beta_1} = \frac{72,76483}{0,85}$ = 85,60568 mm

$$\varepsilon t = \frac{(d-c)}{c}\times 0,003$$

$$= \frac{(635,5\ -\ 85,60568\ )}{85,60568}\ \times 0,003$$

= 0,01927 > 0,005 , Terkendali Tarik Φ = 0,9

$$Mn = 0{,}9 \times As \times fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 1472{,}6216 \times 420 \times \left(635{,}5 - \frac{72{,}76483}{2}\right)$$

$$= 333{,}49937 \times 10^6\ Nmm = 333{,}49937\ kNm$$

Φ *Mn* > Mu *Aman*!

Maka digunakan 3D25

- Perencanaan Tulangan Lapangan Atas

Momen Ultimet (Mu) = 368,603 kN-m (dari ETABS)

Momen Nominal (Mn) = $\frac{Mu}{\emptyset} = \frac{368{,}603}{0{,}9}$ = 409,55889 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 12 + (25/2)

= 64,5 mm

Tinggi efektif (d) = h-d'

= 700 – 64,5

= 635,5 mm

Koefisien $(k) = \frac{Mn}{bd^2}$

$$= \frac{409{,}55889 \text{ x } 10^6}{400\ x\ 635{,}5^2} = 2{,}535276$$

$$\rho = \frac{0{,}85xf'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\ F'c}}\right)$$

$$= \frac{0{,}85x25}{420}\left(1 - \sqrt{1 - \frac{2(2{,}535276)}{0{,}85x25}}\right)$$

= 0,00645

$$\rho\text{maks} = 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy}$$

$$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{420}$$

= 0,0184496

ρmin 1 = $\frac{\sqrt{f'c}}{4\times fy} = \frac{\sqrt{25}}{4\times 420}$ = 0,002976

ρmin 2 = $\frac{1,4}{fy} = \frac{1,4}{420}$ = 0,00333

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,00645 x 400 x 635,5 = 1638,8632 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{1638,8632}{\frac{1}{4}\times \pi \times 25^2} = 3,33866 \approx 4\ buah$$

As use = $4 \times \frac{1}{4} \times \pi \times 25^2$ = 1963,4954 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{400-(2\times 40)-(2\times 12)-(4\times 25)}{4-1}$ = 65,33 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

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

a = $\frac{1963,4954 \times 420}{0,85 \times 25 \times 400}$ = 97,01978 mm

c = $\frac{a}{\beta_1} = \frac{97,01978}{0,85}$ = 114,14091 mm

$$\varepsilon t = \frac{(d-c)}{c} \times 0,003$$

$$= \frac{(635,5 - 114,14091)}{114,14091} \times 0,003$$

$= 0{,}013703 > 0{,}005$, Terkendali Tarik Φ = 0,9

$\Phi Mn = 0{,}9 \times As \times fy \times \left(d - \frac{a}{2}\right)$

$= 0{,}9 \times 1963{,}4954 \times 420 \times \left(635{,}5 - \frac{97{,}01978}{2}\right)$

$= 435{,}6648 \times 10^6\ Nmm = 435{,}6648\ kNm$

Φ *Mn* > Mu *Aman*!

Maka digunakan 4D25

- Perencanaan Tulangan Transversal

Menghitung nilai Mpr balok

Mpr- $= Ast \times 1 \times fy \times \left(d - \frac{a}{2}\right)$

$= 6 \times \frac{1}{4} \times \pi \times 25^2 \times 1 \times 420 \times \left(635{,}5 - \frac{145{,}52966}{2}\right)$

$= 696{,}10459 \times 10^6\ Nmm = 696{,}10459\ kNm$

Mpr+ $= Ast \times 1 \times fy \times \left(d - \frac{a}{2}\right)$

$= 4 \times \frac{1}{4} \times \pi \times 25^2 \times x\ 420\ x\ \left(635{,}5 - \frac{97{,}01978}{2}\right)$

$= 484{,}072 \times 10^6\ Nmm = 484{,}072\ kNm$

Ln = 9,6 m

Vg = 178,14 kN (dari ETABS)

V_{2E} = 194,1162 kN (akibat beban 1,2*D* + 2,0*E* + 1,0*L)*

Vs ways = $\frac{(Mpr-) + (Mpr+)}{Ln} = \frac{696{,}10459 + 484{,}072}{9{,}6}$ = 112,93506 kN

Vu1 = Vs ways +Vg

= 112,93506 kN + 178,14 kN

= 301,08366 kN

Vu2 = V_{2E}

= 194,1162 kN

Vu use = 301,08366 kN (gunakan nilai tegangan geser yang terbesar)

- Tulangan Transversal Tumpuan

Av $= 2 \times \frac{1}{4} \times \pi \times 12^2$ = 226,19467 mm^2

$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$= 0{,}17 \times 1 \times \sqrt{25} \times 400 \times 635{,}5$

= 216070 N

= 216,07 kN

Vs $= \frac{Vu}{\emptyset} - Vc$

$= \frac{301{,}08366}{0{,}75} - 216{,}07$

= 185,37488 kN

Memeriksa batasan dimensi penampang

Vs $< 0{,}66 \times \sqrt{f'c} \times bw \times d$

185,37488 $< 0{,}66 \times \sqrt{25} \times 400 \times 635{,}5$

185,37488 $< 838{,}86\ kN$ (Aman!)

Spasi $= \frac{Av \times fy \times d}{Vs}$

$= \frac{226{,}19467 \times 280 \times 635{,}5}{185{,}37488 \times 10^3}$ = 217,12262 mm

Smaks 1 = $\frac{d}{4} = \frac{635{,}5}{4}$ =158,875 mm

Smaks 2 = d.l x 8 = 25 x 8 = 200 mm

Smaks 3 = d.s x 24 = 12 x 24 = 288 mm

Smaks 4 = 300 mm

Digunakan spasi terkecil yaitu 158,875 mm = 150 mm

Maka digunakan tulangan 2d12-150

- Tulangan Transversal Lapangan

Av $= 2 \times \frac{1}{4} \times \pi \times 12^2$ = 226,19467 mm^2

Ve max = Vsways +Vg

= 122,93506 kN + 178,1486 kN

= 301,08366 kN

Ve min = Vg - Vsways

= 178,1486 kN - 122,93506 kN

= 55,21354 N

Ve lapangan $= \frac{Ln-2h}{Ln}(Ve\ max - Ve\ min) + Ve\ min$

$= \frac{9{,}6 - 2(0{,}7)}{9{,}6}(301{,}08366 - 55{,}21354) + 55{,}21354$

= 265,2276 kN

$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$= 0{,}17 \times 1 \times \sqrt{25} \times 400 \times 635{,}5$

= 21607 N

= 216,07 kN

Vs $= \frac{Vu}{\emptyset} - Vc$

$= \frac{265{,}2276}{0{,}75} - 216{,}07$

= 137,5668 kN

Spasi $= \frac{Av \times fy \times d}{Vs}$

$= \frac{226{,}19467 \times 280 \times 635{,}5}{137{,}5668 \times 10^3}$ = 292,57843 mm

Smaks 1 = $\frac{d}{4} = \frac{635{,}5}{4}$ = 158,875 mm

Smaks 2 = d.l x 8 = 25 x 8 = 200 mm

Smaks 3 = d.s x 24 = 12 x 24 = 288 mm

Smaks 4 = 300 mm

Digunakan spasi terkecil yaitu 158,875 mm = 150 mm

Maka digunakan tulangan 2d12-150

3. Balok Anak

Desain Balok Anak (300x550) mm

Mutu Baja longitudinal:	fy	= 420 MPa
Mutu Baja sengkang:	fys	= 280 MPa
Mutu Beton:	f'c	= 25 MPa
Ukuran Struktur:		
b balok		= 300 mm
h balok		= 550 mm
selimut beton		= 40 mm
diameter tulangan pokok (d.l)		= 19 mm
diameter Sengkang (d.s)		= 8 mm

A. Pemeriksaan Gaya Tekan Aksial Terfaktor (SNI 2847:2019 Pasal 18.4.2.6)

Pu = 0 kN-m (dari ETABS)

$$Ag \times \frac{f'c}{10} = (300 \times 550) \times \frac{25}{10}$$

= 412.500 N

= 412,5 kN > Pu Aman!

B. Desain Tulangan Lentur

- Perencanaan Tulangan Tumpuan Atas

  Momen Ultimet (Mu) = 324,8168 kN-m (dari ETABS)

  Momen Nominal (Mn) = $\frac{Mu}{\emptyset} = \frac{324,8168}{0,9}$ = 360,907556 kN-m

  d' = cc + d.s + (d.l/2)

= 40 + 8 + (19/2)

= 57,5 mm

Tinggi efektif (d) = h-d'

= 550 – 57,5

= 492,5 mm

Koefisien (k) $= \frac{Mn}{bd^2}$

$= \frac{360{,}907556 \text{ x } 10^6}{300 \ x \ 492{,}5^2} = 4{,}95977813$

$\rho = \frac{0{,}85xf'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\ f'c}}\right)$

$= \frac{0{,}85x25}{420}\left(1 - \sqrt{1 - \frac{2(4{,}95977813)}{0{,}85x25}}\right)$

= 0,01365041

ρmaks $= 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy}$

$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{420}$

= 0,0184496

ρmin 1 $= \frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420}$ = 0,002976

ρmin 2 $= \frac{1{,}4}{fy} = \frac{1{,}4}{420}$ = 0,00333

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,01365041 x 300 x 492,5 = 2016,84826 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$n = \frac{2016{,}84826}{\frac{1}{4} \times \pi \times 19^2} = 7{,}11338215 \approx 8 \ buah$

As use = $8\times\frac{1}{4}\times\pi\times19^2$ = 2268 ,23 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{300-(2\times40)-(2\times8)-(8\times19)}{8-1}$ = 7,4285 mm < 25 mm (Tidak Memenuhi!)

Oleh karena spasi antar tulangan tidak memenuhi, maka tulangan dibuat 2 baris dengan

baris pertama (n1) = 5 buah

baris kedua (n2) = 3 buah

Analisis kapasitas momen

Tinggi efektif baru (d) = 476 mm

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

a $= \frac{2268{,}23\times420}{0{,}85\times25\times300}$ = 149,4363 mm

c $= \frac{a}{\beta_1} = \frac{149{,}3463}{0{,}85} = 175{,}8074$mm

$$\varepsilon t = \frac{(d-c)}{c}\times 0{,}003$$

$$= \frac{(476 - 175{,}8074)}{175{,}8074}\times 0{,}003$$

$= 0{,}005123 > 0{,}005$, Terkendali Tarik Φ = 0,9

$$\Phi Mn = 0{,}9\ x\ As\ x\ fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9\ \times 2268{,}23\ x\ 420\ x\ \left(476 - \frac{149{,}4363}{2}\right)$$

$= 344{,}054\ \times 10^6\ Nmm = 344{,}0554\ kNm$

Φ *Mn* > Mu *Aman*!

Maka digunakan 8D19

- Perencanaan Tulangan Tumpuan Bawah

Momen Ultimet (Mu) = 188,8119 kN-m (dari ETABS)

Momen Nominal (Mn) $= \frac{Mu}{\emptyset} = \frac{188,8119}{0,9}$ = 209,791 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 8 + (19/2)

= 57,5 mm

Tinggi efektif (d) = h-d'

= 550 – 57,5

= 492,5 mm

Koefisien (k) $= \frac{Mn}{bd^2}$

$= \frac{209,791 \text{ x } 10^6}{300 \; x \; 492,5^2} = 2,88305$

$\rho = \frac{0,85xf'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0,85\,f'c}}\right)$

$= \frac{0,85x25}{420}\left(1 - \sqrt{1 - \frac{2(2,88305)}{0,85x25}}\right)$

= 0,00740653

ρmaks $= 0,429 \times \frac{0,85 \times f'c \times \beta_1}{fy}$

$= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420}$

= 0,0184496

ρmin 1 = $\frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420}$ = 0,002976

ρmin 2 = $\frac{1,4}{fy} = \frac{1,4}{420}$ = 0,00333

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,00740653 x 300 x 492,5 = 1094,31532 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{1094{,}31532}{\frac{1}{4} \times \pi \times 19^2} = 3{,}85967 \approx 4\ buah$$

As use = $4 \times \frac{1}{4} \times \pi \times 19^2$ = 1134,11495 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{300-(2\times40)-(2\times8)-(4\times19)}{4-1}$ = 42,67 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

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

a = $\frac{1134{,}1149 \times 420}{0{,}85 \times 25 \times 300}$ = 74,7181 mm

c = $\frac{a}{\beta_1} = \frac{74{,}7181}{0{,}85} = 87{,}90371$ mm

$$\varepsilon t = \frac{(d-c)}{c} \times 0{,}003$$

$$= \frac{(492{,}5 - 87{,}90371)}{87{,}90371} \times 0{,}003$$

$= 0{,}001380 > 0{,}005$, Terkendali Tarik Φ = 0,9

$$\Phi Mn = 0{,}9\ x\ As\ x\ fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 1134{,}11495\ \ x\ 420\ x\ \left(492{,}5 - \frac{74{,}7181}{2}\right)$$

$$= 195{,}1168 \times 10^6\ Nmm = 195{,}1168\ kNm$$

Φ *Mn* > Mu *Aman*!

Maka digunakan 4D19

- Perencanaan Tulangan Lapangan Atas

Momen Ultimet (Mu) = 101,353 kN-m (dari ETABS)

Momen Nominal (Mn) = $\frac{Mu}{\emptyset} = \frac{101,353}{0,9}$ = 112.6144 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 8 + (19/2)

= 57,5 mm

Tinggi efektif (d) = h-d'

= 550 – 57,5

= 492,5 mm

Koefisien $(k) = \frac{Mn}{bd^2}$

$= \frac{112,6144 \text{ x } 10^6}{300 \text{ x } 492,5^2} = 1,5476$

$\rho = \frac{0,85xf'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0,85\ f'c}}\right)$

$= \frac{0,85x25}{420}\left(1 - \sqrt{1 - \frac{2(1,5476}{0,85x25}}\right)$

= 0,00382972

$\rho\text{maks} = 0,429 \times \frac{0,85 \times f'c \times \beta_1}{fy}$

$= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420}$

= 0,0184496

$\rho\text{min } 1 = \frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420} = 0,002976$

$\rho\text{min } 2 = \frac{1,4}{fy} = \frac{1,4}{420} = 0,00333$

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,0038972 x 300 x 492,5 = 565,8408 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{565{,}8408}{\frac{1}{4} \times \pi \times 19^2} = 1{,}9957 \approx 2\ buah$$

As use = $2 \times \frac{1}{4} \times \pi \times 19^2$ = 567,0575 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n - 1}$$

$= \frac{300-(2\times40)-(2\times8)-(2\times19)}{2-1}$ = 166 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

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

a $= \frac{567{,}0575 \times 420}{0{,}85 \times 25 \times 300}$ = 37,3591 mm

c $= \frac{a}{\beta_1} = \frac{37{,}3591}{0{,}85} = 43{,}9518$ mm

$$\varepsilon t = \frac{(d - c)}{c} \times 0{,}003$$

$$= \frac{(492{,}5 - 43{,}9518)}{43{,}9518} \times 0{,}003$$

$= 0{,}03062 > 0{,}005$, Terkendali Tarik Φ = 0,9

$$\Phi Mn = 0{,}9\ x\ As\ x\ fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 567{,}0575 \; x\, 420\, x \left(492{,}5 - \frac{43{,}9518}{2}\right)$$

$$= 101{,}562338 \times 10^6\, Nmm = 101{,}562338\, kNm$$

Φ *Mn* > Mu *Aman*!

Maka digunakan 2D13

- Perencanaan Tulangan Lapangan Atas

Momen Ultimet (Mu) = 173,4244 kN-m (dari ETABS)

Momen Nominal (Mn) $= \frac{Mu}{\emptyset} = \frac{173{,}4244}{0{,}9}$ = 192,6938 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 8 + (19/2)

= 57,5 mm

Tinggi efektif (d) = h-d'

= 550 – 57,5

= 492,5 mm

Koefisien (k) $= \frac{Mn}{bd^2}$

$= \frac{192{,}6939 \text{ x } 10^6}{300\, x\, 492{,}5^2} = 2{,}648097$

$$\rho = \frac{0{,}85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\, f'c}}\right)$$

$$= \frac{0{,}85x25}{420}\left(1 - \sqrt{1 - \frac{2(2{,}648097)}{0{,}85x25}}\right)$$

= 0,006756

$$\rho\text{maks} = 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy}$$

$$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{420}$$

= 0,0184496

ρmin 1 = $\frac{\sqrt{f'c}}{4\times fy} = \frac{\sqrt{25}}{4\times 420}$ = 0,002976

ρmin 2 = $\frac{1,4}{fy} = \frac{1,4}{420}$ = 0,00333

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,006756 x 300 x 492,5 = 998,209148 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{998,209148}{\frac{1}{4}\times\pi\times 19^2} = 3,520663 \approx 4\ buah$$

As use = $4 \times \frac{1}{4} \times \pi \times 19^2$ = 1134,11495 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{300-(2\times40)-(2\times8)-(4\times19)}{4-1}$ = 38,75 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

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

a = $\frac{1134,11495\times420}{0,85\times25\times300}$ = 74,718161 mm

c = $\frac{a}{\beta_1} = \frac{74,718161}{0,85}$ = 87,90372 mm

$$\varepsilon t = \frac{(d-c)}{c}\times 0,003$$

$$= \frac{(492,5 - 87,90372)}{87,90372} \times 0,003$$

= 0,0130808 > 0,005 , Terkendali Tarik Φ = 0,9

$$\Phi Mn = 0{,}9\ x\ As\ x\ fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9\ \times\ \ x\ 420\ x\ \left(492{,}5 - \frac{74{,}718161}{2}\right)$$

$$= 195{,}1168\ \times 10^6\ Nmm = 195{,}1168\ kNm$$

Φ *Mn* > Mu *Aman*!

Maka digunakan 4D19

- Perencanaan Tulangan Transversal

Vu Tumpuan = 164,68 kN

Vu Lapangan = 105,1 kN

1. Tulangan Transversal Tumpuan

Av $= 2 \times \frac{1}{4} \times \pi \times 8^2$ = 100,531 mm^2

$$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times bw \times d$$

$$= 0{,}17 \times 1 \times \sqrt{25} \times 300 \times 476$$

= 121380 N

= 121,380 kN

Vs $= \frac{Vu}{\emptyset} - Vc$

$= \frac{164{,}68}{0{,}75} - 121{,}380$

= 98,1933 kN

Memeriksa batasan dimensi penampang

Vs $< 0{,}66 \times \sqrt{f'c} \times bw \times d$

98,1933 $< 0{,}66 \times \sqrt{25} \times 300 \times 476$

98,1933 $< 471{,}240\ kN$ (Aman!)

Spasi $= \frac{Av \times Fy \times d}{Vs}$

$= \frac{100{,}531 \times 280 \times 476}{98{,}1933 \times 10^3}$ = 141,1829 mm

Smaks 1 = $\frac{d}{2} = \frac{476}{2}$ =238 mm

Smaks 2 = 600 mm

Digunakan spasi terkecil yaitu 141,1829 mm = 100 mm

Maka digunakan tulangan 2d8-100

2. Tulangan Transversal Lapangan

Av $= 2 \times \frac{1}{4} \times \pi \times 8^2$ = 100,531 mm^2

$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$= 0{,}17 \times 1 \times \sqrt{25} \times 300 \times 476$

= 121380 N

= 121,380 kN

Vs = $\frac{Vu}{\emptyset} - Vc$

$= \frac{105{,}126}{0{,}75} - 121{,}380$

= 18,787 kN

Spasi $= \frac{Av \times fy \times d}{Vs}$

$= \frac{100{,}531 \times 280 \times 476}{18{,}787 \times 10^3}$ = 737,8868 mm

Smaks 1 = $\frac{d}{2} = \frac{476}{2}$ =238 mm

Smaks 2 = 600 mm

Digunakan spasi terkecil yaitu 238 mm = 200 mm

Maka digunakan tulangan 2d8-200

4. Ring Balok

Desain Ring Balok (300x550) mm

Mutu Baja longitudinal:	fy	= 420 MPa
Mutu Baja sengkang:	fys	= 280 MPa
Mutu Beton:	f'c	= 25 MPa

Ukuran Struktur:

b balok	= 300 mm
h balok	= 550 mm
selimut beton	= 40 mm
diameter tulangan pokok (d.l)	= 19 mm
diameter Sengkang (d.s)	= 8 mm

A. Pemeriksaan gaya tekan aksial terfaktor (SNI 2847:2019 pasal 18.4.2.6)

Pu = 0 kN-m (dari ETABS)

$$Ag \times \frac{f'c}{10} = (300 \times 550) \times \frac{25}{10}$$

= 412.500 N

= 412,5 kN > Pu Aman!

B. Desain Tulangan Lentur

- Perencanaan Tulangan Tumpuan Atas

Momen Ultimet (Mu) = 129,8298 kN-m (dari ETABS)

Momen Nominal (Mn) = $\frac{Mu}{\emptyset} = \frac{129,8298}{0,9}$ = 144,25533 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 8 + (19/2)

= 57,5 mm

Tinggi efektif (d) = h-d'

= 550 – 57,5

= 492,5 mm

Koefisien (k) = $\frac{Mn}{bd^2}$

$$= \frac{144{,}25533 \text{ x } 10^6}{300\ x\ 492{,}5^2} = 1{,}982431$$

$$\rho = \frac{0{,}85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\ f'c}}\right)$$

$$= \frac{0{,}85x25}{420}\left(1 - \sqrt{1 - \frac{2(1{,}982431)}{0{,}85x25}}\right)$$

= 0,0049635

$$\text{ρmaks} = 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy}$$

$$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{420}$$

= 0,0184496

$$\text{ρmin 1} = \frac{\sqrt{F'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420} = 0{,}002976$$

$$\text{ρmin 2} = \frac{1{,}4}{fy} = \frac{1{,}4}{420} = 0{,}00333$$

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,0049635x 300 x 492,5 = 733,3636 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{733{,}3636}{\frac{1}{4} \times \pi \times 19^2} = 2{,}586558 \approx 3\ buah$$

As use = $3 \times \frac{1}{4} \times \pi \times 19^2$ = 850,5862 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\ D_{tul}}{n - 1}$$

$= \frac{300-(2\times40)-(2\times8)-(3\times19)}{3-1}$ = 73,5 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

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

a $= \frac{850{,}5862\times420}{0{,}85\times25\times300}$ = 56,03862 mm

c $= \frac{a}{\beta_1} = \frac{56{,}03862}{0{,}85}$ = 65,9278 mm

$$\varepsilon t = \frac{(d-c)}{c}\times 0{,}003$$

$$= \frac{(492{,}5 - 65{,}9278)}{65{,}9278}\times 0{,}003$$

= 0,0194108 > 0,005 , **Terkendali Tarik** Φ = 0,9

$$\Phi Mn = 0{,}9\ x\ As\ x\ fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 850{,}5862 \times 420 \times \left(492{,}5 - \frac{56{,}03862}{2}\right)$$

$$= 149{,}3405 \times 10^6\ Nmm = 149{,}3405\ kNm$$

Φ *Mn* > Mu *Aman*!

Maka digunakan 3D19

- Perencanaan Tulangan Tumpuan Bawah

  Momen Ultimet (Mu) = 120,2108 kN-m (dari ETABS)

  Momen Nominal (Mn) = $\frac{Mu}{\emptyset} = \frac{120{,}2108}{0{,}9}$ = 133,5675 kN-m

  d' = cc + d.s + (d.l/2)

  = 40 + 8 + (19/2)

  = 57,5 mm

  Tinggi efektif (d) = h-d'

  = 550 – 57,5

= 492,5 mm

Koefisien (k) $= \frac{Mn}{bd^2}$

$= \frac{133{,}5675 \text{ x } 10^6}{300 \; x \; 492{,}5^2} = 1{,}8355$

$\rho = \frac{0{,}85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85 \; f'c}}\right)$

$= \frac{0{,}85 x 25}{420}\left(1 - \sqrt{1 - \frac{2(1{,}8355)}{0{,}85 x 25}}\right)$

= 0,004577

ρmaks $= 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy}$

$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{420}$

= 0,0184496

ρmin 1 $= \frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420} = 0{,}002976$

ρmin 2 $= \frac{1{,}4}{fy} = \frac{1{,}4}{420} = 0{,}00333$

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,004577 x 300 x 492,5 = 676,3154 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$n = \frac{676{,}3154}{\frac{1}{4} \times \pi \times 19^2} = 2{,}38535 \approx 3 \; buah$

As use = $3 \times \frac{1}{4} \times \pi \times 19^2$ = 850,5862 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{300-(2\times40)-(2\times8)-(3\times19)}{3-1}$ = 73,5 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

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

a = $\frac{850{,}5862 \times 420}{0{,}85 \times 25 \times 300}$ = 56,0386 mm

c = $\frac{a}{\beta_1}$ = $\frac{56{,}0386}{0{,}85}$ = 65,927789 mm

$$\varepsilon t = \frac{(d-c)}{c} \times 0{,}003$$

$$= \frac{(492{,}5 - 65{,}927789)}{65{,}927789} \times 0{,}003$$

$= 0{,}001941 > 0{,}005$, **Terkendali Tarik** Φ = 0,9

$$\Phi Mn = 0{,}9\ x\ As\ x\ fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 850{,}5862\ x\ 420\ x\ \left(492{,}5 - \frac{56{,}0386}{2}\right)$$

$$= 149{,}340568 \times 10^6\ Nmm = 149{,}34056\ kNm$$

Φ *Mn* > Mu *Aman*!

Maka digunakan 3D19

- Perencanaan Tulangan Lapangan Atas

Momen Ultimet (Mu) = 97,414 kN-m (dari ETABS)

Momen Nominal (Mn) = $\frac{Mu}{\emptyset}$ = $\frac{97{,}414}{0{,}9}$ = 108,23778 kN-m

d’ = cc + d.s + (d.l/2)

= 40 + 8 + (19/2)

= 57,5 mm

Tinggi efektif (d) = h-d’

= 550 – 57,5

= 492,5 mm

Koefisien (k) $= \frac{Mn}{bd^2}$

$= \frac{108{,}23778 \text{ x } 10^6}{300\ x\ 492{,}5^2} = 1{,}48746$

$\rho = \frac{0{,}85xf'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\ f'c}}\right)$

$= \frac{0{,}85x25}{420}\left(1 - \sqrt{1 - \frac{2(1{,}48746)}{0{,}85x25}}\right)$

= 0,003675

$\rho\text{maks} = 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy}$

$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{420}$

= 0,0184496

ρmin 1 = $\frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420}$ = 0,002976

ρmin 2 = $\frac{1{,}4}{fy} = \frac{1{,}4}{420}$ = 0,00333

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,003675 x 300 x 492,5 = 542.9872 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$n = \frac{542.9872}{\frac{1}{4} \times \pi \times 19^2} = 1{,}9151 \approx 2\ buah$

As use = $2 \times \frac{1}{4} \times \pi \times 19^2$ = 567,0575 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{300-(2\times40)-(2\times8)-(2\times19)}{2-1}$ = 166 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

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

a $= \frac{567{,}0575 \times 420}{0{,}85 \times 25 \times 300} = 37{,}3591$ mm

c $= \frac{a}{\beta_1} = \frac{37{,}3591}{0{,}85} = 43{,}9518$ mm

$$\varepsilon t = \frac{(d-c)}{c} \times 0{,}003$$

$$= \frac{(492{,}5 - 43{,}9518)}{43{,}9518} \times 0{,}003$$

$= 0{,}03062 > 0{,}005$, **Terkendali Tarik** $\Phi = 0{,}9$

$$\Phi Mn = 0{,}9\ x\ As\ x\ fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 567{,}0575\ x\ 420\ x\ \left(492{,}5 - \frac{43{,}9518}{2}\right)$$

$$= 101{,}562338 \times 10^6\ Nmm = 101{,}562338\ kNm$$

Φ *Mn* > Mu *Aman*!

Maka digunakan 2D19

- Perencanaan Tulangan Lapangan Atas

Momen Ultimet (Mu) = 120,2077 kN-m (dari ETABS)

Momen Nominal (Mn) = $\frac{Mu}{\emptyset} = \frac{120{,}2077}{0{,}9}$ = 133,5641 kN-m

d’ = cc + d.s + (d.l/2)

= 40 + 8 + (19/2)

= 57,5 mm

Tinggi efektif (d) = h-d’

= 550 – 57,5

= 492,5 mm

Koefisien (k) $= \frac{Mn}{bd^2}$

$= \frac{133{,}5641 \text{ x } 10^6}{300 \; x \; 492{,}5^2} = 1{,}83551$

$\rho = \frac{0{,}85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85 \; f'c}}\right)$

$= \frac{0{,}85 x 25}{420}\left(1 - \sqrt{1 - \frac{2(1{,}83551)}{0{,}85 x 25}}\right)$

= 0,004577

$\rho\text{maks} = 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy}$

$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{420}$

= 0,0184496

$\rho\text{min } 1 = \frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420} = 0{,}002976$

$\rho\text{min } 2 = \frac{1{,}4}{fy} = \frac{1{,}4}{420} = 0{,}00333$

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As $= \rho$ x b x d

= 0,004577 x 300 x 492,5 = 676,2972 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$n = \frac{676{,}2972}{\frac{1}{4} \times \pi \times 19^2} = 2{,}385286 \approx 3 \; buah$

As use $= 3 \times \frac{1}{4} \times \pi \times 19^2 = 850{,}5862 \; mm^2$

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{300-(2\times40)-(2\times8)-(3\times19)}{3-1}$ = 73,5 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

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

a $= \frac{850{,}5862 \times 420}{0{,}85 \times 25 \times 300} = 56{,}03862$ mm

c $= \frac{a}{\beta_1} = \frac{56{,}03862}{0{,}85} = 65{,}9278$ mm

$$\varepsilon t = \frac{(d-c)}{c} \times 0{,}003$$

$$= \frac{(492{,}5 - 65{,}9278)}{65{,}9278} \times 0{,}003$$

$= 0{,}01941 > 0{,}005$, **Terkendali Tarik** $\Phi = 0{,}9$

$$\Phi Mn = 0{,}9\ x\ As\ x\ fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times \ x\ 420\ x\ \left(492{,}5 - \frac{56{,}03862}{2}\right)$$

$$= 149{,}34056 \times 10^6\ Nmm = 149{,}34056\ kNm$$

Φ *Mn* > Mu *Aman*!

Maka digunakan 3D19

- Perencanaan Tulangan Transversal

Menghitung nilai Mpr balok

$$Mpr^- = Ast \times 1 \times fy \times \left(d - \frac{a}{2}\right)$$

$$= 3 \times \frac{1}{4} \times \pi \times 19^2 \times 1 \times 420 \times \left(492{,}5 - \frac{56{,}038621}{2}\right)$$

$$= 165{,}9339 \times 10^6\ Nmm = 165{,}9339\ kNm$$

$$Mpr^+ = Ast \times 1 \times fy \times \left(d - \frac{a}{2}\right)$$

$$= 3 \times \frac{1}{4} \times \pi \times 19^2 \times x\ 420\ x\ \left(492{,}5 - \frac{56{,}0386}{2}\right)$$

$$= 165{,}9339 \times 10^6\ Nmm = 165{,}933\ kNm$$

Ln = 9,6 m

Vg = 22,9789 kN (dari ETABS)

V_{2E}= 25,4954 kN (akibat beban 1,2*D* + 2,0*E* + 1,0*L)*

Vs ways = $\frac{(Mpr-) + (Mpr+)}{Ln} = \frac{165{,}9339 + 165{,}933}{9{,}6}$ = 34,2132 kN

Vu1 = Vs ways +Vg

= 34,2132 kN + 22,9789 kN

= 57,1921 kN

Vu2 = V_{2E}

= 25,4954 kN

Vu use = 57,1921 kN (gunakan nilai tegangan geser yang terbesar)

- Tulangan Transversal Tumpuan

Av $= 2 \times \frac{1}{4} \times \pi \times 8^2$ = 100,5309 mm^2

$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$= 0{,}17 \times 1 \times \sqrt{25} \times 300 \times 492{,}5$

= 125587,5 N

= 125,5875 kN (nilai Vc sudah lebih besar dari nilai Vu, maka digunakan spasi maks terkecil)

Smaks 1 = $\frac{d}{4} = \frac{492{,}5}{4}$ =123,125 mm

Smaks 2 = d.l x 8 = 19 x 8 = 152 mm

Smaks 3 = d.s x 24 = 8 x 24 = 192 mm

Smaks 4 = 300 mm

Digunakan spasi terkecil yaitu 123,125 mm = 100 mm

Maka digunakan tulangan 2d8-100

- Tulangan Transversal Lapangan

$Av = 2 \times \frac{1}{4} \times \pi \times 8^2$ = 100,5309 mm^2

Ve max = Vsways +Vg

= 34,2132 kN + 22,9789 kN

= 57,1921 kN

Ve min = Vg - Vsways

= 22,9789 kN – 34,2132 kN

= -11,2343 kN

Ve lapangan $= \frac{Ln-2h}{Ln}(Ve\ max - Ve\ min) + Ve\ min$

$= \frac{9,7 - 2(0,55)}{9,7}(57,1921 - (-11,2343)) + (-11,2343)$

= 49,4323 kN

$Vc = 0,17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$= 0,17 \times 1 \times \sqrt{25} \times 300 \times 492,5$

= 125587,5 N

= 125,5875 kN (nilai Vc sudah lebih besar dari nilai Vu, maka digunakan spasi maks terkecil)

Smaks 1 = $\frac{d}{4} = \frac{492,5}{4}$ =123,125 mm

Smaks 2 = d.l x 8 = 19 x 8 = 152 mm

Smaks 3 = d.s x 24 = 8 x 24 = 192 mm

Smaks 4 = 300 mm

Digunakan spasi terkecil yaitu 123,125 mm = 100 mm

Maka digunakan tulangan 2d8-100

5. Sloof

Desain Sloof (250 x450) mm

Mutu Baja longitudinal:	fy	= 420 MPa
Mutu Baja sengkang:	fys	= 280 MPa
Mutu Beton:	f'c	= 25 MPa

Ukuran Struktur:

b balok	= 250 mm
h balok	= 450 mm
selimut beton	= 40 mm
diameter tulangan pokok (d.l)	= 13 mm
diameter Sengkang (d.s)	= 8 mm

A. Pemeriksaan gaya tekan aksial terfaktor (SNI 2847:2019 pasal 18.4.2.6)

Pu = 0 kN-m (dari ETABS)

$$Ag \times \frac{f'c}{10} = (250 \times 450) \times \frac{25}{10}$$

= 281250 N

= 281,25 kN > Pu Aman!

B. Desain Tulangan Lentur

- Perencanaan Tulangan Tumpuan Atas

  Momen Ultimet (Mu) = 40,4504 kN-m (dari ETABS)

  Momen Nominal (Mn) = $\frac{Mu}{\emptyset} = \frac{40,4504}{0,9}$ = 44,94488 kN-m

  d' = cc + d.s + (d.l/2)

  = 40 + 8 + (13/2)

  = 54,5 mm

  Tinggi efektif (d) = h-d'

  = 450 – 54,5

  = 395,5 mm

Koefisien $(k) = \frac{Mn}{bd^2}$

$= \frac{44{,}94488 \text{ x } 10^6}{250\ x\ 395{,}5^2} = 1{,}149336$

$\rho = \frac{0{,}85xf'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\ F'c}}\right)$

$= \frac{0{,}85x25}{420}\left(1 - \sqrt{1 - \frac{2(1{,}149336)}{0{,}85x25}}\right)$

= 0,0028148

$\rho\text{maks} = 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy}$

$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{420}$

= 0,0184496

$\rho\text{min } 1 = \frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420} = 0{,}002976$

$\rho\text{min } 2 = \frac{1{,}4}{fy} = \frac{1{,}4}{420} = 0{,}00333$

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,0028148 x 250 x 395,5 = 278,3149 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$n = \frac{278{,}3149}{\frac{1}{4} \times \pi \times 13^2} = 2{,}09681 \approx 3\ buah$

As use = $3 \times \frac{1}{4} \times \pi \times 13^2$ = 398,19687 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{250-(2\times40)-(2\times8)-(3\times13)}{3-1}$ = 57,5 mm < 25 mm (Memenuhi!)

Analisis kapasitas momen

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

a $= \frac{398{,}19687 \times 420}{0{,}85 \times 25 \times 250}$ = 31,48097 mm

c $= \frac{a}{\beta_1} = \frac{31{,}48097}{0{,}85} = 37{,}036444$ mm

$$\varepsilon t = \frac{(d-c)}{c} \times 0{,}003$$

$$= \frac{(395{,}5 - 37{,}036444)}{37{,}036444} \times 0{,}003$$

$= 0{,}029036 > 0{,}005$, **Terkendali Tarik** Φ = 0,9

$$\Phi Mn = 0{,}9 \times As \times fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 398{,}19687 \times 420 \times \left(395{,}5 - \frac{31{,}48097}{2}\right)$$

$$= 57{,}1608 \times 10^6\ Nmm = 57{,}1608\ kNm$$

Φ *Mn* > Mu *Aman*!

Maka digunakan 3D19

- Perencanaan Tulangan Tumpuan Bawah

Momen Ultimet (Mu) = 16,326 kN-m (dari ETABS)

Momen Nominal (Mn) $= \frac{Mu}{\emptyset} = \frac{16{,}326}{0{,}9}$ = 18,14 kN-m

d’ = cc + d.s + (d.l/2)

= 40 + 8 + (13/2)

= 54,5 mm

Tinggi efektif (d) = h-d’

= 450 – 54,5

= 395,5 mm

Koefisien (k) $= \frac{Mn}{bd^2}$

$= \frac{18{,}14 \text{ x } 10^6}{250\ x\ 395{,}5^2} = 0{,}463878$

$\rho = \frac{0{,}85xf'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\ f'c}}\right)$

$= \frac{0{,}85x25}{420}\left(1 - \sqrt{1 - \frac{2(0{,}463878)}{0{,}85x25}}\right)$

= 0,0011168

$\rho maks = 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy}$

$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{420}$

= 0,0184496

$\rho min\ 1 = \frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420} = 0{,}002976$

$\rho min\ 2 = \frac{1{,}4}{fy} = \frac{1{,}4}{420} = 0{,}00333$

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,0011168 x 250 x 395,5 = 110,42344 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$n = \frac{110{,}42344}{\frac{1}{4} \times \pi \times 13^2} = 0{,}83192 \approx 2\ buah$

As use = $2 \times \frac{1}{4} \times \pi \times 13^2$ = 265,46458 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{250-(2\times40)-(2\times8)-(2\times13)}{2-1}$ = 128 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

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

a = $\frac{265{,}46458 \times 420}{0{,}85 \times 25 \times 250}$ = 20,9873 mm

c = $\frac{a}{\beta_1}$ = $\frac{20{,}9873}{0{,}85}$ = 24,69096 mm

$$\varepsilon t = \frac{(d-c)}{c} \times 0{,}003$$

$$= \frac{(395{,}5 - 24{,}69096)}{24{,}69096} \times 0{,}003$$

$= 0{,}045054 > 0{,}005$, **Terkendali Tarik** Φ = 0,9

$$\Phi Mn = 0{,}9\ x\ As\ x\ fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 265{,}46458\ x\ 420\ x\ \left(395{,}5 - \frac{20{,}9873}{2}\right)$$

$= 38{,}6333697 \times 10^6\ Nmm = 38{,}6333697\ kNm$

Φ *Mn* > Mu *Aman*!

Maka digunakan 2D13

- Perencanaan Tulangan Lapangan Atas

  Momen Ultimet (Mu) = 10,6349 kN-m (dari ETABS)

  Momen Nominal (Mn) = $\frac{Mu}{\emptyset}$ = $\frac{10{,}6349}{0{,}9}$ = 11.81655 kN-m

  d’ = cc + d.s + (d.l/2)

  = 40 + 8 + (13/2)

  = 54,5 mm

  Tinggi efektif (d) = h-d’

= 450 – 54,5

= 492,5 mm

Koefisien (k) $= \frac{Mn}{bd^2}$

$= \frac{11{,}81655 \text{ x } 10^6}{250\ x\ 395{,}5^2} = 0{,}30217$

$\rho = \frac{0{,}85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\ f'c}}\right)$

$= \frac{0{,}85x25}{420}\left(1 - \sqrt{1 - \frac{2(0{,}30217)}{0{,}85x25}}\right)$

= 0,0007246

$\rho maks = 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy}$

$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{420}$

= 0,0184496

$\rho min\ 1 = \frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420} = 0{,}002976$

$\rho min\ 2 = \frac{1{,}4}{fy} = \frac{1{,}4}{420} = 0{,}00333$

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,0007246 x 250 x 395,5 = 71,6500 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$n = \frac{71{,}6500}{\frac{1}{4} \times \pi \times 13^2} = 0{,}53981 \approx 2\ buah$

As use = $2 \times \frac{1}{4} \times \pi \times 13^2$ = 265,464 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{250-(2\times40)-(2\times8)-(2\times13)}{2-1}$ = 128 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

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

a = $\frac{265{,}464\times420}{0{,}85\times25\times250}$ = 20,9873 mm

c = $\frac{a}{\beta_1} = \frac{20{,}9873}{0{,}85}$ = 24,6909 mm

$$\varepsilon t = \frac{(d-c)}{c} \times 0{,}003$$

$$= \frac{(395{,}5 - 24{,}6909)}{24{,}6909} \times 0{,}003$$

$= 0{,}045054 > 0{,}005$, **Terkendali Tarik** Φ = 0,9

$$\Phi Mn = 0{,}9 \times As \times fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 265{,}464 \times 420 \times \left(395{,}5 - \frac{20{,}9873}{2}\right)$$

$= 38{,}633697 \times 10^6\ Nmm = 38{,}633697\ kNm$

Φ *Mn* > Mu *Aman*!

Maka digunakan 2D13

- Perencanaan Tulangan Lapangan Atas

  Momen Ultimet (Mu) = 15,9292 kN-m (dari ETABS)

  Momen Nominal (Mn) = $\frac{Mu}{\emptyset} = \frac{15{,}9292}{0{,}9}$ = 17,6991 kN-m

  d’ = cc + d.s + (d.l/2)

  = 40 + 8 + (13/2)

  = 54,5 mm

Tinggi efektif (d) = h-d'

= 450 – 54,5

= 395,5 mm

Koefisien (k) $= \frac{Mn}{bd^2}$

$= \frac{17,6991 \text{ x } 10^6}{250 \ x \ 395,5^2} = 0,45264$

$\rho = \frac{0,85xf'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0,85\ f'c}}\right)$

$= \frac{0,85x25}{420}\left(1 - \sqrt{1 - \frac{2(0,45264)}{0,85x25}}\right)$

= 0,0010893

$\rho maks = 0,429 \times \frac{0,85 \times f'c \times \beta_1}{fy}$

$= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420}$

= 0,0184496

$\rho min\ 1 = \frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420} = 0,002976$

$\rho min\ 2 = \frac{1,4}{fy} = \frac{1,4}{420} = 0,00333$

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,0010893 x 250 x 395,5 = 107,7101 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$n = \frac{107,7101}{\frac{1}{4} \times \pi \times 13^2} = 0,8114 \approx 2\ buah$

As use = $2 \times \frac{1}{4} \times \pi \times 13^2$ = 265,46458 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{250-(2\times40)-(2\times8)-(2\times13)}{2-1}$ = 128 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

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

$a = \frac{265{,}464 \times 420}{0{,}85 \times 25 \times 250}$ = 20,9873 mm

$c = \frac{a}{\beta_1} = \frac{20{,}9873}{0{,}85} = 24{,}6909$ mm

$$\varepsilon t = \frac{(d-c)}{c} \times 0{,}003$$

$$= \frac{(395{,}5 - 24{,}6909)}{24{,}6909} \times 0{,}003$$

$= 0{,}045054 > 0{,}005$, **Terkendali Tarik** $\Phi = 0{,}9$

$$Mn = 0{,}9\ x\ As\ x\ fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 265{,}464x\ 420\ x\ \left(395{,}5 - \frac{20{,}9873}{2}\right)$$

$$= 38633697 \times 10^6\ Nmm = 38{,}633697\ kNm$$

Φ *Mn* > Mu *Aman*!

Maka digunakan 2D13

- Perencanaan Tulangan Transversal

Menghitung nilai Mpr balok

$$Mpr^- = Ast \times 1 \times fy \times \left(d - \frac{a}{2}\right)$$

$$= 2 \times \frac{1}{4} \times \pi \times 16^2 \times 1 \times 420 \times \left(394 - \frac{31{,}7914}{2}\right)$$

$= 63858796{,}1 \times 10^6\ Nmm = 63{,}8588\ kNm$

$Mpr^+ = Ast \times 1 \times fy \times \left(d - \frac{a}{2}\right)$

$= 2 \times \frac{1}{4} \times \pi \times 16^2 \times x\ 420\ x\ \left(394 - \frac{31{,}7914}{2}\right)$

$= 63858796{,}1 \times 10^6\ Nmm = 63{,}8588\ kNm$

Ln = 9,6 m

Vg = 12,8415 kN (dari ETABS)

V_{2E}= 15,539 kN (akibat beban 1,2*D* + 2,0*E* + 1,0*L)*

Vs ways = $\frac{(Mpr-) + (Mpr+)}{Ln} = \frac{63{,}8588 + 63{,}8588}{9{,}6}$ = 13,0992 kN

Vu1 = Vs ways +Vg

= 13,0992 kN + 12,8415 kN

= 25,9407 kN

Vu2 = V_{2E}

= 15,539 kN

Vu use = 25,9407 kN (gunakan nilai tegangan geser yang terbesar)

- Tulangan Transversal Tumpuan

Av = $2 \times \frac{1}{4} \times \pi \times 8^2$ = 100,5309 mm^2

$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$= 0{,}17 \times 1 \times \sqrt{25} \times 250 \times 394$

= 83725 N = 83,725 kN (nilai Vc sudah lebih besar dari nilai Vu, maka digunakan nilai spasi maks terkecil)

Smaks 1 = $\frac{d}{4} = \frac{394}{4}$ = 98,5 mm

Smaks 2 = d.l x 8 = 16 x 8 = 128 mm

Smaks 3 = d.s x 24 = 8 x 24 = 192 mm

Smaks 4 = 300 mm

Digunakan spasi terkecil yaitu 98,5 mm = 50 mm

Maka digunakan tulangan 2d8-50

- Tulangan Transversal Lapangan

Av $= 2 \times \frac{1}{4} \times \pi \times 8^2$ = 100,5309 mm^2

Ve max= Vsways +Vg

= 13,0992 kN + 12,8415 kN

= 25,9407 kN

Ve min = Vg - Vsways

= 12,8415 kN – 13,0994 kN

= -0,2579 kN

Ve lapangan $= \frac{Ln-2h}{Ln}(Ve\ max - Ve\ min) + Ve\ min$

$= \frac{9{,}75 - 2(0{,}45)}{9{,}75}(25{,}9407 - (-0{,}2579)) + (-0{,}2579)$

= 23,5224 kN

$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$= 0{,}17 \times 1 \times \sqrt{25} \times 250 \times 394$

= 83,725 N

= 83,725 kN (nilai Vc sudah lebih besar dari nilai Vu, maka digunakan nilai spasi maks terkecil)

Smaks 1 = $\frac{d}{4} = \frac{394}{4}$ = 98,5 mm

Smaks 2 = d.l x 8 = 16 x 8 = 128 mm

Smaks 3 = d.s x 24 = 8 x 24 = 192 mm

Smaks 4 = 300 mm

Digunakan spasi terkecil yaitu 98,5 mm = 50 mm

Maka digunakan tulangan 2d8-50

6. Balok Lisplang

Desain Balok Lisplank (250x900) mm

Mutu Baja longitudinal: fy = 420 MPa

Mutu Baja sengkang: fys = 280 MPa

Mutu Beton: f'c = 25 MPa

Ukuran Struktur:

b balok = 250 mm

h balok = 600 mm

selimut beton = 40 mm

diameter tulangan pokok (d.l) = 16 mm

diameter Sengkang (d.s) = 8 mm

A. Pemeriksaan gaya tekan aksial terfaktor (SNI 2847:2019 pasal 18.4.2.6)

Pu = 0 kN-m (dari ETABS)

$$Ag \times \frac{f'c}{10} = (250 \times 600) \times \frac{25}{10}$$

= 375000 N

= 375 kN > Pu Aman!

B. Desain Tulangan Lentur

- Perencanaan Tulangan Tumpuan Atas

Momen Ultimet (Mu) = 239,0537 kN-m (dari ETABS)

Momen Nominal (Mn) = $\frac{Mu}{\emptyset} = \frac{239,0537}{0,9}$ = 265,61522 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 8 + (16/2)

= 56 mm

Tinggi efektif (d) = h-d'

= 600 – 56

= 544 mm

Koefisien (k) $= \frac{Mn}{bd^2}$

$= \frac{265{,}61522 \text{ x } 10^6}{250 \; x \; 544^2} = 3{,}5902$

$\rho = \frac{0{,}85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85 \, f'c}}\right)$

$= \frac{0{,}85x25}{420}\left(1 - \sqrt{1 - \frac{2(3{,}5902)}{0{,}85x25}}\right)$

= 0,0094

$\rho maks = 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy}$

$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{420}$

= 0,0184496

$\rho min \; 1 = \frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420} = 0{,}002976$

$\rho min \; 2 = \frac{1{,}4}{fy} = \frac{1{,}4}{420} = 0{,}00333$

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,0094x 250 x 544 = 1281,9474 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$n = \frac{1281{,}9474}{\frac{1}{4} \times \pi \times 16^2} = 6{,}3759 \approx 7 \; buah$

As use = $7 \times \frac{1}{4} \times \pi \times 16^2$ = 1407,4335 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{250-(2\times40)-(2\times8)-(7\times16)}{7-1}$ = 7 mm < 25 mm (Tidak Memenuhi!)

Oleh karena spasi antar tulangan tidak memenuhi, maka tulangan dibuat 2 baris dengan

baris pertama (n1) = 4 buah

baris kedua (n2) = 3 buah

Analisis kapasitas momen

Tinggi efektif = 526,4286 mm

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

a = $\frac{1407{,}433 \times 420}{0{,}85 \times 25 \times 250}$ = 111,27 mm

c = $\frac{a}{\beta_1}$ = $\frac{111{,}27}{0{,}85}$ = 130,9059 mm

$\varepsilon t = \frac{(d-c)}{c} \times 0{,}003$

$= \frac{(526{,}4286 - 130{,}9059)}{130{,}9059} \times 0{,}003$

$= 0{,}00906 > 0{,}005$, **Terkendali Tarik** Φ = 0,9

$\Phi Mn = 0{,}9\ x\ As\ x\ fy \times \left(d - \frac{a}{2}\right)$

$= 0{,}9 \times 1407{,}4335\ x\ 420\ x\ \left(526{,}4286 - \frac{111{,}27}{2}\right)$

$= 250{,}4668 \times 10^6\ Nmm = 250{,}4668\ kNm$

Φ *Mn* > Mu *Aman*!

Maka digunakan 7D16

- Perencanaan Tulangan Tumpuan Bawah

Momen Ultimet (Mu) = 182,0667 kN-m (dari ETABS)

Momen Nominal (Mn) = $\frac{Mu}{\emptyset} = \frac{182,0667}{0,9}$ = 202,29633 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 8 + (16/2)

= 56 mm

Tinggi efektif (d) = h-d'

= 600 – 56

= 544 mm

Koefisien $(k) = \frac{Mn}{bd^2}$

$= \frac{202,29633 \text{ x } 10^6}{250 \text{ x } 544^2} = 2,7343$

$\rho = \frac{0,85xf'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0,85\ f'c}}\right)$

$= \frac{0,85x25}{420}\left(1 - \sqrt{1 - \frac{2(2,7343)}{0,85x25}}\right)$

= 0,00699

$\rho maks = 0,429 \times \frac{0,85 \times f'c \times \beta_1}{fy}$

$= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420}$

= 0,0184496

ρmin 1 = $\frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420}$ = 0,002976

ρmin 2 = $\frac{1,4}{fy} = \frac{1,4}{420}$ = 0,00333

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,00699x 250 x 544 = 951,1373 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{951{,}1373}{\frac{1}{4} \times \pi \times 16^2} = 4{,}7305 \approx 5\ buah$$

As use = $5 \times \frac{1}{4} \times \pi \times 16^2$ = 1005,3096 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{250-(2\times40)-(2\times8)-(5\times16)}{5-1}$ = 18,5 mm < 25 mm (Tidak Memenuhi!)

Oleh karena spasi antar tulangan tidak memenuhi, maka tulangan dibuat 2 baris dengan

baris pertama (n1) = 4 buah

baris kedua (n2) = 1 buah

Analisis kapasitas momen

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

a $= \frac{1005{,}3096 \times 420}{0{,}85 \times 25 \times 250}$ = 79,4786 mm

c $= \frac{a}{\beta_1} = \frac{79{,}4786}{0{,}85} = 93{,}5042$ mm

$$\varepsilon t = \frac{(d-c)}{c} \times 0{,}003$$

$$= \frac{(535{,}8 - 93{,}5042)}{93{,}5042} \times 0{,}003$$

$= 0{,}01412 > 0{,}005$, **Terkendali Tarik** $\Phi = 0{,}9$

$$\Phi Mn = 0{,}9\ x\ As\ x\ fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 1005{,}3096 \; x\, 420\, x \left(535{,}8 - \frac{79{,}4786}{2}\right)$$

$$= 188{,}5065 \times 10^6\, Nmm = 188{,}5065\, kNm$$

Φ *Mn* > Mu *Aman*!

Maka digunakan 3D16

- Perencanaan Tulangan Lapangan Atas

Momen Ultimet (Mu) = 100,4865 kN-m (dari ETABS)

Momen Nominal (Mn) = $\frac{Mu}{\emptyset} = \frac{100{,}4865}{0{,}9}$ = 111,65167 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 10 + (16/2)

= 56 mm

Tinggi efektif (d) = h-d'

= 600 – 56

= 544 mm

Koefisien (k) $= \frac{Mn}{bd^2}$

$$= \frac{111{,}65167 \text{ x } 10^6}{250\, x\, 544^2} = 1{,}5091$$

$$\rho = \frac{0{,}85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\, f'c}}\right)$$

$$= \frac{0{,}85 x 25}{420}\left(1 - \sqrt{1 - \frac{2(1{,}5091)}{0{,}85 x 25}}\right)$$

= 0,003731

$$\rho\text{maks} = 0{,}429 \times \frac{0{,}85 \times f'c \times \beta_1}{fy}$$

$$= 0{,}429 \times \frac{0{,}85 \times 25 \times 0{,}85}{420}$$

= 0,0184496

ρmin 1 = $\frac{\sqrt{f'c}}{4\times fy} = \frac{\sqrt{25}}{4\times 420}$ = 0,002976

ρmin 2 = $\frac{1,4}{fy} = \frac{1,4}{420}$ = 0,00333

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,003731 x 250 x 544 = 507,3776 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{507,3776}{\frac{1}{4}\times \pi \times 16^2} = 2,5235 \approx 3\ buah$$

As use = $3 \times \frac{1}{4} \times \pi \times 16^2$ = 603,1858 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{250-(2\times 40)-(2\times 8)-(3\times 16)}{3-1}$ = 53 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

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

a = $\frac{603,1858 \times 420}{0,85 \times 16 \times 250}$ = 47,6872 mm

c = $\frac{a}{\beta_1} = \frac{47,6872}{0,85}$ = 56,1025 mm

$$\varepsilon t = \frac{(d-c)}{c} \times 0,003$$

$$= \frac{(544 - 56,1025)}{56,1025} \times 0,003$$

= 0,026089 > 0,005 , **Terkendali Tarik** Φ = 0,9

$$\Phi Mn = 0{,}9\ x\ As\ x\ Fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9\ \times 603{,}1858\ \ x\ 420\ x\ \left(844 - \frac{47{,}6872}{2}\right)$$

$$= 118{,}5978\ \times 10^6\ Nmm = 118{,}5978\ kNm$$

Φ *Mn* > Mu *Aman*!

Maka digunakan 3D16

- Perencanaan Tulangan Lapangan Atas

Momen Ultimet (Mu) = 137,58 kN-m (dari ETABS)

Momen Nominal (Mn) = $\frac{Mu}{\emptyset} = \frac{157{,}58}{0{,}9}$ = 152,86667 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 8 + (16/2)

= 56 mm

Tinggi efektif (d) = h-d'

= 500 – 56

= 544 mm

Koefisien (k) $= \frac{Mn}{bd^2}$

$= \frac{152{,}86667\ \text{x}\ 10^6}{250\ x\ 544^2} = 2{,}0662$

$$\rho = \frac{0{,}85 \times f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85 \times f'c}}\right)$$

$$= \frac{0{,}85 \times 25}{420}\left(1 - \sqrt{1 - \frac{2(2{,}0662)}{0{,}85 \times 25}}\right)$$

= 0,005185

$$\rho\text{maks} = 0{,}429\ \times \frac{0{,}85\ \times f'c\ \times \beta_1}{fy}$$

$$= 0{,}429\ \times \frac{0{,}85\ \times 25\ \times 0{,}85}{420}$$

= 0,0184496

ρmin 1 = $\frac{\sqrt{f'c}}{4\times fy} = \frac{\sqrt{25}}{4\times 420}$ = 0,002976

ρmin 2 = $\frac{1,4}{fy} = \frac{1,4}{420}$ = 0,00333

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,005185 x 250 x 644 = 705,1953 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{705,1953\ 1}{\frac{1}{4}\times\pi\times 16^2} = 3,5073 \approx 4\ buah$$

As use = $4 \times \frac{1}{4}\times\pi\times 16^2$ = 804,2477 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{250-(2\times40)-(2\times8)-(4\times16)}{4-1}$ = 30 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

a = $\frac{As\times Fy}{0,85\times f'c\times b}$

a = $\frac{804,2477\ \times 420}{0,85\times 25\times 250}$ = 63,2477 mm

c = $\frac{a}{\beta_1} = \frac{63,2477}{0,85}$ = 74,8034 mm

$$\varepsilon t = \frac{(d-c)}{c}\times 0,003$$

$$= \frac{(544\ -74,8034\ )}{74,8034}\ \times 0,003$$

$= 0{,}01882 > 0{,}005$, **Terkendali Tarik** $\Phi = 0{,}9$

$$\Phi Mn = 0{,}9 \times As \times Fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 804{,}2477 \times 420 \times \left(544 - \frac{63{,}2477}{2}\right)$$

$$= 155{,}7142 \times 10^6\ Nmm = 155{,}7142\ kNm$$

Φ *Mn* > Mu *Aman*!

Maka digunakan 4D16

- Perencanaan Tulangan Transversal

Vu Tumpuan = 102.5 kN

Vu Lapangan = 74.1718 kN

1. Tulangan Transversal Tumpuan

$Av = 2 \times \frac{1}{4} \times \pi \times 8^2$ = 100,531 mm^2

$$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times bw \times d$$

$$= 0{,}17 \times 1 \times \sqrt{25} \times 250 \times 544$$

= 115600 N

= 115,600 kN

Vs $= \frac{Vu}{\emptyset} - Vc$

$= \frac{102{,}4521}{0{,}75} - 115{,}600$

= 21,0028 kN

Memeriksa batasan dimensi penampang

Vs $< 0{,}66 \times \sqrt{f'c} \times bw \times d$

21,0028 $< 0{,}66 \times \sqrt{25} \times 250 \times 544$

21,0028 < 448,800 kN (Aman!)

Spasi $= \frac{Av \times fy \times d}{Vs}$

$= \frac{100,531 \times 280 \times 544}{21,00282 \times 10^3}$ = 729,0873 mm

Smaks 1 = $\frac{d}{2} = \frac{544}{2}$ =272 mm

Smaks 2 = 600 mm

Digunakan spasi terkecil yaitu 272 mm = 250 mm

Maka digunakan tulangan 2d8-250

- Tulangan Transversal Lapangan

Av $= 2 \times \frac{1}{4} \times \pi \times 8^2$ = 100,531 mm^2

$Vc = 0,17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$= 0,17 \times 1 \times \sqrt{25} \times 250 \times 544$

= 111866,1 N

= 111,8661 kN (nilai Vc sudah lebih besar dari nilai Vu, maka digunakan nilai spasi maks terkecil)

Smaks 1 = $\frac{d}{2} = \frac{544}{2}$ =272 mm

Smaks 2 = 600 mm

Digunakan spasi terkecil yaitu 272 mm = 250 mm

Maka digunakan tulangan 2d8-250

7. Balok Kantilever

Desain Balok Kantilever (400x600) mm

Mutu Baja longitudinal: fy = 420 MPa

Mutu Baja sengkang: fys = 280 MPa

Mutu Beton: f'c = 25 MPa

Ukuran Struktur:

b balok = 400 mm

h balok = 600 mm

selimut beton = 40 mm

diameter tulangan pokok (d.l) = 25 mm

diameter Sengkang (d.s) = 12 mm

C. Pemeriksaan gaya tekan aksial terfaktor (SNI 2847:2019 pasal 18.4.2.6)

Pu = 0 kN-m (dari ETABS)

$$Ag \times \frac{f'c}{10} = (400 \times 600) \times \frac{25}{10}$$

= 600.000 N

= 600 kN > Pu Aman!

D. Desain Tulangan Lentur

- Perencanaan Tulangan Tumpuan Atas

Momen Ultimet (Mu) = 177,6695 kN-m (dari ETABS)

Momen Nominal (Mn) = $\frac{Mu}{\emptyset} = \frac{177,6695}{0,9}$ =197,4105 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 12 + (25/2)

= 64,5 mm

Tinggi efektif (d) = h-d'

= 600 – 64,5

= 535,5 mm

Koefisien $(k) = \frac{Mn}{bd^2}$

$= \frac{197,4105 \text{ x } 10^6}{400 \, x \, 535,5^2} = 1,72104$

$$\rho = \frac{0,85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0,85\, f'c}}\right)$$

$= \frac{0,85x25}{420}\left(1-\sqrt{1-\frac{2(1,72104)}{0,85x25}}\right)$

= 0,004278

$$\rho maks = 0,429 \times \frac{0,85 \times f'c \times \beta_1}{fy}$$

$$= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420}$$

= 0,0184496

ρmin 1 = $\frac{\sqrt{f'c}}{4\times fy} = \frac{\sqrt{25}}{4\times 420}$ = 0,002976

ρmin 2 = $\frac{1,4}{fy} = \frac{1,4}{420}$ = 0,00333

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,004278 x 400 x 535,5 = 916,4829 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{916,4829}{\frac{1}{4}\times\pi\times 25^2} = 1,86704 \approx 2\ buah$$

As use = $2\times\frac{1}{4}\times\pi\times 25^2$ = 981,7477 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n-1}$$

$= \frac{400-(2\times40)-(2\times12)-(2\times25)}{2-1}$ = 246 mm > 29 mm (Memenuhi!)

Analisis kapasitas momen

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

a = $\frac{981,7477 \times 420}{0,85 \times 25 \times 400}$ = 48,50989 mm

c = $\frac{a}{\beta_1}$ = $\frac{48,50989}{0,85}$ = 57,0704 mm

$$\varepsilon t = \frac{(d-c)}{c} \times 0,003$$

$$= \frac{(535,5 - 57,0704)}{57,0704} \times 0,003$$

$= 0,0050021$ **Terkendali Tarik** $\Phi = 0,9$

$$\Phi Mn = 0,9 \times As \times fy \times \left(d - \frac{a}{2}\right)$$

$$= 0,9 \times 981,7477 \times 420 \times \left(535,5 - \frac{48,50989}{2}\right)$$

$$= 189,7233 \times 10^6\ Nmm = 189,7233\ kNm$$

Φ *Mn* > Mu *Aman!*

Maka digunakan 2D25

- Perencanaan Tulangan Tumpuan Bawah

Momen Ultimet (Mu) = 224,367 kN-m (dari ETABS)

Momen Nominal (Mn) = $\frac{Mu}{\emptyset}$ = $\frac{224,367}{0,9}$ = 249,29667 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 12 + (25/2)

= 64,5 mm

Tinggi efektif (d) = h-d'

= 600 – 64,5

= 535,5 mm

Koefisien (k) = $\frac{Mn}{bd^2}$

$$= \frac{249,29667 \text{ x } 10^6}{400\ x\ 535,5^2} = 2,1734$$

$$\rho = \frac{0,85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0,85\ f'c}}\right)$$

$= \frac{0,85x25}{420}\left(1 - \sqrt{1 - \frac{2(2,1734)}{0,85x25}}\right)$

= 0,00547

$$\rho maks = 0,429 \times \frac{0,85 \times f'c \times \beta_1}{fy}$$

$$= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420}$$

= 0,0184496

ρmin 1 = $\frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420}$ = 0,002976

ρmin 2 = $\frac{1,4}{fy} = \frac{1,4}{420}$ = 0,00333

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,00547 x 400 x 535,5 = 1171,7761 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{1171,7761}{\frac{1}{4} \times \pi \times 25^2} = 2,3871 \approx 3 \; buah$$

As use = $3 \times \frac{1}{4} \times \pi \times 25^2$ = 1472,6216 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n - 1}$$

$= \frac{400-(2\times40)-(2\times12)-(3\times25)}{3-1}$ = 110,5 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

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

a = $\frac{1472{,}6216 \times 420}{0{,}85 \times 25 \times 400}$ = 72,7648 mm

c = $\frac{a}{\beta_1}$ =$\frac{72{,}7648}{0{,}85}$ = 85,6057 mm

$$\varepsilon t = \frac{(d-c)}{c} \times 0{,}003$$

$$= \frac{(535{,}5 - 85{,}6057)}{85{,}6057} \times 0{,}003$$

$= 0{,}015766 > 0{,}005$, **Terkendali Tarik** Φ = 0,9

$$\Phi Mn = 0{,}9 \times As \times fy \times \left(d - \frac{a}{2}\right)$$

$$= 0{,}9 \times 1472{,}6216 \times 420 \times \left(535{,}5 - \frac{72{,}7648}{2}\right)$$

$$= 277{,}834277 \times 10^6\ Nmm = 277{,}834277\ kNm$$

Φ *Mn* > Mu *Aman!*

Maka digunakan 3D25

- Perencanaan Tulangan Lapangan Atas

Momen Ultimet (Mu) = 177,6695 kN-m (dari ETABS)

Momen Nominal (Mn) = $\frac{Mu}{\emptyset}$ = $\frac{177{,}6695}{0{,}9}$ = 197,4105 kN-m

d’ = cc + d.s + (d.l/2)

= 40 + 12 + (25/2)

= 64,5 mm

Tinggi efektif (d) = h-d’

= 600 – 64,5

= 535,5 mm

Koefisien (k) = $\frac{Mn}{bd^2}$

$$= \frac{197{,}4105 \times 10^6}{400 \times 535{,}5^2} = 1{,}72104$$

$$\rho = \frac{0{,}85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0{,}85\ f'c}}\right)$$

$= \frac{0,85x25}{420}\left(1 - \sqrt{1 - \frac{2(1,72104)}{0,85x25}}\right)$

= 0,004278

$$\rho maks = 0,429 \times \frac{0,85 \times f'c \times \beta_1}{fy}$$

$$= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420}$$

= 0,0184496

ρmin 1 = $\frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420}$ = 0,002976

ρmin 2 = $\frac{1,4}{fy} = \frac{1,4}{420}$ = 0,00333

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,004278 x 400 x 535,5 = 916,4829 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{916,4829}{\frac{1}{4} \times \pi \times 25^2} = 1,86704 \approx 2 \; buah$$

As use = $2 \times \frac{1}{4} \times \pi \times 25^2$ = 981,7477 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n - 1}$$

$= \frac{400-(2\times40)-(2\times12)-(2\times25)}{2-1}$ = 246 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

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

a = $\frac{981,7477 \times 420}{0,85 \times 25 \times 400}$ = 48,50989 mm

c = $\frac{a}{\beta_1}$ =$\frac{48,50989}{0,85}$ = 57,0704 mm

$$\varepsilon t = \frac{(d-c)}{c} \times 0,003$$

$$= \frac{(535,5 - 57,0704)}{57,0704} \times 0,003$$

$= 0,0161 > 0,005$, **Terkendali Tarik** Φ = 0,9

$$\Phi Mn = 0,9 \times As \times fy \times \left(d - \frac{a}{2}\right)$$

$$= 0,9 \times 981,7477 \times 420 \times \left(535,5 - \frac{48,50989}{2}\right)$$

$$= 189,7233 \times 10^6 \, Nmm = 189,7233 \, kNm$$

Φ *Mn* > Mu *Aman!*

Maka digunakan 2D25

- Perencanaan Tulangan Lapangan Atas

Momen Ultimet (Mu) = 224,367 kN-m (dari ETABS)

Momen Nominal (Mn) = $\frac{Mu}{\emptyset}$ = $\frac{224,367}{0,9}$ = 249,2967 kN-m

d' = cc + d.s + (d.l/2)

= 40 + 12 + (25/2)

= 64,5 mm

Tinggi efektif (d) = h-d'

= 600 – 64,5

= 535,5 mm

Koefisien $(k) = \frac{Mn}{bd^2}$

$$= \frac{249,2967 \text{ x } 10^6}{400 \, x \, 535,5^2} = 2,1734$$

$$\rho = \frac{0,85 x f'c}{fy}\left(1 - \sqrt{1 - \frac{2k}{0,85 \, f'c}}\right)$$

$= \frac{0,85x25}{420}\left(1 - \sqrt{1 - \frac{2(2,1734)}{0,85x25}}\right)$

= 0,00547

$$\rho maks = 0,429 \times \frac{0,85 \times f'c \times \beta_1}{fy}$$

$$= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420}$$

= 0,0184496

ρmin 1 = $\frac{\sqrt{f'c}}{4 \times fy} = \frac{\sqrt{25}}{4 \times 420}$ = 0,002976

ρmin 2 = $\frac{1,4}{fy} = \frac{1,4}{420}$ = 0,00333

ρmin use = 0,00333 (terbesar)

ρmin < ρ < ρmaks (Aman!)

As = ρ x b x d

= 0,00547 x 400 x 535,5 = 1171,7762 mm^2

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{1171,7762}{\frac{1}{4} \times \pi \times 25^2} = 2,38712 \approx 3 \; buah$$

As use = $3 \times \frac{1}{4} \times \pi \times 25^2$ = 1472,6216 mm^2

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n\,D_{tul}}{n - 1}$$

$= \frac{400-(2\times40)-(2\times12)-(3\times25)}{3-1}$ = 110,5 mm > 25 mm (Memenuhi!)

Analisis kapasitas momen

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

a = $\frac{1472,6216 \times 420}{0,85 \times 25 \times 400}$ = 72,7648 mm

c = $\frac{a}{\beta_1}$ = $\frac{72,7648}{0,85}$ = 85,6057 mm

$$\varepsilon t = \frac{(d-c)}{c} \times 0,003$$

$$= \frac{(535,5 - 85,6057)}{85,6057} \times 0,003$$

$= 0,015766 > 0,005$, **Terkendali Tarik** Φ = 0,9

$$\Phi Mn = 0,9 \times As \times fy \times \left(d - \frac{a}{2}\right)$$

$$= 0,9 \times 1472,6216 \times 420 \times \left(535,5 - \frac{72,7648}{2}\right)$$

$$= 277834277 \times 10^6\ Nmm = 277,834277\ kNm$$

Φ *Mn* > Mu *Aman*!

Maka digunakan 3D25

- Perencanaan Tulangan Transversal

Menghitung nilai Mpr balok

$$Mpr^- = Ast \times 1 \times fy \times \left(d - \frac{a}{2}\right)$$

$$= 2 \times \frac{1}{4} \times \pi \times 25^2 \times 1 \times 420 \times \left(535,5 - \frac{48,50988}{2}\right)$$

$$= 210,8037 \times 10^6\ Nmm = 210,8037\ kNm$$

$$Mpr^+ = Ast \times 1 \times fy \times \left(d - \frac{a}{2}\right)$$

$$= 3 \times \frac{1}{4} \times \pi \times 25^2 \times x\ 420\ x\ \left(535,5 - \frac{72,7648}{2}\right)$$

$$= 308,70475 \times 10^6\ Nmm = 308,70475\ kNm$$

Ln = 9,6 m

Vg = 146,1674 kN (dari ETABS)

V_{2E} = 146,7416 kN (akibat beban 1,2*D* + 2,0*E* + 1,0*L)*

Vs ways $= \frac{(Mpr-) + (Mpr+)}{Ln} = \frac{210,8037 + 308,70475}{9,6} = 54,1155$ kN

Vu1 = Vs ways +Vg

= 54,1155 kN + 146,1674 kN

= 200,2829 kN

Vu2 = V_{2E}

= 146,7416 kN

Vu use = 200,2829 kN (gunakan nilai tegangan geser yang terbesar)

- Tulangan Transversal Tumpuan

Av $= 2 \times \frac{1}{4} \times \pi \times 12^2$ = 226,19467 mm^2

$Vc = 0,17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$= 0,17 \times 1 \times \sqrt{25} \times 400 \times 535,5$

= 182070 N

= 182,070 kN

Vs $= \frac{Vu}{\emptyset} - Vc$

$= \frac{200,2829}{0,75} - 182,070$

= 84,9738 kN

Memeriksa batasan dimensi penampang

Vs $< 0,66 \times \sqrt{f'c} \times bw \times d$

71,3764 $< 0,66 \times \sqrt{25} \times 400 \times 545,5$

71,3764 $< 706,86\ kN$ (Aman!)

Spasi $= \frac{Av \times fy \times d}{Vs}$

$= \frac{226{,}19467 \times 280 \times 525{,}5}{84{,}9738 \times 10^3}$ = 399,1303 mm

Smaks 1 = $\frac{d}{4} = \frac{535{,}5}{4}$ =133,875 mm

Smaks 2 = d.l x 8 = 25 x 8 = 200 mm

Smaks 3 = d.s x 24 = 12 x 24 = 288 mm

Smaks 4 = 300 mm

Digunakan spasi terkecil yaitu 133,875 mm = 100 mm

Maka digunakan tulangan 2d12-100

- Tulangan Transversal Lapangan

Av $= 2 \times \frac{1}{4} \times \pi \times 12^2$ = 226,19467 mm^2

Ve max = Vsways +Vg

= 54,1155 kN + 146,9174 kN

= 201,0329 kN

Ve min = Vg - Vsways

= 146,1674 kN - 54,1155 kN

= 92,8019 kN

Ve lapangan $= \frac{Ln-2h}{Ln}(Ve\ max - Ve\ min) + Ve\ min$

$= \frac{9{,}6 - 2(0{,}6)}{9{,}6}(201{,}0329 - 92{,}8019) + 92{,}8019$

= 186,754 kN

$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$= 0{,}17 \times 1 \times \sqrt{25} \times 400 \times 535{,}5$

= 182070 N

= 182,070 kN

Vs $= \frac{Vu}{\emptyset} - Vc$

$= \frac{186,754}{0,75} - 182,070$

= 66,9353 kN

Spasi $= \frac{Av \times fy \times d}{Vs}$

$= \frac{226,19467 \times 280 \times 535,5}{66,9353 \times 10^3}$ = 506,6925 mm

Smaks 1 = $\frac{d}{4} = \frac{535,5}{4}$ = 133,875 mm

Smaks 2 = d.l x 8 = 25 x 8 = 200 mm

Smaks 3 = d.s x 24 = 12 x 24 = 288 mm

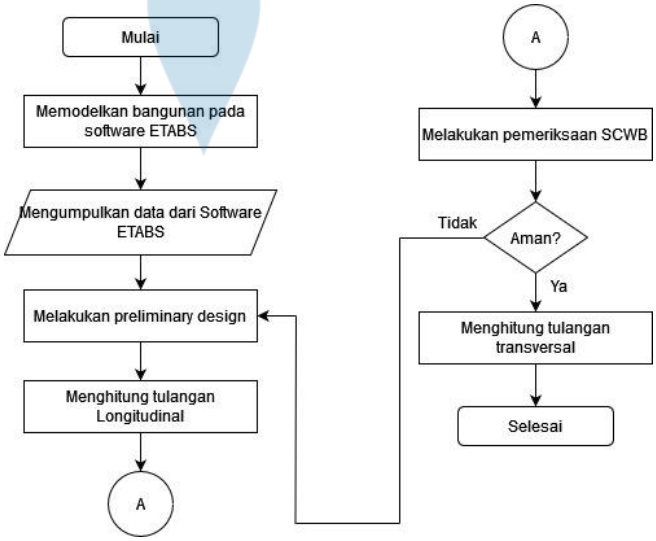
Smaks 4 = 300 mm

Digunakan spasi terkecil yaitu 133,875 mm = 100 mm

Maka digunakan tulangan 2d12-100

2.5. Perancangan Kolom

Perancangan terakhir adalah perancangan kolom. Pada perancangan kolom, kolom dimodelkan pada software ETABS. Setelah itu dilakukakan dilakukan analisis perliminary design untuk kolom dinyatakan aman atau tidak. Setelah itu dilakukan perhitungan tulangan transversal. Untuk urutan pekerjaannya dapat dilihat pada flowchart di gambar 2.24



Gambar 2.24 *Flowchart* Perancangan Kolom

2.5.1 Perancangan kolom Tipe 1

Diameter = 900 mm

Selimut beton (cc) = 40 mm

Diameter tulangan utama (d.l) = 25 mm

Diameter tulangan sengkang (d.s) = 13 mm

A. Perencanaan tulangan Longitudinal

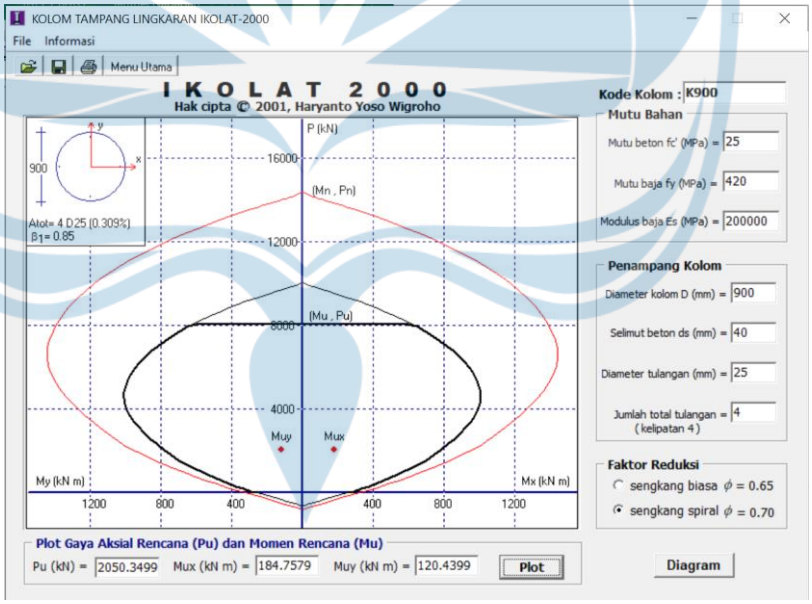
Mu2 = 120,4399 kNm (dari ETABS)

Mu3 = 184,7579 kNm (dari ETABS)

Mpr_{kiri} = 1221,798 kNm

Mpr_{kanan} = 928,6286 kNm

Diagram interaksi kolom jika menggunakan tulangan 4D25



Gambar 2.25 Nilai Mu2 dan Mu3 pada diagram interaksi kolom Tipe 1

Pada gambar 2.25 menunjukkan nilai Mu2 dan Mu3 untuk interaksi kolom Tipe 1Kolom harus memenuhi persyaratan Strong Coloum-Weak Beam (SCWB) berikut:

$1{,}2\ (Mpr_{kiri} + Mpr_{kanan}) \leq (Mnca + Mncb)$

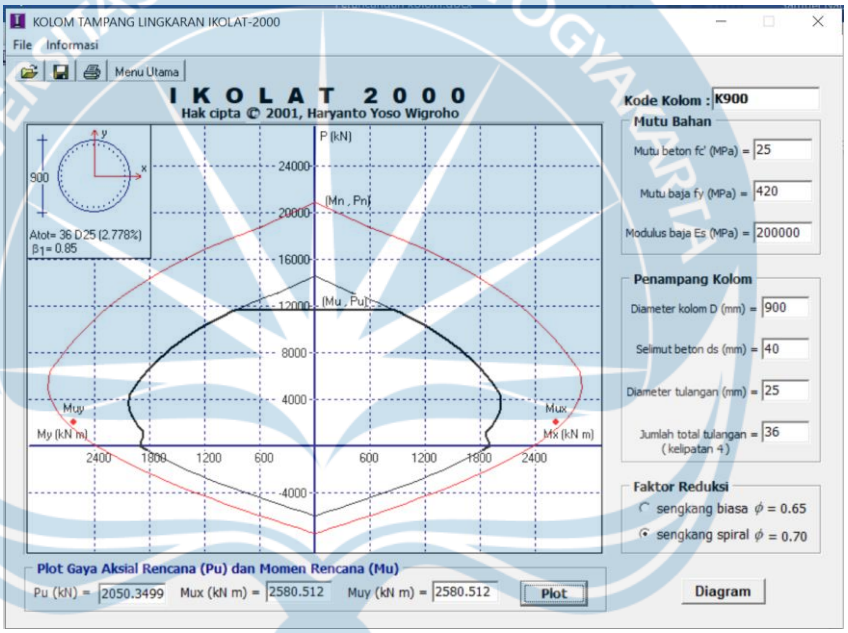
Dari diagram diatas dapat diketahui bahwa nilai Mncb adalah sebesar 950 kNm

1,2 (1221,798 + 928,6286) ≤ (0 + 950)

2580,512 kNm ≥ 950 (Tidak Aman!)

Oleh karena Kolom masih belum aman terhadap SCWB, maka perlu dilakukan penambahan tulangan agar nilai momen nominal kolom lebih besar dari 1,2 momen nominal balok.

Digunakan tulangan 36D25



Gambar 2.26 Nilai Mnc pada diagram interaksi kolom Tipe 1

Pada gambar 2.26 Diagram IKOLAT diatas, didapatkan nilai Mncb sebesar 2650 kNm > 2580,512 kNm (sudah memenuhi SCWB). Maka kolom tipe 1 menggunakan tulangan 36D25

B. Perencanaan Tulangan Transversal

- Tukangan Transversal daerah Lo

$$Ag = \frac{1}{4} \times \pi \times 900^2 = 636172{,}5\ mm^2$$

$$Ach = \frac{1}{4} \times \pi \times (900 - (2 \times 40))^2 = 528101{,}7\ mm^2$$

Rasio Volumetrik tulangan spiral

ρs min $= 0{,}45\left(\frac{Ag}{Ach} - 1\right)\frac{F'c}{Fyt}$

$= 0{,}45\left(\frac{636172{,}5}{528101{,}7} - 1\right)\frac{25}{420} = 0{,}005481$

Smaks 1 $= \frac{\text{Ast}}{\text{bc x ρs min}}$

$= \frac{2 \times \frac{1}{4} \times \pi \times 13^2}{(900 - 2(40)) \times 0{,}005481}$

$= 59{,}0607$ mm

Smaks 2 = d.l x 8 = 25 x 8 = 200 mm

Smaks 3 = d.s x 24 = 13 x 24 = 312 mm

Smaks 4 = 0,5 x 900 = 450 mm

Smaks 5 = 300 mm

Digunakan Smaks terkecil yaitu 59,0607 mm

Ve1 $= \frac{\Sigma M\ prb\ atas \times DF\ atas + \Sigma M\ prb\ bawah \times DF\ bawah}{4{,}5}$

$= \frac{(1221{,}798 + 928{,}6286) \times 0{,}5 + (1221{,}798 + 928{,}6286) \times 0{,}5}{4{,}5}$

$= 573{,}4471$ kN

Ve2 = 56,6519 kN (dari ETABS)

Digunakan Ve terbesar, yaitu 573,4471 kN

$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$= 0{,}17 \times 1 \times \sqrt{25} \times 621226$ -> 621226 adalah luas efektif kolom

= 528042 N

= 528,042 kN

Vs $= \frac{Vu}{\emptyset} - Vc$

$= \frac{573,4471}{0,75} - 528,042$

= 236,554 kN

Spasi $= \frac{Av \times fy \times d}{Vs}$

$= \frac{132,7323 \times 420 \times 834,5}{236,554 \times 10^3}$

= 196,6627 mm

Oleh karena nilai spasi lebih besar dari spasi maks, maka digunakan nilai spasi maks yaitu sebesar 59,0607 mm atau dibulatkan menjadi 50 mm.

Tulangan transversal yang digunakan D13-50

- Tulangan Transversal diluar Lo

$Vc = 0,17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$= 0,17 \times 1 \times \sqrt{25} \times 621226$ -> 621226 adalah luas efektif kolom

= 528042 N

= 528,042 kN

Vs $= \frac{Vu}{\phi} - Vc$

$= \frac{573,4471}{0,75} - 528,042$

= 236,554 kN

Spasi $= \frac{Av \times fy \times d}{Vs}$

$= \frac{132,7323 \times 420 \times 834,5}{236,554 \times 10^3}$

= 196,6627 mm

Tulangan transversal yang digunakan D13-150

2.5.2 Perancangan kolom Tipe 2

Diameter = 750 mm

Selimut beton (cc) = 40 mm

Diameter tulangan utama (d.l) = 25 mm

Diameter tulangan sengkang (d.s) = 13 mm

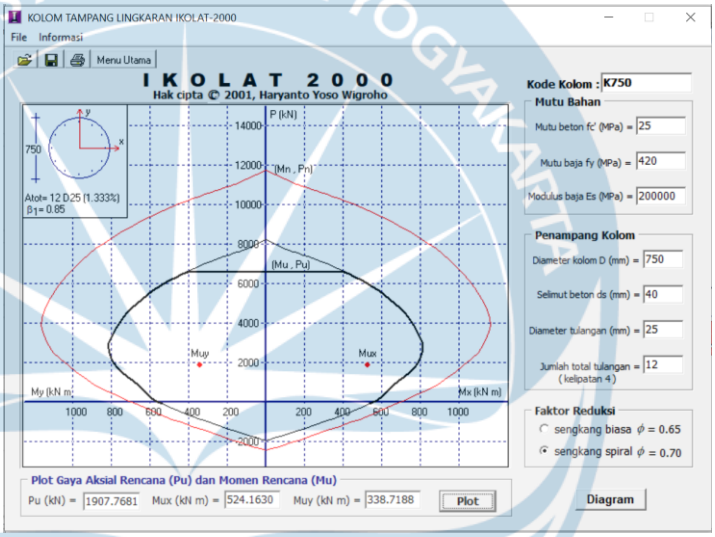
A. Perencanaan tulangan Longitudinal

- Momen kolom bawah

  Mu_2= 338,7188 kNm (dari ETABS)

  Mu_3= 524,1630 kNm (dari ETABS)

  Diagram interaksi kolom jika menggunakan tulangan 12D25



Gambar 2.27 Nilai Mu2 dan Mu3 kolom bawah pada diagram interaksi kolom Tipe 2

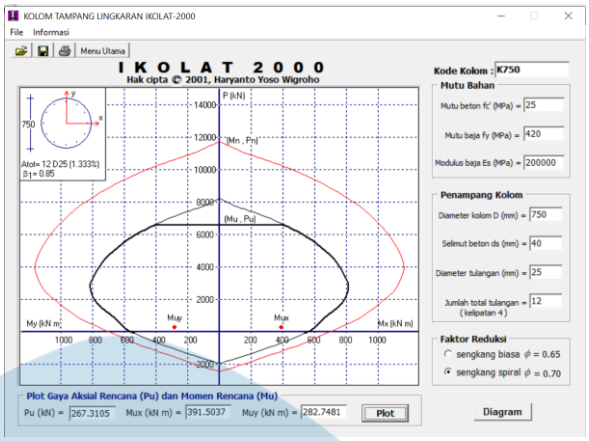
Pada gambar 2.27 menunjukkan nilai Mu2 dan Mu3 untuk interaksi kolom Tipe 2

- Momen kolom atas

  Mu_2 = 282,7481 kNm (dari ETABS)

  Mu_3 = 391,5037 kNm (dari ETABS)

  Diagram interaksi kolom jika menggunakan tulangan 12D25



Gambar 2.28 Nilai Mu2 dan Mu3 kolom atas pada diagram interaksi kolom Tipe 2

Pada gambar 2.28 menunjukkan nilai Mu2 dan Mu3 kolom atas pada diagaram interaksi kolom Tipe 1.Kolom harus memenuhi persyaratan Strong Coloum-Weak Beam (SCWB) berikut:

$1{,}2\ (Mpr_{kiri} + Mpr_{kanan}) \leq (Mnca + Mncb)$

Dari diagram diatas dapat diketahui bahwa nilai Mnca adalah sebesar 710 kNm dan Mncb sebesar 1000 kNm

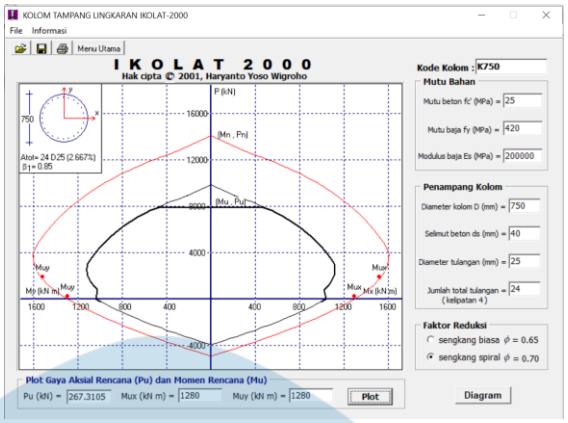
$1{,}2\ (Mpr_{kiri} + Mpr_{kanan}) \leq (Mnca + Mncb)$

$1{,}2\ (1221{,}798 + 928{,}6286) \leq (710 + 1000)$

$2580{,}512\ \text{kNm} \geq 1710$ (Tidak Aman!)

Oleh karena Kolom masih belum aman terhadap SCWB, maka perlu dilakukan penambahan tulangan agar nilai momen nominal kolom lebih besar dari 1,2 momen nominal balok.

Digunakan tulangan 24D25



Gambar 2.29 Nilai Mu2 dan Mu3 kolom atas pada diagram interaksi kolom Tipe 2 (2)

Dari gambar 2.29 Diagram IKOLAT diatas, didapatkan nilai Mnca sebesar 1280 kNm dan Mncb sebesar 1500 kNm sehingga totalnya menjadi 2780 kNm > 2580,512 kNm (sudah memenuhi SCWB). Maka kolom tipe 2 menggunakan tulangan 24D25

B. Perencanaan Tulangan Transversal

$$Ag = \frac{1}{4} \times \pi \times 750^2 = 441786{,}4669\ mm^2$$

$$Ach = \frac{1}{4} \times \pi \times (750 - (2 \times 40))^2 = 352565{,}2355\ mm^2$$

Rasio Volumetrik tulangan spiral

$$\rho s\ min = 0{,}45\left(\frac{Ag}{Ach} - 1\right)\frac{f'c}{fyt}$$

$$= 0{,}45\left(\frac{441786{,}4669}{352565{,}2355} - \right)\frac{25}{420} = 0{,}0067785$$

$$Smaks\ 1 = \frac{Ast}{bc \times \rho s\ min}$$

$$= \frac{2 \times \frac{1}{4} \times \pi \times 13^2}{(750 - 2(40)) \times 0{,}0067785}$$

$$= 58{,}4518\ mm$$

Smaks 2 = d.l x 8 = 25 x 8 = 20 mm

Smaks 3 = d.s x 24 = 13 x 24 = 312 mm

Smaks 4 = 0,5 x 750 = 375 mm

Smaks 5 = 300 mm

Digunakan Smaks terkecil yaitu 58,4518 mm

Ve1 $= \frac{\Sigma M\ prb\ atas \times DF\ atas + \Sigma M\ prb\ bawah \times DF\ bawah}{4,5}$

$= \frac{(1221,798+928,6286) \times 0,5 + (1221,798+928,6286) \times 0,5}{4,5}$

= 573,4471 kN

Ve2 = 100,0382 kN (dari ETABS)

Digunakan Ve terbesar, yaitu 573,4471 kN

$Vc = 0,17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$= 0,17 \times 1 \times \sqrt{25} \times 428191,7$ -> $428191,7$ adalah luas efektif kolom

= 363962,945 N

= 363,9629 kN

Vs $= \frac{Vu}{\emptyset} - Vc$

$= \frac{573,4471}{0,75} - 363,9629$

= 400,633 kN

Spasi $= \frac{Av \times fy \times d}{Vs}$

$= \frac{132,7323 \times 420 \times 684,5}{400,633 \times 10^3}$

= 95,2402 mm

Oleh karena nilai spasi lebih besar dari spasi maks, maka digunakan nilai spasi maks yaitu sebesar 58,4518 mm atau dibulatkan menjadi 50 mm.

Tulangan transversal yang digunakan D13-50

- Tulangan Transversal diluar Lo

$Vc = 0{,}17 \times \lambda \times \sqrt{f'c} \times bw \times d$

$= 0{,}17 \times 1 \times \sqrt{25} \times 428191{,}7$ -> $428191{,}7$ adalah luas efektif kolom

= 363962,945 N

= 363,9629 kN

Vs = $\frac{Vu}{\emptyset} - Vc$

= $\frac{573{,}4471}{0{,}75} - 363{,}9629$

= 400,633 kN

Spasi = $\frac{Av \times fy \times d}{Vs}$

= $\frac{132{,}7323 \times 420 \times 684{,}5}{400{,}633 \times 10^3}$

= 95,2402 mm

Tulangan transversal yang digunakan D13-50