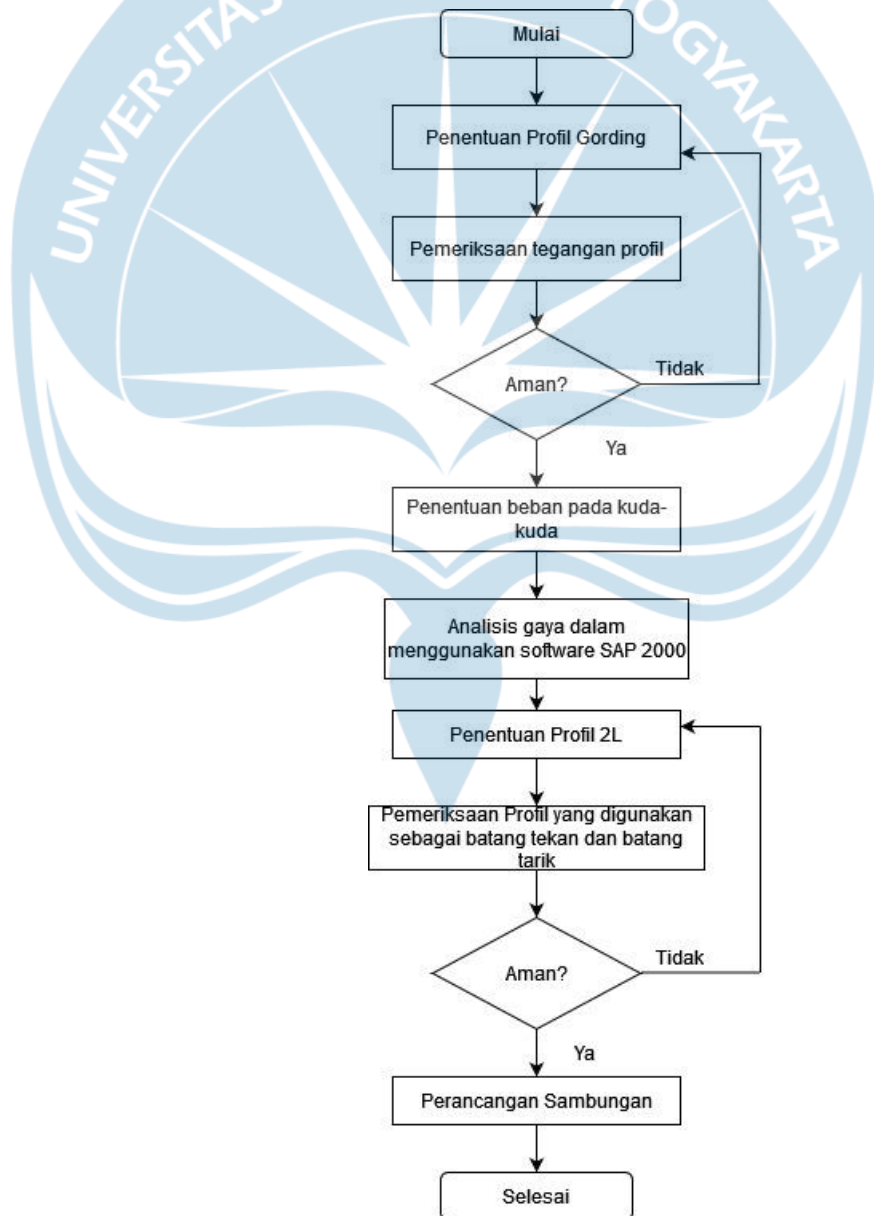


BAB II

PERANCANGAN STRUKTUR ATAS

2.1. Metode Perancangan

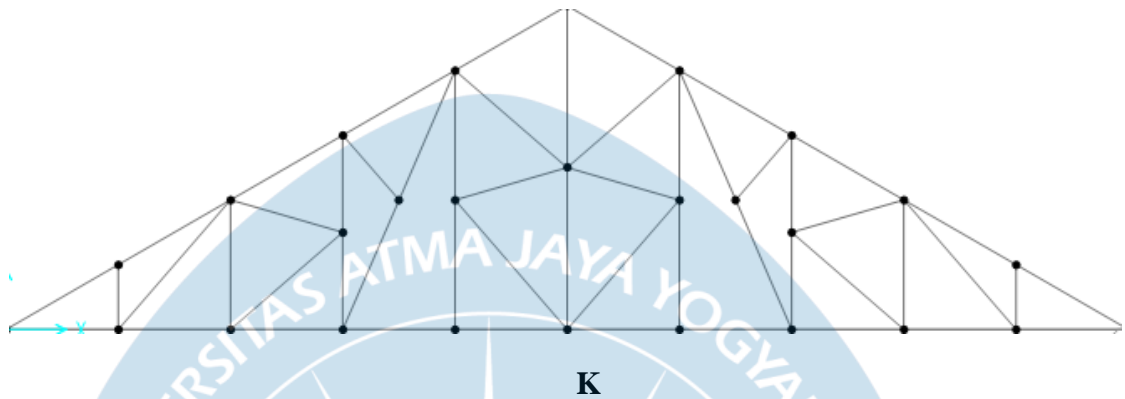
Untuk menentukan keamanan pada atap maka diperlukan perancangan atap dengan baik mulai dari mengecek keamanan profil gording, menentukan beban kuda-kuda, penentuan dan pemeriksaan profil pada batang tekan dan tarik hingga merancang sambungan yang akan dipakai. Untuk selengkapnya dapat dilihat *flowchart*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



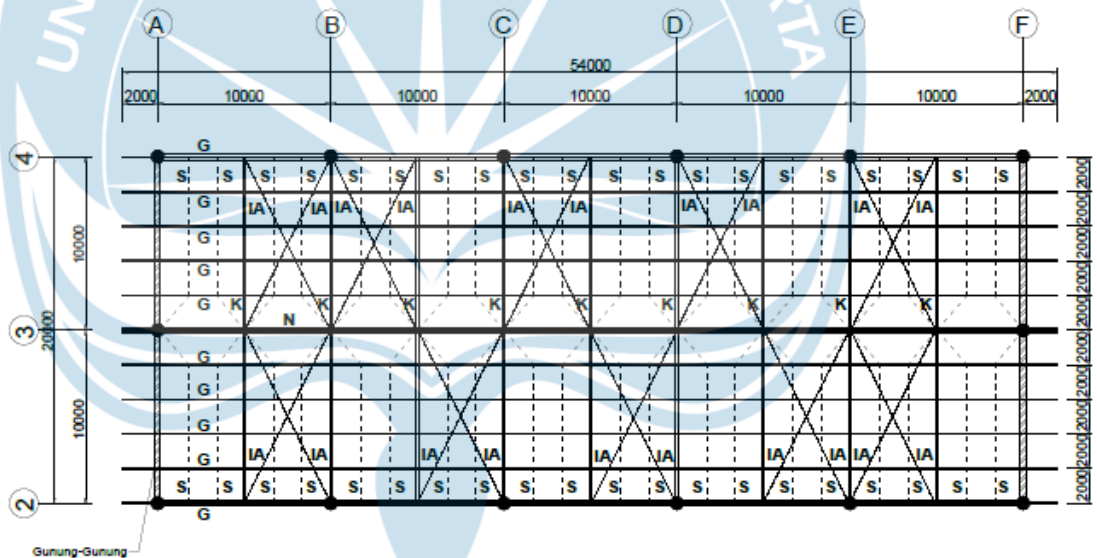
Gambar 2.1 *Flowchart* Perancangan Atap

2.1.1. Perencanaan Gording

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

$$\text{Berat sendiri} = 10 \text{ kg / m}' = 0,1 \text{ kN/m}'$$

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

$$\text{Berat Plafond} = 2 \times 0,18 = 0,36 \text{ kN/m}' +$$

$$\text{Dead Load (D) rencana gording } q = 1,384 \text{ kN/m}'$$

Beban Hidup (L) diambil sebesar 1,0 kN

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

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

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

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

$$M_{3,U} = 1,4 \times 3,746 = 5,244 \text{ kNm'}$$

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

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

$$M_{2,U} = 1,4 \times 0,240 = 0,336 \text{ kNm'}$$

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

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

Cek Tegangan Pada Profil C

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

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

Dengan Data-data:

$$I_x = 2.670.000 \text{ mm}^4$$

$$I_y = 440.000 \text{ mm}^4$$

$$W_3 = Z_x = 35.600 \text{ mm}^3$$

$$W_2 = Z_y = 10.000 \text{ mm}^3$$

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

Cari profil lain

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

Dengan Data-data:

$$I_x = 3.320.000 \text{ mm}^4$$

$$I_y = 540.000 \text{ mm}^4$$

$$W_3 = Z_x = 44.200 \text{ mm}^3$$

$$W_2 = Z_y = 12.200 \text{ mm}^3$$

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

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

Cek Defleksi Gording

$$\delta_2 = \frac{5}{384} \times \frac{1,384 \times \cos 30 \times 5000^4}{200.000 \times 3.320.000} + \frac{1}{48} \times \frac{1 \times \cos 30 \times 5000^3}{200.000 \times 3.320.000}$$
$$= 14,693 \text{ mm}$$

$$\delta_3 = \frac{5}{384} \times \frac{1,384 \times \sin 30}{200.000 \times 540000} \times \left(\frac{5000}{3}\right)^4 + \frac{1}{48} \times \frac{1 \times \sin 30}{200.000 \times 540000} \times \left(\frac{5000}{3}\right)^3$$
$$= 0,644 \text{ mm}$$

$$\delta = \sqrt{14,693^2 + 0,644^2} \leq \frac{1}{240} L$$
$$= 14,707 \leq 20,833$$

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

Rencana Sag-Rod

Gaya Sag-Rod

- $F_{t,D} = n \left(\frac{L}{3} \times q \times \sin \alpha\right)$
 $F_{t,D} = 5 \left(\frac{5}{3} \times 1,384 \times \sin 30\right) = 5,77 \text{ kN}$
- $F_{t,L} = \frac{n}{2} \times P \times \sin \alpha$
 $F_{t,L} = \frac{5}{2} \times 1 \times \sin 30 = 1,25 \text{ kN}$

Kombinasi Pembebanan

- $F_{t,U} = 1,4F_{t,D}$
 $= 1,4 \times 5,77 = 8,078 \text{ kN}$
- $F_{t,U} = 1,2F_{t,D} + 1,6F_{t,L}$
 $= 1,4 \times 5,77 + 1,6 \times 1,25 = 10,078 \text{ kN (Dipilih yang terbesar)}$

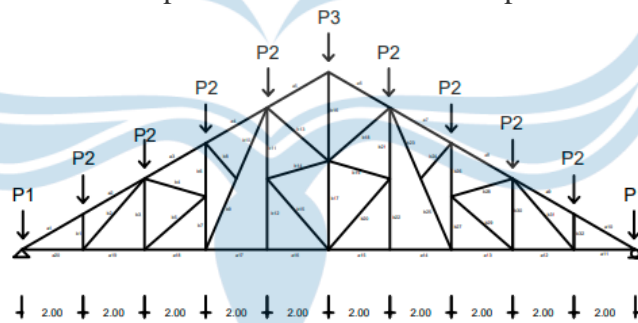
Luas Batang Sag-rod yang dibutuhkan

$$\begin{aligned} A_{sr} &= \frac{F_t \cdot 10^3}{\phi F_y} \text{ mm}^2 \\ &= \frac{10,078 \cdot 10^3}{0,9 \times 240} \text{ mm}^2 \\ &= 46,66 \text{ mm}^2 \end{aligned}$$

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 $= \frac{2}{2} \times 0,5 = 0,5 \text{ kN}$
- Berat gording $= 5 \times 0,0751 = 0,376 \text{ kN}$
- Berat atap $= \frac{(\frac{2}{2} + 2)}{\cos 30} \times 5 \times 0,4 = 6,928 \text{ kN}$
- Berat plafond $= (\frac{2}{2} + 2) \times 5 \times 0,2 = \underline{3 \text{ kN}} + 10,804 \text{ kN}$

Beban P2:

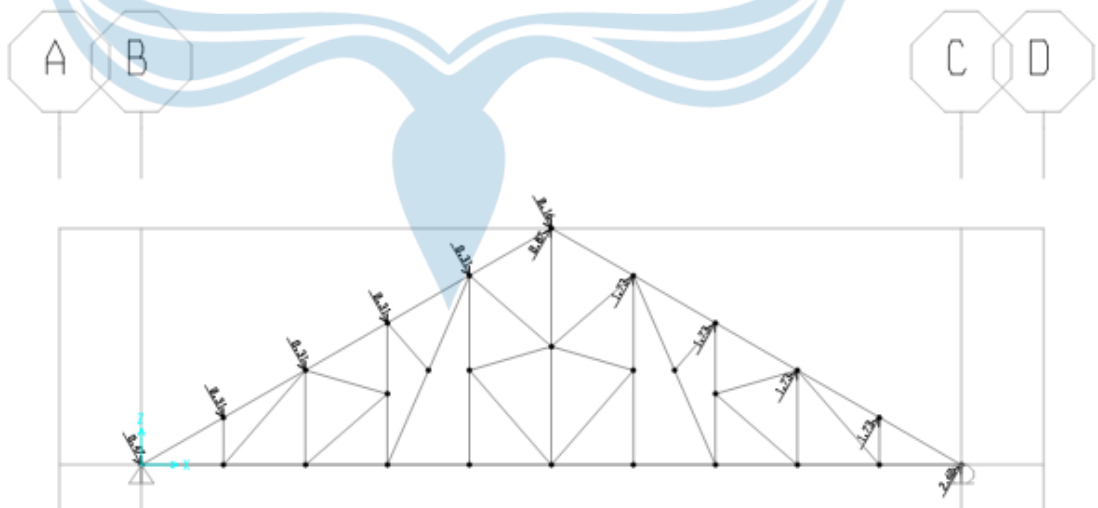
- Berat sendiri kuda-kuda = $2 \times 0,5$ = 1 kN
- Berat gording = $5 \times 0,0751$ = 0,375 kN
- Berat atap = $= \frac{2}{\cos 30} \times 5 \times 0,4$ = 4,619 kN
- Berat plafond = $= 2 \times 5 \times 0,2$ = 2 kN +
7,994 kN

Beban P3:

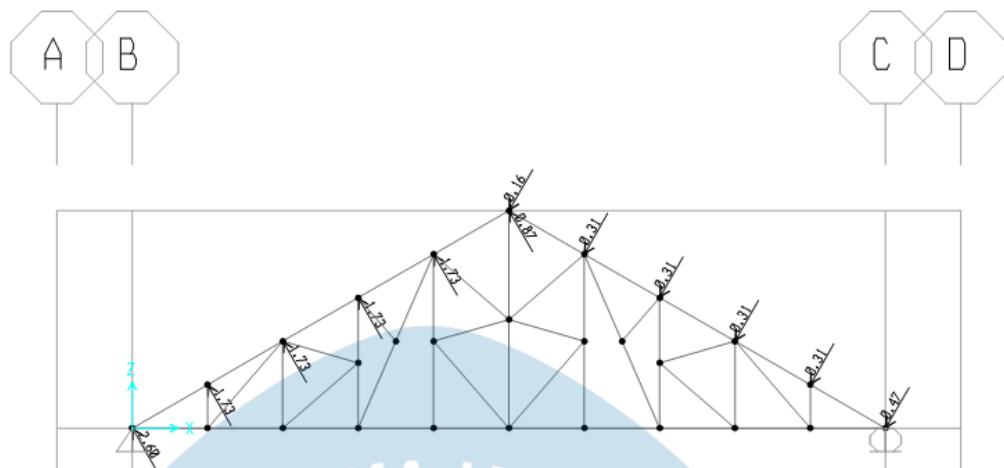
- Berat sendiri kuda-kuda = $2 \times 0,5$ = 1 kN
- Berat gording = $= 2 \times 5 \times 0,0751$ = 0,751 kN
- Berat atap = $= \frac{2}{\cos 30} \times 5 \times 0,4$ = 4,619 kN
- Berat plafond = $= 2 \times 5 \times 0,2$ = 2 kN +
8,37 kN

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

$$h = (10+5,8)/2 = 7,9 \text{ m}$$

$$\alpha = 30^\circ$$

$$h/L = 0,329$$

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

$$C_{is} = -0,6 \text{ efek angin hisap}$$

$$\begin{aligned} \text{Beban } W_1 &= \frac{\left(\frac{a}{2}+b\right)}{\cos \alpha} \times C_{ti} \times L \times Q_w \\ &= \frac{\left(\frac{2}{2}+2\right)}{\cos 30} \times 0,1088 \times 5 \times 0,25 = 0,471 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{Beban } W_2 &= \frac{a}{\cos \alpha} \times C_{ti} \times L \times Q_w \\ &= \frac{2}{\cos 30} \times 0,1088 \times 5 \times 0,25 = 0,314 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{Beban } W_3 &= \frac{1}{2} \frac{a}{\cos \alpha} \times C_{ti} \times L \times Q_w \\ &= \frac{1}{2} \frac{2}{\cos 30} \times 0,1088 \times 5 \times 0,25 = 0,157 \text{ kN} \end{aligned}$$

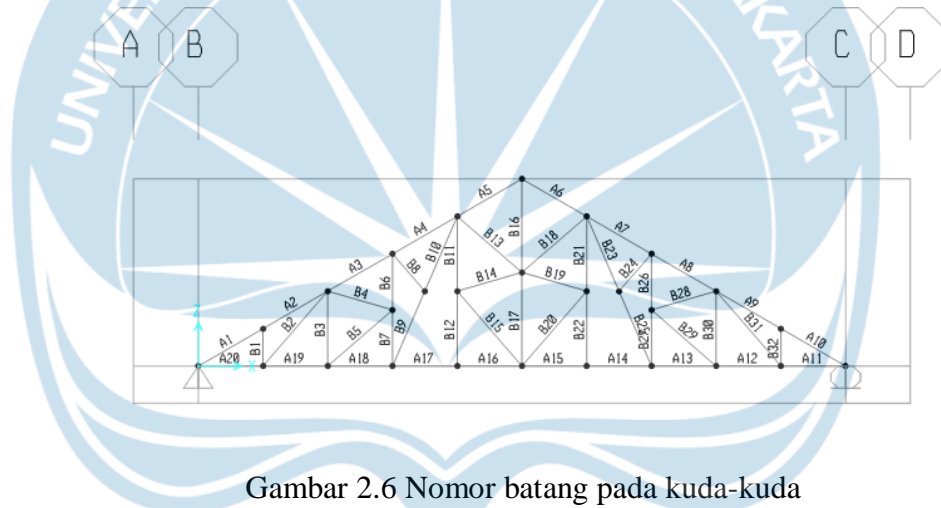
$$\text{Beban } W_4 = \frac{1}{2} \frac{a}{\cos \alpha} \times C_{is} \times L \times Q_w$$

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

$$\begin{aligned} \text{Beban } W_5 &= \frac{a}{\cos \alpha} \times C_{is} \times L \times Q_w \\ &= \frac{2}{\cos 30} \times -0,6 \times 5 \times 0,25 = -1,732 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{Beban } W_6 &= \frac{\left(\frac{a}{2}+b\right)}{\cos \alpha} \times C_{is} \times L \times Q_w \\ &= \frac{\left(\frac{2}{2}+2\right)}{\cos 30} \times -0,6 \times 5 \times 0,25 = -2,598 \text{ kN} \end{aligned}$$

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	Panjang g (m)	Beban DL (kN)	Beban LL (KN)	Beban Angin Kiri Wiki (KN)	Beban Angin Kanan Wiki (KN)	1,4 DL	1,2DL + 1,6 LL	1,2DL + 1,3 Wki + 0,5 LL	1,2DL + 1,3 Wka + 0,5 LL	Gaya rencana (kN)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(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	Panjang (m)	Beban DL (kN)	Beban LL (KN)	Beban Angin Kiri Wiki (KN)	Beban Angin Kanan Wiki (KN)	1,4 DL	1,2DL + 1,6 LL	1,2DL + 1,3 Wki + 0,5 LL	1,2DL + 1,3 Wka + 0,5 LL	Gaya rencana (kN)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(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

$$A = 691 \text{ mm}^2$$

$$I_x = I_y = 227900 \text{ mm}^4$$

$$C_x = C_y = 17 \text{ mm}$$

$$T_p = 10 \text{ mm}$$

Properti Profil gabungan 2L

$$A = 2 \times 691 = 1382 \text{ mm}^2$$

$$I_{xg} = 2 \times 227900 = 455800 \text{ mm}^4$$

$$I_{yg} = (2 \times I_y) + (2 \times A_g \times (C_y + \frac{T_p}{2})^2) = 1124688 \text{ mm}^4$$

$$r_{xg} = \sqrt{\frac{I_{xg}}{A_{Profil}}} = \sqrt{\frac{455800}{1382}} = 18.162 \text{ mm}$$

$$r_{yg} = \sqrt{\frac{I_{yg}}{A_{Profil}}} = \sqrt{\frac{1124688}{1382}} = 28.53 \text{ mm}$$

digunakan nilai yang terkecil yaitu 18.162 mm

1. Analisis Batang Tekan

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

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

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

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

$$F_e = 123.06 \text{ MPa}$$

$$F_{cr} = 106.102 \text{ MPa}$$

$$\Phi P_n = 0.9 \times 106.102 \times 1382$$

$$= 131969.667 \text{ N}$$

$$= 131.969 > 114.35 \text{ kN (Pu)...aman}$$

2. Analisis Batang Tarik

Syarat:

$$\frac{L}{i_{min}} = \frac{3000}{18.162} = 165.18 < 240 \text{ (aman)}$$

$$\Phi P_n = 0.9 \times 240 \times 1382$$

$$= 298512 \text{ N}$$

$$= 298.512 \text{ kN} > 98.95 \text{ kN} \dots \text{aman}$$

B. Profil L 50x50x5 (batang interior)

$$\text{Gaya tekan max} = -31,85 \text{ kN}$$

$$\text{Gaya tarik max} = 37,62 \text{ kN}$$

$$A = 480,2 \text{ mm}^2$$

$$I_x = I_y = 111000 \text{ mm}^4$$

$$C_x = C_y = 14,1 \text{ mm}$$

$$T_p = 10 \text{ mm}$$

Properti Profil gabungan 2L

$$A = 2 \times 480,2 = 960,4 \text{ mm}^2$$

$$I_{xg} = 2 \times 111000 = 222000 \text{ mm}^4$$

$$I_{yg} = (2 \times I_y) + (2 \times A_g \times (C_y + \frac{T_p}{2})^2) = 572363,5 \text{ mm}^4$$

$$r_{xg} = \sqrt{\frac{I_{xg}}{A_{Profil}}} = \sqrt{\frac{222000}{960,4}} = 15,2037 \text{ mm}$$

$$r_{yg} = \sqrt{\frac{I_{yg}}{A_{Profil}}} = \sqrt{\frac{572363,5}{960,4}} = 24,4124 \text{ mm}$$

digunakan nilai yang terkecil yaitu 15,2037 mm

1. Analisis Batang Tekan

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

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

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

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

$$F_e = 67,4969 \text{ MPa}$$

$$F_{cr} = 59,1948 \text{ MPa}$$

$$\Phi P_n = 0.9 \times 59,1948 \times 960,4$$

$$= 51165,61 \text{ N}$$

$$= 51,1656 > 31,85 \text{ kN (Pu)} \dots \text{aman}$$

2. Analisis Batang Tarik

Syarat:

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

$$\Phi P_n = 0.9 \times 240 \times 960,4$$

$$= 207446,4 \text{ N}$$

$$= 207,446 \text{ kN} > 37,62 \text{ kN} \dots \text{aman}$$

2.1.4. Rencana Sambungan Elemen Kuda-Kuda

1. Kegagalan Geser

Diketahui:

$$\Phi f = 0.75$$

$$R_1 = 0.4 \text{ (ulir pada seluruh bagian baut)}$$

$$f_{ub} = 565 \text{ MPa}$$

$$A_b = 0.25 \times \pi \times 12^2 = 113.0973 \text{ mm}^2$$

$$\begin{aligned} V_d &= \Phi_f \times r_l \times f_{ub} \times A_b \\ &= 0.75 \times 0.4 \times 565 \times 113.0973 \\ &= 19170 \text{ N} = 19.17 \text{ kN} \end{aligned}$$

2. Kegagalan Tumpu

$$\Phi_f = 0.9$$

$$d_b = 12 \text{ mm}$$

$$t_p = 10 \text{ mm}$$

$$f_u = 565 \text{ MPa}$$

$$\begin{aligned} R_d &= 2.4 \times \Phi_f \times d_b \times t_p \times f_u \\ &= 2.4 \times 0.75 \times 12 \times 10 \times 565 \\ &= 122040 \text{ N} = 122,04 \text{ kN} \end{aligned}$$

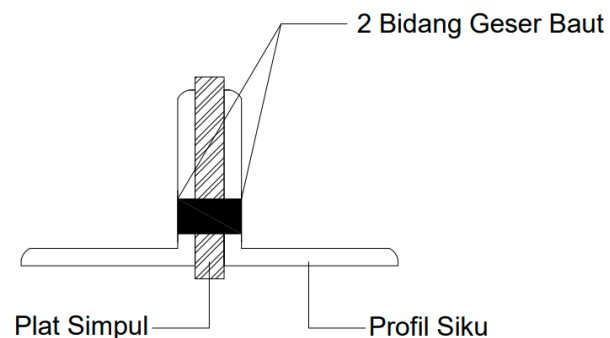
Digunakan nilai yang terkecil antara 2 V_d dan R_d , maka:

$$n_b = \frac{114.35}{2 \times 19.17} = 2,9825 \approx 3 \text{ buah baut}$$

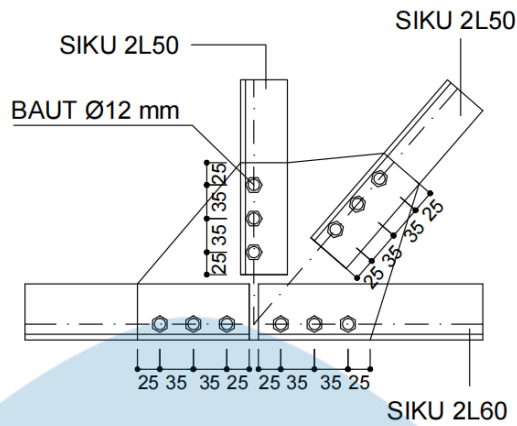
$$\text{Jarak baut ke tepi} = 2 \times 12 \text{ mm} = 24 \text{ mm}$$

$$\text{Jarak antar baut} = 3 \times 12 = 36 \text{ mm}$$

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



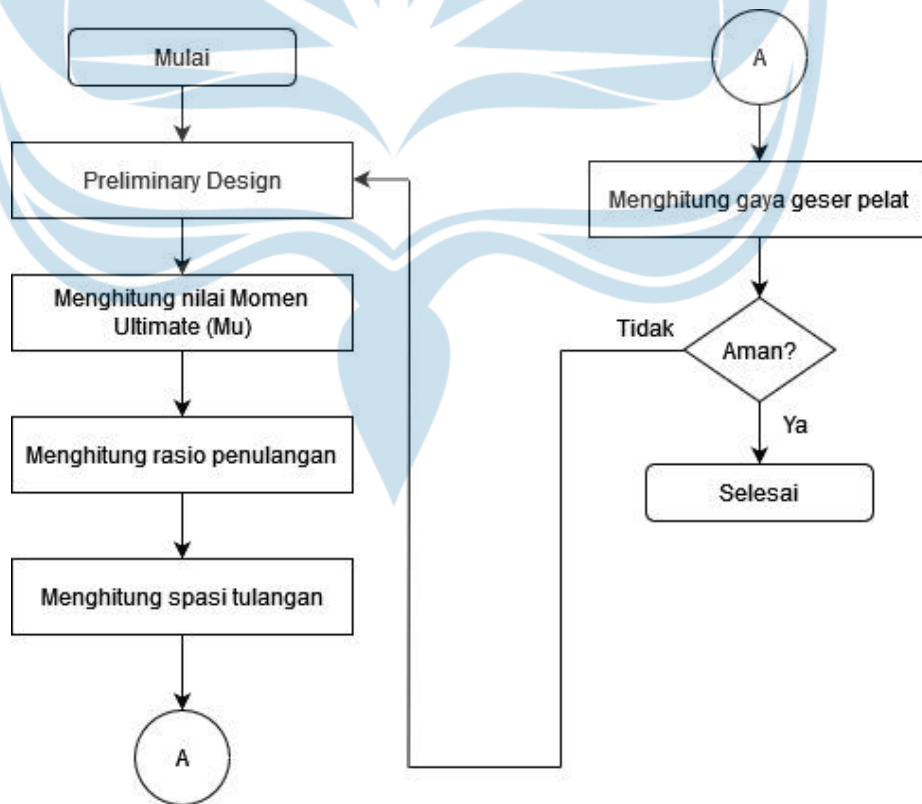
Gambar 2.7 Penampang Geser Baut



Gambar 2.8 Detail Sambungan Baut Kuda-Kuda Siku

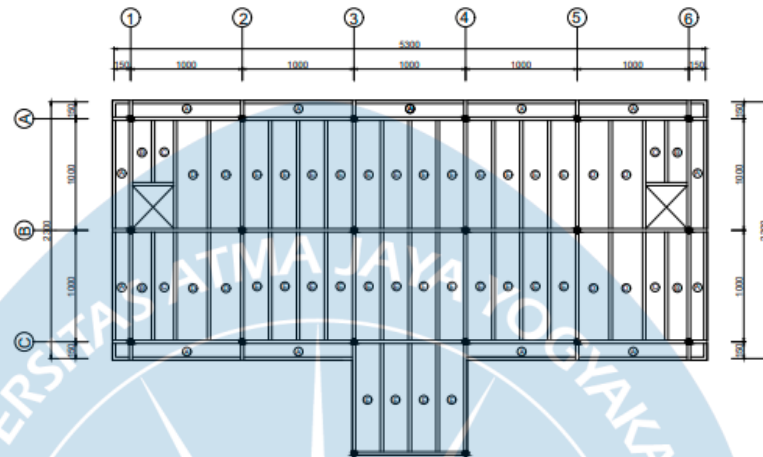
2.1.5. Rencana Pelat Lantai

Setelah melakukan perancangan atap, selanjutnya dilakukan perancangan pelat lantai. Untuk serangkaian urutan pekerjaan yang dilaksanakan selengkapny 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	$W_u = 1.2D + 1.6L$
		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

1. Rencana Penulangan Pelat Lantai

Penentuan tebal pelat (SNI 2847:2019 pasal 7.3.1.1)

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

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

Maka diambil tebal pelat sebesar 120 mm

A. Pelat lantai A (Pelat 1 Arah)

$$L_y = 10 \text{ m}$$

$$L_x = 1.5 \text{ m}$$

$$M_u = \frac{1}{2} \times q \times L^2$$

$$M_u = \frac{1}{2} \times 16.092 \times 1.5^2$$

$$M_u = 18,1035 \text{ kNm}$$

$$= 18,1035 \times 10^6 \text{ Nmm}$$

$$\text{Selimut beton (ts)} = 20 \text{ mm}$$

$$f_y = 280 \text{ MPa}$$

$$f'_c = 25 \text{ MPa}$$

$$\text{Tebal Pelat (ht)} = 120 \text{ mm}$$

$$b = 1000 \text{ mm}$$

$$\beta_1 = 0,85 \text{ (karena } f'_c = 25 \text{ MPa)}$$

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

$$d = 120 - 26 = 94 \text{ mm}$$

1. Perhitungan Tulangan Pokok

$$k = \frac{M_n}{bd^2} = \frac{M_u(-)}{\Phi bd^2}$$
$$= \frac{18,1035 \times 10^6}{0,9 \times 1000 \times 94^2} = 2,27648$$

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

$$= \frac{0,85 \times 25}{280} \left(1 - \sqrt{1 - \frac{2(2,227648)}{0,85 \times 25}} \right)$$

$$= 0,00861981$$

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

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

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

$$A_s \text{ min} = 0,002 \times b \times h \text{ (SNI 2847:2019 Pasal 7.6.1.1)}$$

$$A_s \text{ min} = 0,002 \times 1000 \times 120 = 240 \text{ mm}^2$$

$$A_s = \rho \times b \times d$$

$$= 0,00861981 \times 1000 \times 94 = 810,262 \text{ mm}^2$$

$$A_s \geq A_s \text{ min} \dots (\text{digunakan nilai } A_s)$$

Hitung Spasi Maksimum tulangan

$$S \text{ maks} = 3 \times h$$

$$= 3 \times 120 = 360 \text{ mm}$$

atau 450 mm

Hitung spasi tulangan

$$\bullet \quad s = \frac{\frac{1}{4} \times \pi \times 12^2 \times 1000}{810,262} = 139,5812 \text{ mm}$$

• Diambil 100 mm

• $s < s_{\text{maks}} \dots$ maka digunakan d12-100

2. Perhitungan Tulangan Bagi

$$A_s = 0,002 \times b \times h$$

$$= 0,002 \times 1000 \times 120$$

$$= 240 \text{ mm}$$

Hitung Spasi Maksimum tulangan

$$S \text{ maks} = 5xh$$

$$= 5 \times 120 = 600 \text{ mm}$$

atau 450 mm

Hitung spasi tulangan

- $s = \frac{\frac{1}{4} \times \pi \times 8^2 \times 1000}{240} = 209,4395 \text{ mm}$

- Diambil 200 mm

- $s < s_{maks}$...maka digunakan d8-200

-

3. Perhitungan Geser

$$V_c = 0,17 \times \lambda \times \sqrt{f'c} \times b_w \times d$$

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

$$= 79900 \text{ N}$$

$$\Phi V_c = 0,75 \times 79900$$

$$= 59925 \text{ N} \rightarrow 59,925 \text{ KN}$$

$$\Phi V_c > V_u \dots (\text{Aman!})$$

B. Pelat lantai B (pelat 1 arah)

$$L_y = 5,86 \text{ m}$$

$$L_x = 2 \text{ m}$$

$$M_{u1} = \frac{1}{24} \times q \times L^2$$

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

$$= 2,682 \text{ kNm}$$

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

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

$$= 6,4368 \text{ kNm}$$

$$Mu^- \text{ use} = 6,4368 \text{ kNm}$$

$$Mu^+ = 4,5977 \text{ kNm}$$

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

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

$$= 18,5058 \text{ kN}$$

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

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

$$= 16,092 \text{ kN}$$

$$Vu \text{ use} = 18,5058 \text{ kN}$$

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

$$d = 120 - 25 = 95 \text{ mm}$$

1. Tulangan Tumpuan

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

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

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

$$= \frac{0,85 \times 25}{280} \left(1 - \sqrt{1 - \frac{2(0,792465)}{0,85 \times 25}} \right)$$

$$= 0,0028851$$

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

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

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

$$A_s \text{ min} = 0,002 \times b \times h \text{ (SNI 2847:2019 Pasal 7.6.1.1)}$$

$$A_s \text{ min} = 0,002 \times 1000 \times 120 = 240 \text{ mm}^2$$

$$A_s = \rho \times b \times d$$

$$= 0,0028851 \times 1000 \times 95 = 274,0818 \text{ mm}^2$$

$$A_s \geq A_s \text{ min} \dots (\text{digunakan nilai } A_s)$$

Hitung Spasi Maksimum tulangan

$$S \text{ maks} = 3xh$$

$$= 3 \times 120 = 360 \text{ mm}$$

atau 450 mm

Hitung spasi tulangan

$$\bullet \quad s = \frac{\frac{1}{4} \times \pi \times 10^2 \times 1000}{274,0818} = 286,5561 \text{ mm}$$

• Diambil 250 mm

• $s < s_{\text{maks}} \dots$ maka digunakan d10-250

2. Tulangan Lapangan

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

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

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

$$= \frac{0,85 \times 25}{280} \left(1 - \sqrt{1 - \frac{2(0,56605)}{0,85 \times 25}} \right)$$

$$= 0,0020493$$

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

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

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

$$A_s \text{ min} = 0,002 \times b \times h \text{ (SNI 2847:2019 Pasal 7.6.1.1)}$$

$$A_s \text{ min} = 0,002 \times 1000 \times 120 = 240 \text{ mm}^2$$

$$A_s = \rho \times b \times d$$

$$= 0,0020493 \times 1000 \times 95 = 194,6799 \text{ mm}^2$$

$$A_s < A_s \text{ min} \dots (\text{digunakan nilai } A_s \text{ min})$$

Hitung Spasi Maksimum tulangan

$$S \text{ maks} = 3xh$$

$$= 3 \times 120 = 360 \text{ mm}$$

atau 450 mm

Hitung spasi tulangan

$$\bullet \quad s = \frac{\frac{1}{4} \times \pi \times 10^2 \times 1000}{240} = 327,2492 \text{ mm}$$

• Diambil 300 mm

• $s < s_{\text{maks}} \dots$ maka digunakan d10-300

3. Perhitungan Tulangan Bagi

$$A_s = 0,002 \times b \times h$$

$$= 0,002 \times 1000 \times 120$$

$$= 240 \text{ mm}$$

Hitung Spasi Maksimum tulangan

$$S_{\text{maks}} = 5xh$$

$$= 5 \times 120 = 600 \text{ mm}$$

atau 450 mm

Hitung spasi tulangan

$$\bullet \quad s = \frac{\frac{1}{4} \times \pi \times 8^2 \times 1000}{240} = 209,4395 \text{ mm}$$

• Diambil 200 mm

• $s < s_{\text{maks}}$...maka digunakan d8-200

4. Perhitungan Geser

$$V_c = 0,17 \times \lambda \times \sqrt{f'_c} \times b_w \times d$$

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

$$= 80750 \text{ N}$$

$$\Phi V_c = 0,75 \times 80750$$

$$= 60562,5 \text{ N} \rightarrow 60,5625 \text{ KN}$$

$\Phi V_c > V_u$... (Aman!)

C. Pelat lantai C (pelat 1 arah)

$$L_y = 5,86 \text{ m}$$

$$L_x = 2 \text{ m}$$

$$\begin{aligned} Mu^- &= \frac{1}{11} \times q \times L^2 \\ &= \frac{1}{11} \times 16,092 \times 2^2 \\ &= 5,85164 \text{ kNm} \end{aligned}$$

$$Mu^+ = 6,4368 \text{ kNm}$$

$$\begin{aligned} Vu &= \frac{wu \times ln}{2} \\ &= \frac{16,092 \times 2}{2} \\ &= 16,092 \text{ kN} \end{aligned}$$

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

$$d = 120 - 25 = 95 \text{ mm}$$

1. Tulangan Tumpuan

$$\begin{aligned} k &= \frac{Mn}{bd^2} = \frac{Mu(-)}{\Phi bd^2} \\ &= \frac{5,85164 \times 10^6}{0,9 \times 1000 \times 95^2} = 0,720423 \end{aligned}$$

$$\begin{aligned} \rho &= \frac{0,85 f'c}{f_y} \left(1 - \sqrt{1 - \frac{2k}{0,85 f'c}} \right) \\ &= \frac{0,85 \times 25}{280} \left(1 - \sqrt{1 - \frac{2(0,720423)}{0,85 \times 25}} \right) \\ &= 0,0026181 \end{aligned}$$

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

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

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

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

$$As_{\text{min}} = 0,002 \times 1000 \times 120 = 240 \text{ mm}^2$$

$$As = \rho \times b \times d$$

$$= 0,026181 \times 1000 \times 95 = 248,7193 \text{ mm}^2$$

As ≥ As min ... (digunakan nilai As)

Hitung Spasi Maksimum tulangan

$$S_{\text{maks}} = 3xh$$

$$= 3 \times 120 = 360 \text{ mm}$$

atau 450 mm

Hitung spasi tulangan

$$\bullet \quad s = \frac{\frac{1}{4} \times \pi \times 10^2 \times 1000}{248,7193} = 315,7769 \text{ mm}$$

• Diambil 300 mm

• s < smaks... maka digunakana d10-300

2. Tulangan Lapangan

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

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

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

$$= \frac{0,85 \times 25}{280} \left(1 - \sqrt{1 - \frac{2(0,495291)}{0,85 \times 25}} \right)$$

$$= 0,00179$$

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

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

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

$$A_s \text{ min} = 0,002 \times b \times h \text{ (SNI 2847:2019 Pasal 7.6.1.1)}$$

$$A_s \text{ min} = 0,002 \times 1000 \times 120 = 240 \text{ mm}^2$$

$$A_s = \rho \times b \times d$$

$$= 0,00179 \times 1000 \times 95 = 170,0505 \text{ mm}^2$$

$$A_s < A_s \text{ min} \dots (\text{digunakan nilai } A_s \text{ min})$$

Hitung Spasi Maksimum tulangan

$$S \text{ maks} = 3xh$$

$$= 3 \times 120 = 360 \text{ mm}$$

atau 450 mm

Hitung spasi tulangan

$$\bullet \quad s = \frac{\frac{1}{4} \times \pi \times 10^2 \times 1000}{240} = 327,2492 \text{ mm}$$

• Diambil 300 mm

• $s < s_{\text{maks}} \dots$ maka digunakan d10-300

3. Perhitungan Tulangan Bagi

$$A_s = 0,002 \times b \times h$$

$$= 0,002 \times 1000 \times 120$$

$$= 240 \text{ mm}$$

Hitung Spasi Maksimum tulangan

$$S \text{ maks} = 5xh$$

$$= 5 \times 120 = 600 \text{ mm}$$

atau 450 mm

Hitung spasi tulangan

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

4. Perhitungan Geser

$$V_c = 0,17 \times \lambda \times \sqrt{f'_c} \times b_w \times d$$

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

$$= 80750 \text{ N}$$

$$\Phi V_c = 0,75 \times 80750$$

$$= 60562,5 \text{ N} \rightarrow 60,5625 \text{ KN}$$

$$\Phi V_c > V_u \dots (\text{Aman!})$$

D. Pelat lantai D (pelat 1 arah)

$$L_y = 10 \text{ m}$$

$$L_x = 3 \text{ m}$$

$$M_u = \frac{1}{11} \times q \times L^2$$

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

$$= 13,1662 \text{ kNm}$$

$$Mu^+ = 9,05175 \text{ kNm}$$

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

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

$$= 24,138 \text{ kN}$$

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

$$d = 120 - 25 = 95 \text{ mm}$$

1. Tulangan Tumpuan

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

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

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

$$= \frac{0,85 \times 25}{280} \left(1 - \sqrt{1 - \frac{2(1,620952)}{0,85 \times 25}} \right)$$

$$= 0,006029$$

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

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

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

$$As_{min} = 0,002 \times b \times h \text{ (SNI 2847:2019 Pasal 7.6.1.1)}$$

$$As_{min} = 0,002 \times 1000 \times 120 = 240 \text{ mm}^2$$

$$As = \rho \times b \times d$$

$$= 0,006029 \times 1000 \times 95 = 572,7125 \text{ mm}^2$$

$A_s \geq A_{s \text{ min}}$... (digunakan nilai A_s)

Hitung Spasi Maksimum tulangan

$$S \text{ maks} = 3xh$$

$$= 3 \times 120 = 360 \text{ mm}$$

atau 450 mm

Hitung spasi tulangan

$$\bullet \quad s = \frac{\frac{1}{4} \times \pi \times 10^2 \times 1000}{572,7125} = 137,1365 \text{ mm}$$

• Diambil 100 mm

• $s < s_{\text{maks}}$... maka digunakan d10-100

2. Tulangan Lapangan

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

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

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

$$= \frac{0,85 \times 25}{280} \left(1 - \sqrt{1 - \frac{2(1,114404)}{0,85 \times 25}} \right)$$

$$= 0,0040902$$

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

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

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

$$A_{s \text{ min}} = 0,002 \times b \times h \text{ (SNI 2847:2019 Pasal 7.6.1.1)}$$

$$A_s \text{ min} = 0,002 \times 1000 \times 120 = 240 \text{ mm}^2$$

$$A_s = \rho \times b \times d$$

$$= 0,0040902 \times 1000 \times 94 = 388,57254 \text{ mm}^2$$

$A_s < A_s \text{ min}$... (digunakan nilai $A_s \text{ min}$)

Hitung Spasi Maksimum tulangan

$$S \text{ maks} = 3xh$$

$$= 3 \times 120 = 360 \text{ mm}$$

atau 450 mm

Hitung spasi tulangan

$$\bullet \quad s = \frac{\frac{1}{4} \times \pi \times 10^2 \times 1000}{388,57254} = 202,12395 \text{ mm}$$

• Diambil 200 mm

• $s < s_{\text{maks}}$...maka digunakan d10-200

3. Perhitungan Tulangan Bagi

$$A_s = 0,002 \times b \times h$$

$$= 0,002 \times 1000 \times 120$$

$$= 240 \text{ mm}$$

Hitung Spasi Maksimum tulangan

$$S \text{ maks} = 5xh$$

$$= 5 \times 120 = 600 \text{ mm}$$

atau 450 mm

Hitung spasi tulangan

$$\bullet \quad s = \frac{\frac{1}{4} \times \pi \times 8^2 \times 1000}{240} = 209,4395 \text{ mm}$$

• Diambil 200 mm

- $s < s_{maks}$...maka digunakan d8-200

4. perhitungan Geser

$$V_c = 0,17 \times \lambda \times \sqrt{f'_c} \times bw \times d$$

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

$$= 80750 \text{ N}$$

$$\Phi V_c = 0,75 \times 80750$$

$$= 60562,5 \text{ N} \rightarrow 60,5625 \text{ KN}$$

$$\Phi V_c > V_u \dots (\text{Aman!})$$

E. Pelat Lantai E (pelat 1 arah)

$$L_y = 10 \text{ m}$$

$$L_x = 2,5 \text{ m}$$

$$M_u^- = \frac{1}{11} \times q \times L^2$$

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

$$= 9,143182 \text{ kNm}$$

$$M_u^+ = 6,285938 \text{ kNm}$$

$$V_u = \frac{w_u \times l_n}{2}$$

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

$$= 20,115 \text{ kN}$$

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

$$d = 120 - 25 = 95 \text{ mm}$$

1. Tulangan Tumpuan

$$k = \frac{Mn}{bd^2} = \frac{Mu(-)}{\Phi bd^2}$$
$$= \frac{9,143182 \times 10^6}{0,9 \times 1000 \times 95^2} = 1,12566$$

$$\rho = \frac{0,85 f'c}{f_y} \left(1 - \sqrt{1 - \frac{2k}{0,85 f'c}} \right)$$
$$= \frac{0,85 \times 25}{280} \left(1 - \sqrt{1 - \frac{2(1,12566)}{0,85 \times 25}} \right)$$
$$= 0,0041327$$

$$\rho_{maks} = 0,429 \times \frac{0,85 \times f'c \times \beta_1}{f_y}$$
$$= 0,429 \times \frac{0,85 \times 25 \times 0,85}{280}$$
$$= 0,027674 \quad \rho \leq \rho_{maks} \dots(\text{OK!})$$

$$A_s \text{ min} = 0,002 \times b \times h \text{ (SNI 2847:2019 Pasal 7.6.1.1)}$$

$$A_s \text{ min} = 0,002 \times 1000 \times 120 = 240 \text{ mm}^2$$

$$A_s = \rho \times b \times d$$

$$= 0,0041327 \times 1000 \times 95 = 392,6105 \text{ mm}^2$$

$$A_s \geq A_s \text{ min} \dots(\text{digunakan nilai } A_s)$$

Hitung Spasi Maksimum tulangan

$$S \text{ maks} = 3xh$$

$$= 3 \times 120 = 360 \text{ mm}$$

atau 450 mm

Hitung spasi tulangan

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

- Diambil 200 mm

- $s < s_{maks}$...maka digunakan d10-200

2. Tulangan Lapangan

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

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

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

$$= \frac{0,85 \times 25}{280} \left(1 - \sqrt{1 - \frac{2(0,773892)}{0,85 \times 25}} \right)$$

$$= 0,002816$$

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

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

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

$$A_s \text{ min} = 0,002 \times b \times h \text{ (SNI 2847:2019 Pasal 7.6.1.1)}$$

$$A_s \text{ min} = 0,002 \times 1000 \times 120 = 240 \text{ mm}^2$$

$$A_s = \rho \times b \times d$$

$$= 0,002816 \times 1000 \times 94 = 267,53417 \text{ mm}^2$$

$$A_s < A_s \text{ min} \dots(\text{digunakan nilai } A_s \text{ min})$$

Hitung Spasi Maksimum tulangan

$$S \text{ maks} = 3xh$$

$$= 3 \times 120 = 360 \text{ mm}$$

atau 450 mm

Hitung spasi tulangan

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

3. Perhitungan Tulangan Bagi

$$A_s = 0,002 \times b \times h$$

$$= 0,002 \times 1000 \times 120$$

$$= 240 \text{ mm}$$

Hitung Spasi Maksimum tulangan

$$S_{maks} = 5xh$$

$$= 5 \times 120 = 600 \text{ mm}$$

atau 450 mm

Hitung spasi tulangan

- $s = \frac{\frac{1}{4} \times \pi \times 8^2 \times 1000}{240} = 209,4395 \text{ mm}$

- Diambil 200 mm
- $s < s_{maks} \dots$ maka digunakan d8-200

4. Perhitungan Geser

$$V_c = 0,17 \times \lambda \times \sqrt{f'_c} \times b_w \times d$$

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

$$= 80750 \text{ N}$$

$$\Phi V_c = 0,75 \times 80750$$

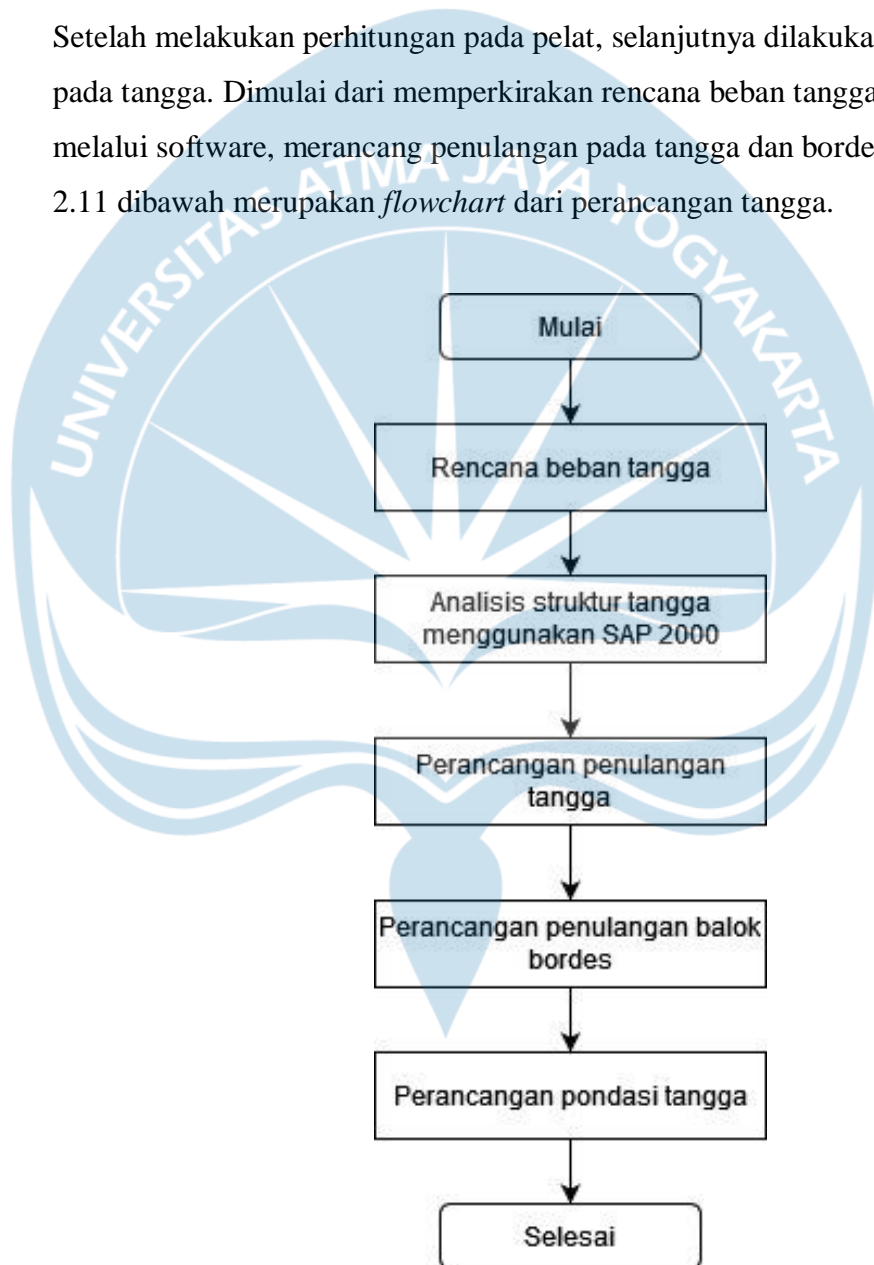
$$= 60562,5 \text{ N} \rightarrow 60,5625 \text{ KN}$$

$\Phi V_c > V_u \dots$ (Aman!)

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

2.2. Perencanaan Tangga Dan Pelat

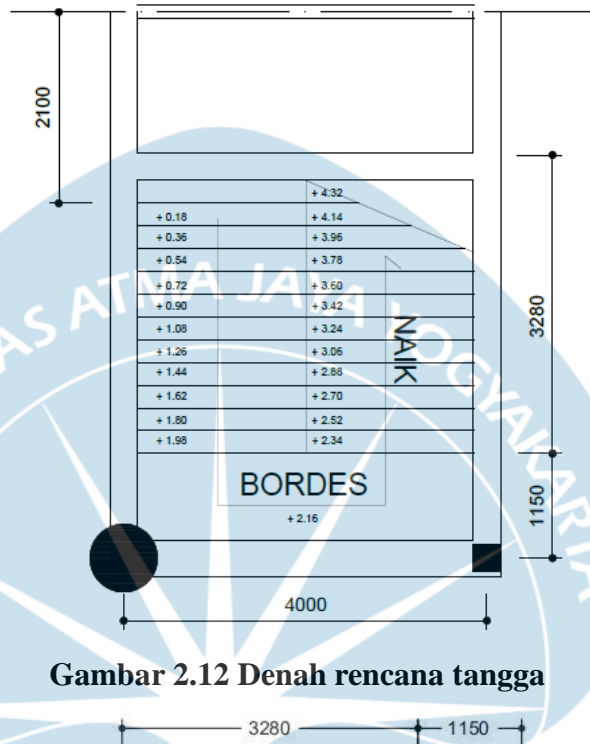
Setelah melakukan perhitungan pada pelat, selanjutnya dilakukan perhitungan pada tangga. Dimulai dari memperkirakan rencana beban tangga, menganalisis melalui software, merancang penulangan pada tangga dan bordes. Pada gambar 2.11 dibawah merupakan *flowchart* dari perancangan tangga.



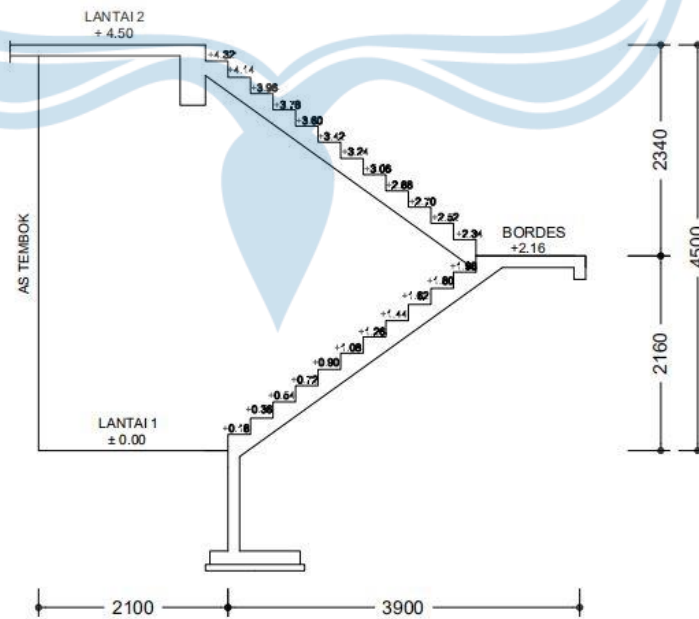
Gambar 2.11 *Flowchart* Perancangan Tangga

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

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

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

c. Antrade (A)

A = 250 mm (Dari rencana gambar arsitek)

$$\begin{aligned} \text{Lebar tangga (L}_{tg}) &= \left(\frac{1}{2} \times \frac{h_{lt}}{O}\right) A \\ &= \left(\frac{1}{2} \times \frac{4500}{180}\right) 250 = 3125 \text{ mm} \end{aligned}$$

d. Sudut kemiringan tangga

$$\begin{aligned} \alpha &= \tan^{-1} \left(\frac{O}{A}\right) \\ &= \tan^{-1} \left(\frac{180}{250}\right) = 35,75^\circ \end{aligned}$$

Kesimpulan :

Lebar Bordes = 1150 m

Jumlah anak tangga = 25 anak tangga

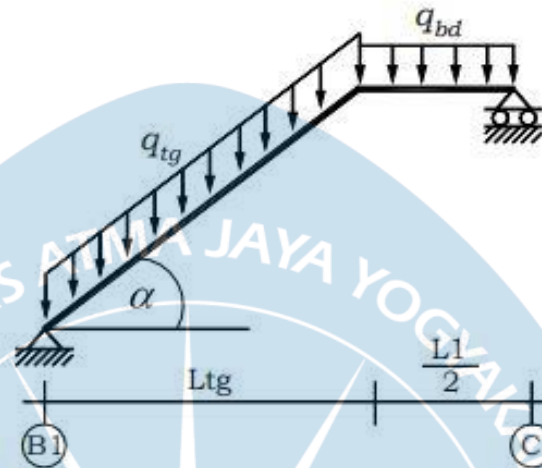
Optrade (naik) = 180 mm

Antrade(datar) = 250 mm

Sudut kemiringan tangga = 35,75 °

2.2.2. Rencana Beban Tangga

Sesuai panduan praktik perancangan 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

$\alpha = 35,75^\circ$

1. Beban Mati

a. Beban q_{tg} :

$$\text{- berat sendiri tangga} = \frac{0,13}{\cos 35,75} \times 24 = 3,844 \text{ kN/m}^2$$

$$\text{- berat anak tanga} = \frac{1}{2} \times 0,18 \times 24 = 2,16 \text{ kN/m}^2$$

$$\text{- berat ubin \& spesi} = 0,05 \times 21 = 1,05 \text{ kN/m}^2$$

$$\text{- berat railing (diperkirakan)} = 1,00 \text{ kN/m}^2$$

$$\text{Beban } q_{tg} = 8,054 \text{ kN/m}^2$$

b. Beban qbd :

- berat sendiri tangga = $0,13 \times 24$ = $3,12 \text{ kN/m}^2$

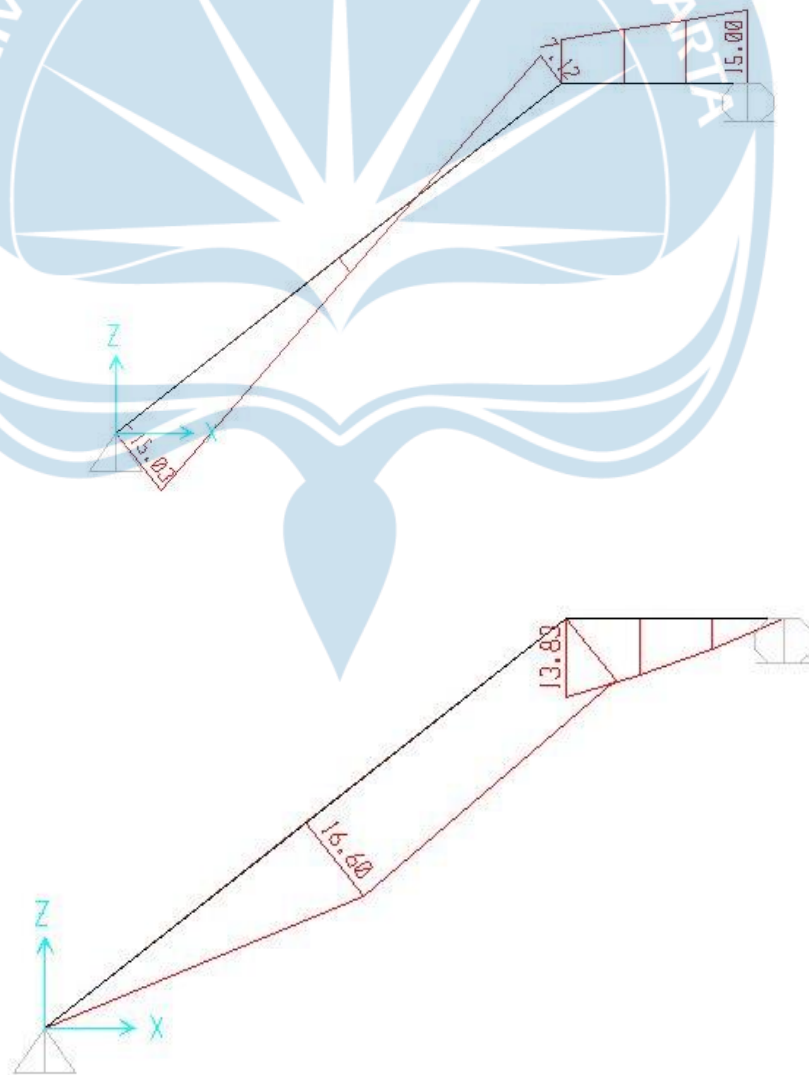
- berat ubin & spesi = $0,05 \times 21$ = $1,05 \text{ kN/m}^2$

- berat railing (diperkirakan) = $1,00 \text{ kN/m}^2$

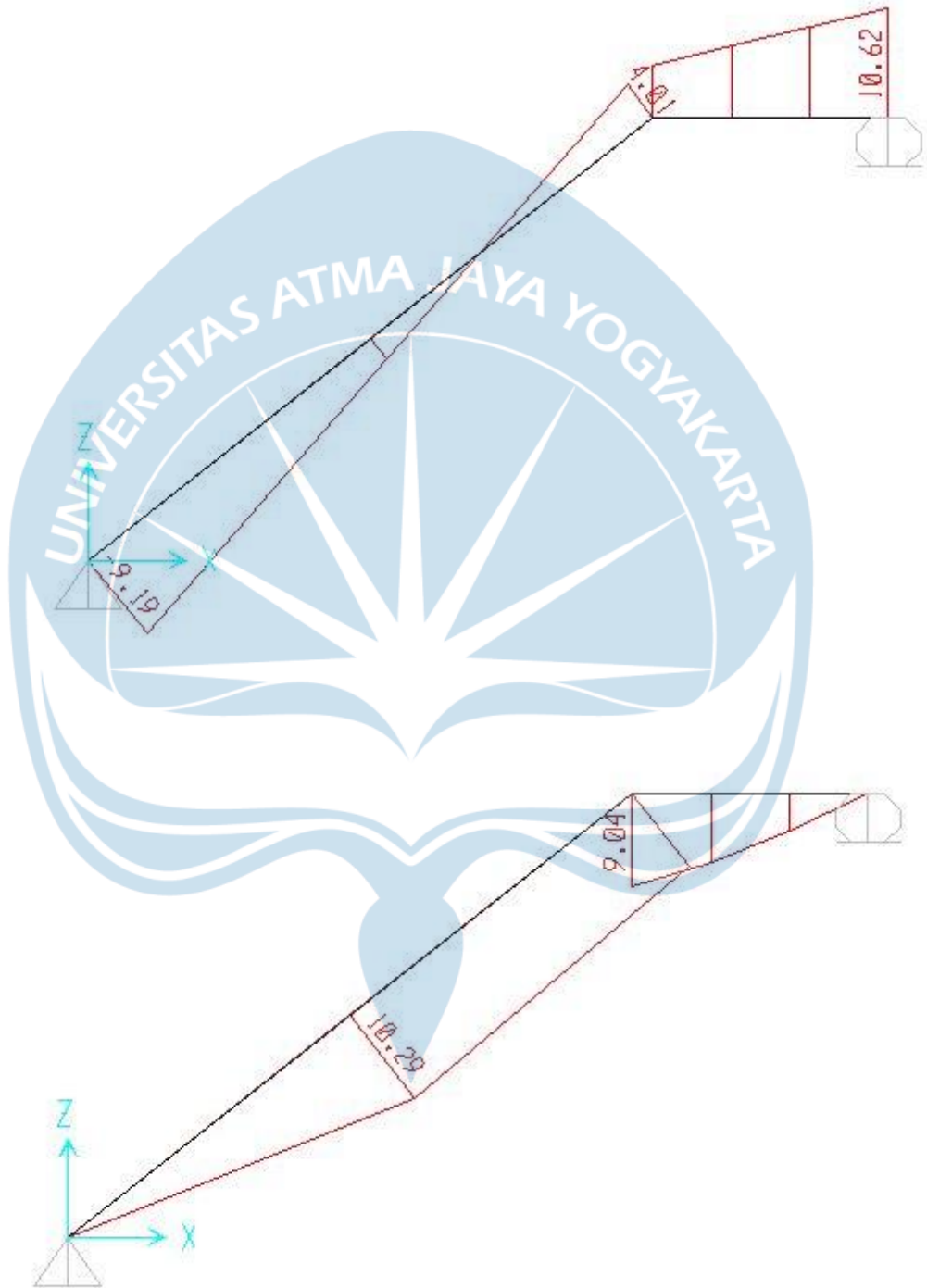
Beban qbd = $5,17 \text{ kN/ m}^2$

2. Beban hidup bangunan kantor: $4,8 \text{ kN/ m}^2$

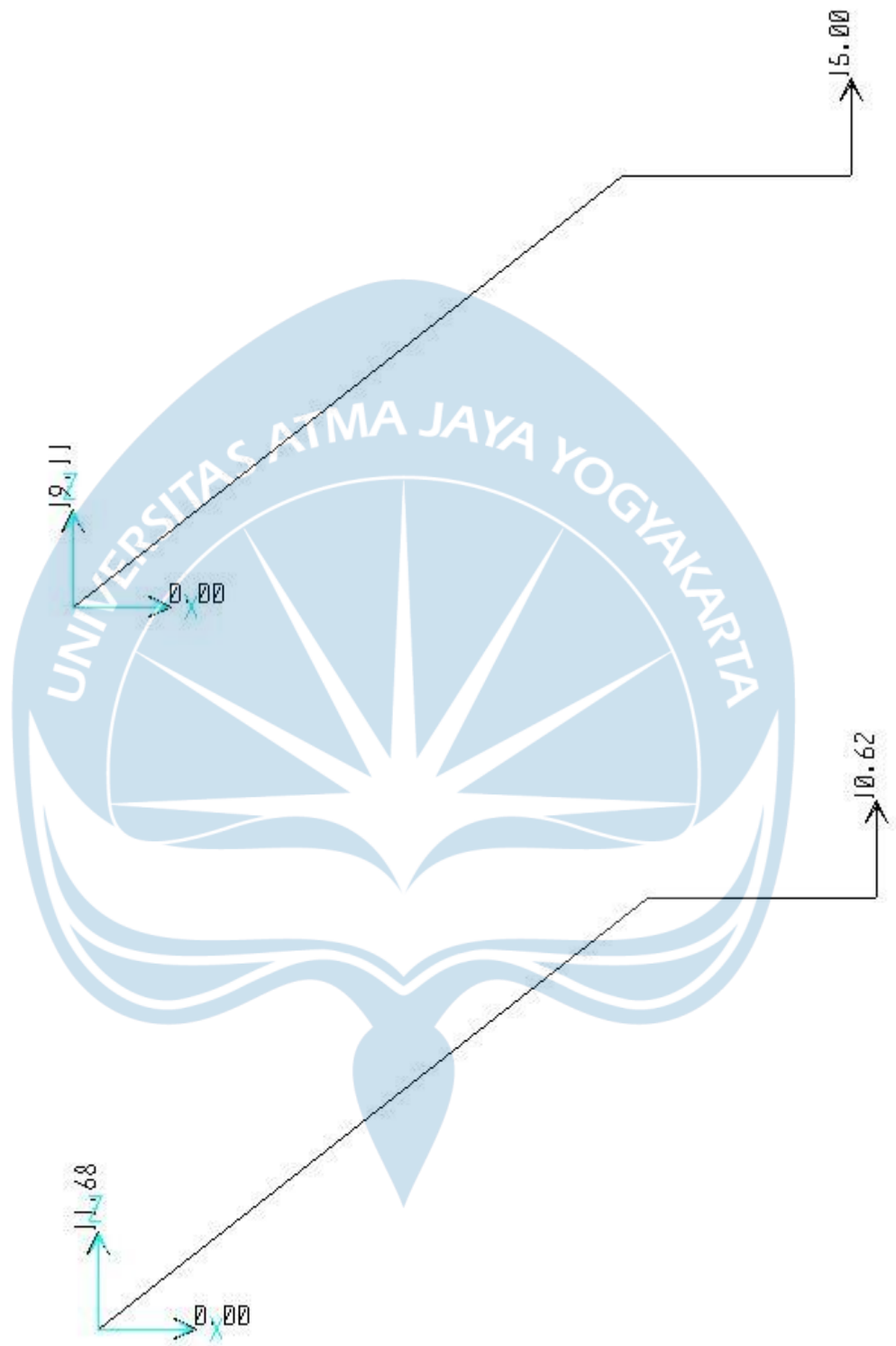
Pada gambar dibawah merupakan shear force diagram yang diakibatkan pembebanan pada daerah tangga. Nilai-nilai ini didapat melalui software SAP 2000.



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

$$Mu^- \text{ (Momen negatif)} = 0,5 \times \text{Mur} = 0,5 \times 36,384 = 18,192 \text{ kNm}$$

Direncanakan :

- Tulangan Pokok (D13)

$$As = \frac{1}{4} \times \pi \times D^2 = \frac{1}{4} \times \pi \times 13 \times 13 = 132,732 \text{ mm}^2$$

- Tulangan Susut (P8)

$$As = \frac{1}{4} \times \pi \times P^2 = \frac{1}{4} \times \pi \times 8 \times 8 = 50,265 \text{ mm}^2$$

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

$$ds = h - (ti + (\frac{1}{2} \times D)) = 130 - (20 + \frac{13}{2}) = 103,5 \text{ mm}$$

$$k = \frac{Mux}{\phi \cdot b \cdot ds^2} = \frac{18,192 \times 10^6}{0,9 \cdot 1000 \cdot 103,5^2} = 1,887 \text{ MPa}$$

$$\begin{aligned}\rho_{\text{perlu}} &= \frac{0,85}{f_y} \cdot f_c \left(1 - \sqrt{1 - \frac{2k}{0,85 \cdot f_c}} \right) \\ &= \frac{0,85}{420} \cdot 25 \left(1 - \sqrt{1 - \frac{2 \cdot 1,887}{0,85 \cdot 25}} \right) \\ &= 4,71 \cdot 10^{-3}\end{aligned}$$

$$\rho_{\text{min}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 3,33 \cdot 10^{-3}$$

$$\begin{aligned}\rho_{\text{max}} &= 0,75 \cdot \left(\frac{0,85 \cdot f_c \cdot \beta}{f_y} \right) \left(\frac{600}{600 + f_y} \right) \\ &= 0,75 \cdot \left(\frac{0,85 \cdot 25 \cdot 0,85}{420} \right) \left(\frac{600}{600 + 420} \right) \\ &= 0,019\end{aligned}$$

Maka, $\rho_{\text{min}} < \rho_{\text{perlu}} < \rho_{\text{max}} >>> \text{OK!}$

$$A_s_{\text{perlu}} = \rho_{\text{perlu}} \cdot b \cdot d_s = 4,71 \cdot 10^{-3} \cdot 1000 \cdot 103,5 = 487,485 \text{ mm}^2$$

$$A_s_{\text{min}} = \rho_{\text{min}} \cdot b \cdot d_s = 3,33 \cdot 10^{-3} \cdot 1000 \cdot 103,5 = 344,655 \text{ mm}^2$$

$$A_s_{\text{perlu}} \geq A_s_{\text{min}}$$

$$\begin{aligned}\text{Spasi} &= \frac{A_s_{\text{tulangan}}}{A_s_{\text{perlu}}} \cdot b \\ &= \frac{132,732}{487,485} \cdot 1000 = 272,280 \approx 250 \text{ mm}\end{aligned}$$

➤ Maka digunakan Tulangan Utama D13-250

Cek terhadap geser

$$\begin{aligned}V_c &= 0,17 \cdot \lambda \cdot \sqrt{f_c} \cdot b \cdot d_s \\ &= 0,17 \cdot 1 \cdot \sqrt{25} \cdot 1000 \cdot 103,5 = 104,975 \text{ kN}\end{aligned}$$

$$\begin{aligned}\phi V_c &= 0,75 \cdot V_c \\ &= 0,75 \cdot 104,975 = 78,731 \text{ kN}\end{aligned}$$

$$V_{ur} = 32,74 \text{ kN}$$

Karena $\phi V_c \geq V_{ur}$ (Aman)

Tulangan Susut

$$A_s \text{ min} = 0,002 \times b \times d_s$$

$$= 0,002 \times 1000 \times 103,5 = 207 \text{ mm}^2$$

$$A_s \text{ tulangan} = 0,25 \times \pi \times P^2 = 0,25 \times \pi \times 8^2 = 50,265 \text{ mm}^2$$

$$\text{Spasi} = \frac{A_s \text{ Tulangan}}{A_s \text{ min}} \cdot b$$

$$= \frac{50,265}{207} \cdot 1000 = 242,826 \approx 200 \text{ mm}$$

$$A_s = A_s \text{ tulangan} \cdot \frac{b}{s}$$
$$= 50,265 \cdot \frac{1000}{200} = 251,327 \text{ mm}^2$$

$A_s > A_s \text{ min} >>> \text{Ok (Aman)}$

Maka digunakan Tulangan Susut P8-200

2. Rencana Penulangan Lapangan Tangga

$$M_u^+ \text{ (Momen positif)} = 0,8 \times M_{\text{ur}} = 0,8 \times 36,384 = 29,107 \text{ kNm}$$

Direncanakan:

Tulangan Utama (D13)

$f'_c = 25 \text{ MPa}$; $f_y = 420 \text{ MPa}$; selimut beton = 20 mm ; $b = 1000 \text{ mm}$; $\phi = 0,9$

$$d_s = h - (t_i + (\frac{1}{2} \times D)) = 130 - (20 + 13/2) = 103,5 \text{ mm}$$

$$k = \frac{M_{ux}}{\phi \cdot b \cdot d_s^2} = \frac{29,107 \times 10^6}{0,9 \cdot 1000 \cdot 103,5^2} = 3,019 \text{ MPa}$$

$$\rho \text{ perlu} = \frac{0,85}{f_y} \cdot f'_c \left(1 - \sqrt{1 - \frac{2k}{0,85 \cdot f'_c}} \right)$$
$$= \frac{0,85}{420} \cdot 25 \left(1 - \sqrt{1 - \frac{2 \cdot 3,019}{0,85 \cdot 25}} \right)$$
$$= 7,79 \cdot 10^{-3}$$

$$\rho \text{ min} = \frac{1,4}{f_y} = \frac{1,4}{420} = 3,33 \cdot 10^{-3}$$

$$\rho \text{ max} = 0,75 \cdot \left(\frac{0,85 \cdot f'_c \cdot \beta}{f_y} \right) \left(\frac{600}{600 + f_y} \right)$$

$$= 0,75 \cdot \left(\frac{0,85 \cdot 25 \cdot 0,85}{420} \right) \left(\frac{600}{600+420} \right)$$

$$= 0,019$$

Maka, $\rho_{\min} < \rho_{\text{perlu}} < \rho_{\max} \gg \gg$ OK!

$$A_s \text{ perlu} = \rho_{\text{perlu}} \times b \times d_s = 0,0079 \cdot 1000 \cdot 103,5 = 817,65 \text{ mm}^2$$

$$A_s \text{ min} = \rho_{\min} \times b \times d_s = 3,33 \cdot 10^{-3} \cdot 1000 \cdot 103,5 = 344,655 \text{ mm}^2$$

$$\text{Spasi} = \frac{A_s \text{ tulangan}}{A_s \text{ perlu}} \cdot b$$

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

➤ Maka digunakan Tulangan Utama D13-150

Cek terhadap geser

$$V_c = 0,17 \cdot \lambda \cdot \sqrt{f_c} \cdot b \cdot d_s$$

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

$$\phi V_c = 0,75 \cdot V_c$$

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

$$V_{ur} = 32,74 \text{ kN}$$

Karena $\phi V_c \geq V_{ur}$ (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:

$$h_{\text{minimum}} = \frac{4000}{16} = 250 \text{ mm}$$

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 = $(0,25 \times 0,35) \times 24 = 2,1 \text{ kN/m}$
- Reaksi tangga (DL) = 15,00 kN/m
- Berat dinding = $2,34 \times 2,5 \text{ kN/m}^2 = 5,85 \text{ kN/m}$
QDL = 22,95 kN/m
QLL = 10,62 kN/m

$$Q_u = 1,2 \text{ DL} + 1,6 \text{ LL} = 1,2(22,95) + 1,6(10,62) = 44,532 \text{ kN/m}$$

$$M_u = 1/8 \times q_u \times L^2 = \frac{1}{8} \times 44,532 \times 4^2 = 89,064 \text{ kNm}$$

$$M_u \text{ tumpuan} = 0,5 \times 89,064 = 44,532 \text{ kNm}$$

$$M_u^+ \text{ lapangan} = 0,8 \times 89,064 = 71,2512 \text{ kNm}$$

$$V_u \text{ tumpuan} = q_u \times L_1 = 44,532 \times 4 = 178,128 \text{ kN}$$

$$V_u \text{ lapangan} = \frac{1}{2} \times q_u \times L_1 = \frac{1}{2} \times 44,532 \times 4 = 89,064 \text{ kN}$$

Spesifikasi balok:

$$f_y = 420 \text{ Mpa}$$

$$f'_c = 25 \text{ Mpa}$$

$$\text{Selimut} = 40 \text{ mm}$$

$$B_1 = 0,85$$

1. Tulangan tumpuan

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

$$d = h - d_s$$

$$= 350 - 56,5 = 293,5 \text{ mm}$$

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

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

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

$$= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(2,29759)}{0,85 \times 25}} \right)$$

$$= 0,0058033$$

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

Digunakan yang besar = $\rho_{\min} = 0,00333$

$$\rho_{\max} = 0,429 \times \frac{0,85 \times f'c \times \beta_1}{f_y}$$

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

$$= 0,0184495$$

$$\rho_{\min} \leq \rho \leq \rho_{\max} \dots (\text{OK!})$$

$$A_s = \rho \times b \times d$$

$$= 0,0058033 \times 250 \times 293,5 = 425,8159 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

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

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

Menghitung spasi tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkang} - n D_{tul}}{n - 1}$$
$$= \frac{250 - (2 \times 40) - (2 \times 10) - (4 \times 13)}{4 - 1} = 32,667 \text{ mm} > 25 \text{ mm (Aman!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'_c \times b}$$

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

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

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

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

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

$$M_n = 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2} \right)$$

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

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

$$\Phi M_n > M_u \text{ Aman!}$$

Perhitungan Geser

$$V_c = 0,17 \times \lambda \times \sqrt{f'_c} \times b \times d$$

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

$$= 62368,75 \text{ N}$$

$$V_s = \frac{V_u}{\Phi} - V_c$$

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

Cek nilai V_s

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

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

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

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

$$s = \frac{A_v \times f_{yt} \times d}{V_s}$$

$$s = \frac{157,0796 \times 280 \times 293,5}{175135,25} = 73,70763 \text{ mm}$$

Diambil spasi = 50 mm

➤ Sehingga tulangan Sengkang yang digunakan adalah 2P10-50

2. Tulangan Lapangan

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

$$d = h - d_s$$

$$= 350 - 56,5 = 293,5 \text{ mm}$$

$$k = \frac{M_n}{b d^2} = \frac{M_u(\mp)}{\Phi b d^2}$$

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

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

$$= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(3,67615)}{0,85 \times 25}} \right)$$

$$= 0,009678$$

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

Digunakan yang besar = $\rho_{\min} = 0,00333$

$$\begin{aligned} \rho_{\max} &= 0,429 \times \frac{0,85 \times f'c \times \beta_1}{f_y} \\ &= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420} \\ &= 0,0184495 \end{aligned}$$

$\rho_{\min} \leq \rho \leq \rho_{\max}$... (OK!)

$$\begin{aligned} A_s &= \rho \times b \times d \\ &= 0,009678 \times 250 \times 293,5 = 710,1559 \text{ mm}^2 \end{aligned}$$

Hitung Jumlah tulangan yang dibutuhkan

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

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

Menghitung spasi tulangan

$$\begin{aligned} s_1 &= \frac{b - 2c_c - 2d_{\text{senggang}} - n D_{\text{tul}}}{n - 1} \\ &= \frac{250 - (2 \times 40) - (2 \times 10) - (6 \times 13)}{6 - 1} = 14,4 \text{ mm} < 25 \text{ mm (Tidak OK!)} \end{aligned}$$

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

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

$$d = h - d_s$$

$$= 350 - 75,5 = 274,5 \text{ mm}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'c \times b}$$

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

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

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

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

$$= 0,008887 > 0,005 \rightarrow \text{Terkendali Tarik } \Phi = 0,9$$

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

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

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

$$\Phi Mn > Mu \text{ Aman!}$$

Perhitungan Geser

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

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

$$= 58331,25 \text{ N}$$

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

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

Cek nilai Vs

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

$$60420,75 \leq 226462,5 \dots(\text{OK!})$$

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

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

$$s = \frac{A_v \times f_{yt} \times d}{V_s}$$

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

Diambil spasi = 150 mm

➤ Sehingga tulangan Senggang yang digunakan adalah 2P10-150

Perhitungan Pondasi (Dimensi dan Tulangan)

$$\gamma_{\text{tanah}} = 16,3 \text{ kN/m}^3$$

$$\sigma_{\text{tanah}} = 310 \text{ kN/m}^2$$

$$\gamma_{\text{beton}} = 24 \text{ kN/m}^3$$

$$H_{\text{pondasi}} = 0,15 \text{ m}$$

$$B_{\text{tg}} = 0,15 \text{ m}$$

$$d = 1,5 \text{ m}$$

$$B = 1,2 \text{ m (asumsi)}$$

Beban tangga pada pondasi:

$$\text{-Beban mati tangga (DL)} = 19,11 \text{ kN/m}$$

$$\text{-Beban hidup tangga (LL)} = 11,68 \text{ kN/m}$$

$$\text{-Beban dinding} = 0,15 \times 1,5 \times 25 = 5,4 \text{ kN/m}$$

$$36,19 \text{ kN/m}$$

Direncanakan:

$$B = 1,2 \text{ m}$$

$$e = 0,5 \times \frac{Mu}{qtg} = 0,5 \times \frac{36,38}{36,19} = 0,503 \text{ m}$$

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

$$\begin{aligned}\sigma_{\text{netto}} &= 310 - (1.5 - 0.15)(16,3) - (0.15 \times 24) \\ &= 284,395 \text{ kN/m}^2\end{aligned}$$

Cek tegangan:

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

Menghitung tegangan terfaktor

$$\text{-Beban mati tangga (DL) } \times 1,2 = 19,11 \times 1,2 = 22,932 \text{ kN/m}$$

$$\text{-Beban hidup tangga (LL) } \times 1,6 = 11,68 \times 1,6 = 18,69 \text{ kN/m}$$

$$\text{-Beban dinding} = 0,15 \times 1,5 \times 24 \times 1,2 = 6,48 \text{ kN/m}$$

$$48,1 \text{ kN/m}$$

$$e = 0,5 \times \frac{Mu}{qutg} = 0,5 \times \frac{36,38}{48,1} = 0,3782 \text{ m}$$

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

$$\begin{aligned}\sigma_{\text{netto}} &= 310 - (1.5 - 0.15)(16,3) - (0.15 \times 24) \\ &= 284,395 \text{ kN/m}^2\end{aligned}$$

Cek tegangan:

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

Rencana penulangan pelat

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

$$= 8,1742 \text{ kNm}$$

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

$$Vu = 16,3483 \text{ kN}$$

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

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

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

$$= 104975 \text{ N} = 104,975 \text{ kN}$$

$$\Phi V_c = 0,75 \times 104,975$$

$$= 78,7313 \text{ kN}$$

Karena $\Phi V_c > V_u$, maka pondasi aman terhadap geser

4. Menghitung Tulangan Utama

$$k = \frac{Mn}{bd^2} = \frac{Mu}{\Phi bd^2} = \frac{8174163}{0,9 \times 1000 \times 123,5^2} = 0,5954796$$

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

$$= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(0,5954796)}{0,85 \times 25}} \right)$$

$$\rho = 0,001439$$

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

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

$$= 0,01845$$

$\rho < \rho_{\text{maks}}$ -> aman

Menghitung As min (Sni 2847:2019 pasal 7.6.1.1)

$$As_{\text{min 1}} = \frac{0,0018 \times 420}{f_y} \times A_g$$

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

$$= 222,3 \text{ mm}^2$$

$$As_{\text{min 2}} = 0,0014 A_g$$

$$= 0,0014 \times 1000 \times 123,5$$

$$= 172,9 \text{ mm}^2$$

Nilai As min yang menentukan adalah nilai As min terbesar yaitu $222,3 \text{ mm}^2$

Menghitung nilai As

$$As = \rho \times b \times d$$

$$= 0,001439 \times 1000 \times 123,5$$

$$= 177,62398 \text{ mm}^2$$

Oleh karena nilai $As < As_{\text{min}}$, maka yang digunakan adalah nilai As min

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

$$S_{min 1} = 3 \times h = 3 \times 150 = 450 \text{ mm}$$

$$S_{min 2} = 450 \text{ mm}$$

Nilai smin yang menentukan adalah yang terkecil yaitu 450 mm

Menghitung nilai Spasi

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

Spasi yang digunakan adalah 450 mm

➤ Maka, digunakan tulangan D13- 450

5. Menghitung Tulangan Susut

Digunakan tulangan P8 dengan f_{yt} 280 Mpa

$$d = 150 - 20 - 13 - (8/2) = 113 \text{ mm}$$

$$A_s = 0,002 \times 1000 \times 113 = 226 \text{ mm}^2$$

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

➤ 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) $\rightarrow b \times h = 400 \times 800 \text{ (mm)}$

- Balok induk

Bentang B2 = 10 m

Balok Induk Lantai 2 (Tipe 2) → $b \times h = 400 \times 700$ (mm)

- Balok anak

Bentang BA = 10 m

Balok Anak → $b \times h = 300 \times 550$ (mm)

- Ring Balk

Bentang RB = 10 m

Ring Balk → $b \times h = 300 \times 550$ (mm)

- Sloof

Bentang S = 10 m

Sloof → $b \times h = 250 \times 450$ (mm)

- Balok lisplang

Bentang BL = 10 m

Balok Lisplang → $b \times h = 250 \times 600$ (mm)

- Balok Kantilever

Bentang BK = 1,5 m

Balok Kantilever → $b \times h = 400 \times 600$ (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/m²
LL = 4,8 kN/m²

d. Beban Gempa

Bangunan terletak di Kecamatan Sungai Kunjang, maka beban gempa menggunakan respon spektrum kota Samarinda dengan nilai $S_s = 0.1167$ g dan $S_1 = 0.0956$ 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

E_c : $4700 \sqrt{f'c} = 23500$ 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 S_s dan S_1

Cek Hasil Analisis :

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

Tabel 2.4 *Mass Contribution Factor*

<i>Load</i>	<i>Multiplier</i>
SIDL	1
LL	0,3

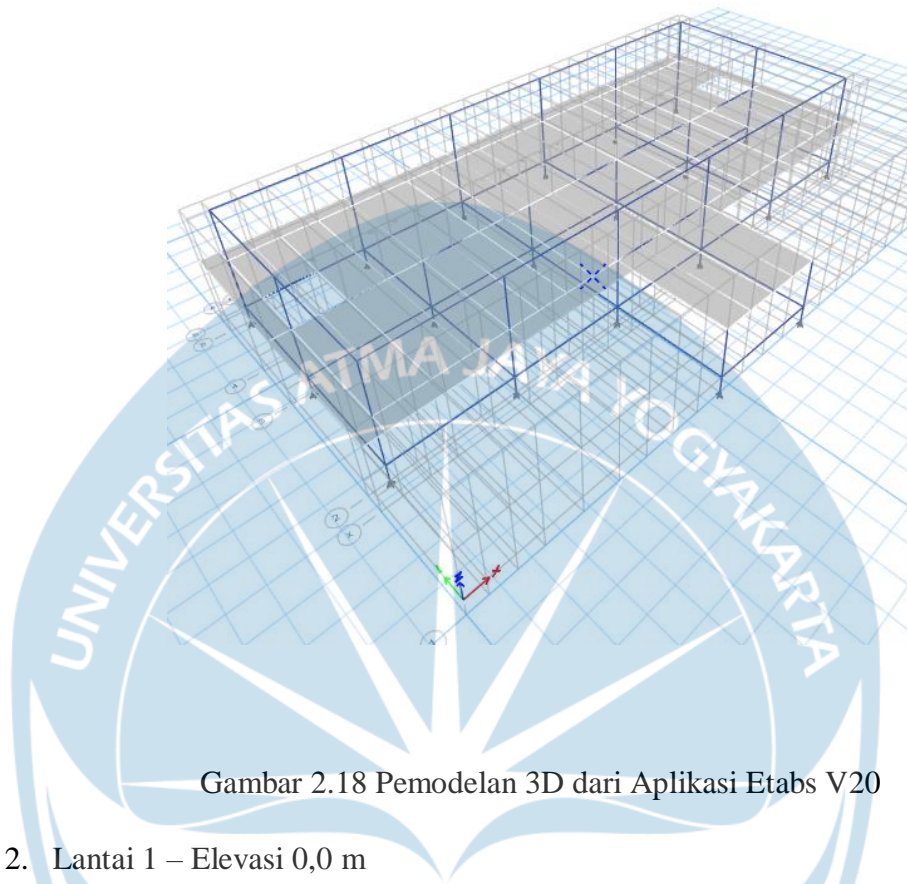
Koefisien respon seismik

$$C_s = 0,0249$$

2.3.4. Pemodelan

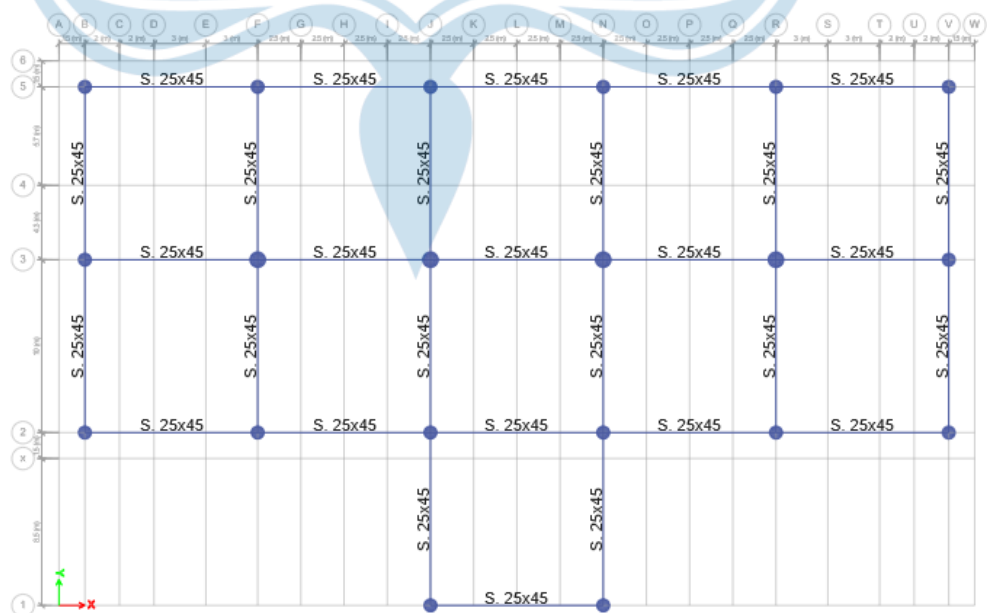
Berdasarkan data-data yang ada, dilakukan pemodelan pada Etabs V20 sesuai dengan gambar dibawah ini.

1. 3D View



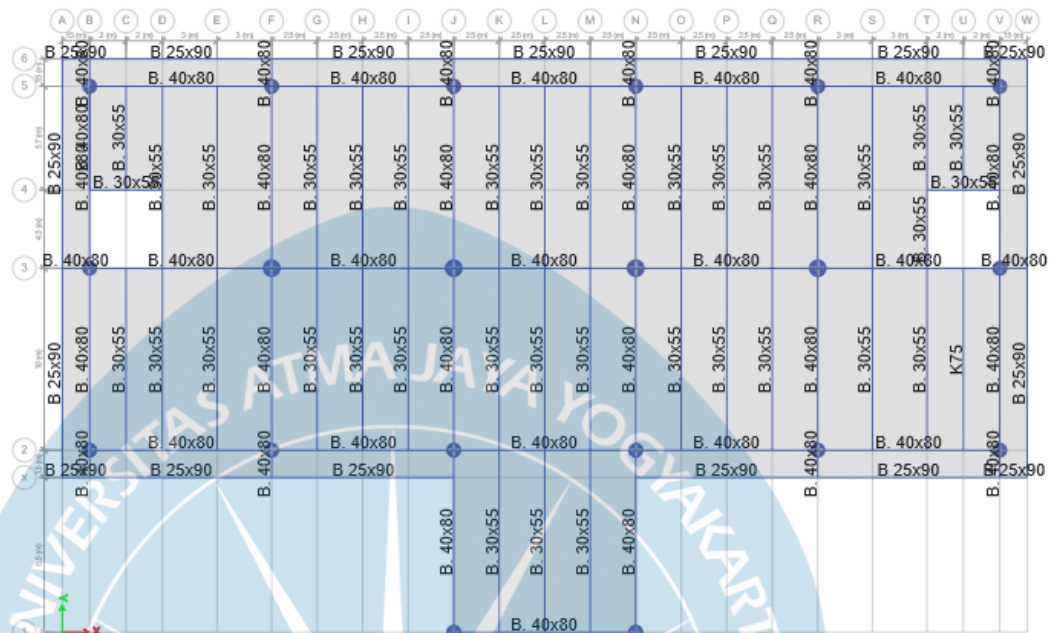
Gambar 2.18 Pemodelan 3D dari Aplikasi Etabs V20

2. Lantai 1 – Elevasi 0,0 m



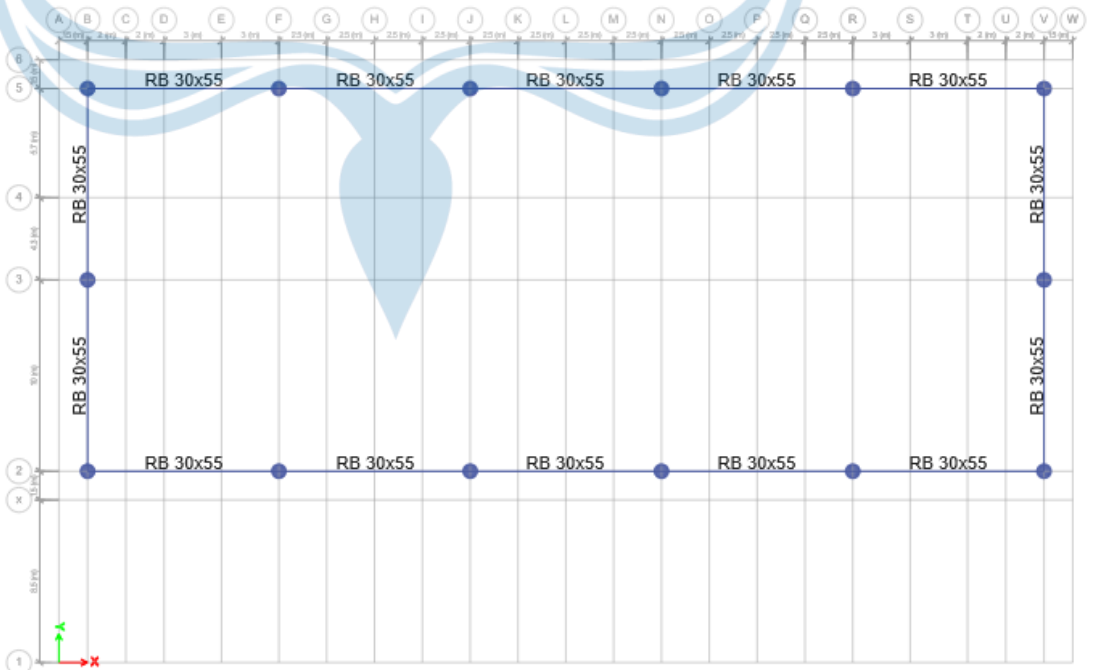
Gambar 2.19 Denah balok lantai 1

3. Lantai 2 – Elevasi 4,5 m



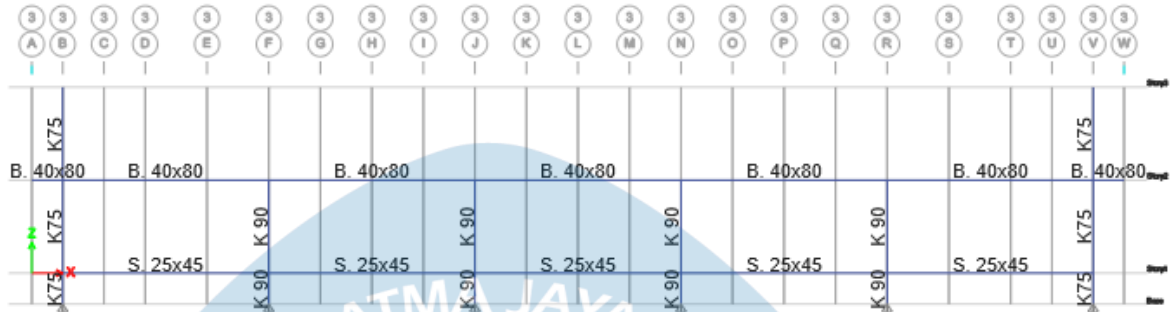
Gambar 2.20 Denah balok lantai 2

4. RING – Elevasi 9 m



Gambar 2.21 Denah ring balk

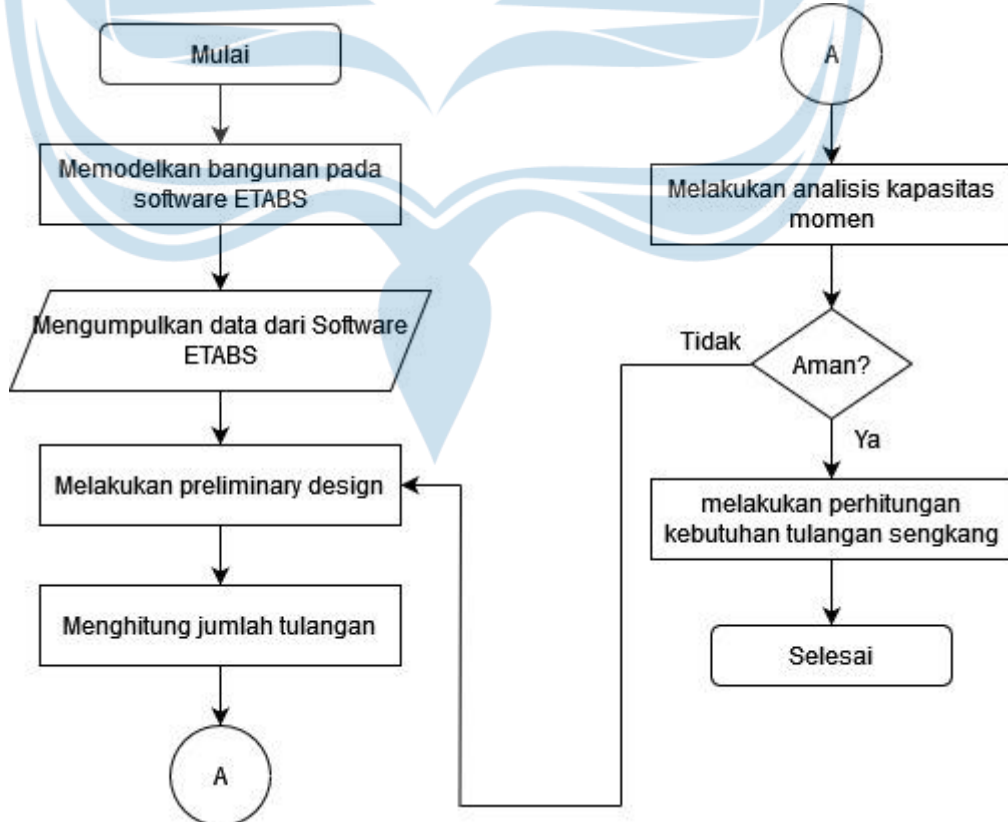
2.4. Perancangan Portal



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: $f_y = 420$ MPa

Mutu Baja sengkang: $f_{ys} = 280$ 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)

$P_u = 0$ kN-m (dari ETABS)

$$\begin{aligned} A_g \times \frac{f'_c}{10} &= (400 \times 800) \times \frac{25}{10} \\ &= 800.000 \text{ N} \\ &= 800 \text{ kN} > P_u \text{ Aman!} \end{aligned}$$

B. Desain Tulangan Lentur

➤ Perencanaan Tulangan Tumpuan Atas

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

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

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

$$= 40 + 12 + (25/2)$$

$$= 64,5 \text{ mm}$$

$$\text{Tinggi efektif (d)} = h - d'$$

$$= 800 - 64,5$$

$$= 735,5 \text{ mm}$$

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

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

$$\begin{aligned}\rho &= \frac{0,85x f'c}{f_y} \left(1 - \sqrt{1 - \frac{2k}{0,85 f'c}} \right) \\ &= \frac{0,85x25}{420} \left(1 - \sqrt{1 - \frac{2(5,30541)}{0,85x25}} \right) \\ &= 0,0148\end{aligned}$$

$$\begin{aligned}\rho_{maks} &= 0,429 \times \frac{0,85 \times f'c \times \beta_1}{f_y} \\ &= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420} \\ &= 0,0184496\end{aligned}$$

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

$$\rho_{min 2} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{min use} = 0,00333 \text{ (terbesar)}$$

$$\rho_{min} < \rho < \rho_{maks} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,0148 \times 400 \times 735,5 = 4352,73316 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

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

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

Spasi antar tulangan

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

$$= \frac{400 - (2 \times 40) - (2 \times 12) - (9 \times 25)}{9 - 1} = 8,875 \text{ mm} < 25 \text{ mm (Tidak Memenuhi!)}$$

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

$$a = \frac{A_s \times f_y}{0,85 \times f'_c \times b}$$

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

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

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

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

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

$$\Phi M_n = 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2}\right)$$

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

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

$\Phi M_n < M_u$ Tidak Aman!

Coba menggunakan 10 tulangan

baris pertama (n1) = 6 buah

baris kedua (n2) = 4 buah

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

Analisis kapasitas momen

Tinggi efektif baru (d) = 713,5 mm

$$a = \frac{A_s \times f_y}{0,85 \times f'_c \times b}$$

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

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

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

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

$$= 0,00450546$$

$$\Phi = (0,75 + (\epsilon_t - 0,002)) \times 50$$

$$= (0,75 + (0,00450546 - 0,002)) \times 50$$

$$\Phi = 0,875273$$

$$\Phi M_n = 0,875273 \times A_s \times f_y \times \left(d - \frac{a}{2}\right)$$

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

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

$\Phi M_n > M_u$ Aman!

Maka digunakan 10D25

➤ Perencanaan Tulangan Tumpuan Bawah

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

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

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

$$= 40 + 12 + (25/2)$$

$$= 64,5 \text{ mm}$$

$$\text{Tinggi efektif (d)} = h - d'$$

$$= 800 - 64,5$$

$$= 735,5 \text{ mm}$$

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

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

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

$$= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(4,01378)}{0,85 \times 25}} \right)$$

$$= 0,01068$$

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

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

$$= 0,0184496$$

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

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\text{min use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\text{min}} < \rho < \rho_{\text{maks}} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,01068 \times 400 \times 735,5 = 3143,48595 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

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

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

Spasi antar tulangan

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

$$= \frac{400 - (2 \times 40) - (2 \times 12) - (7 \times 25)}{7 - 1} = 20,17 \text{ mm} < 25 \text{ mm (Tidak Memenuhi!)}$$

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

$$a = \frac{A_s \times f_y}{0,85 \times f'_c \times b}$$

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

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

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

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

$$= 0,007939 > 0,005, \text{ Terkendali Tarik } \Phi = 0,9$$

$$\Phi M_n = 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2} \right)$$

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

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

$\Phi Mn > Mu$ Aman!

Maka digunakan 7D25

➤ Perencanaan Tulangan Lapangan Atas

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

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

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

$$= 40 + 12 + (25/2)$$

$$= 64,5 \text{ mm}$$

$$\text{Tinggi efektif (d)} = h - d'$$

$$= 800 - 66,5$$

$$= 735,5 \text{ mm}$$

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

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

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

$$= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(2,58124)}{0,85 \times 25}} \right)$$

$$= 0,006573$$

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

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

$$= 0,0184496$$

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

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$\rho_{min\ use} = 0,00333$ (terbesar)

$\rho_{min} < \rho < \rho_{maks}$ (Aman!)

$$A_s = \rho \times b \times d$$

$$= 0,006573 \times 400 \times 735,5 = 1933,66979 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

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

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

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkan} - n D_{tul}}{n - 1}$$
$$= \frac{400 - (2 \times 40) - (2 \times 12) - (4 \times 25)}{4 - 1} = 65,33 \text{ mm} > 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'_c \times b}$$

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

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

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

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

$$= 0,01633 > 0,005, \text{ Terkendali Tarik } \Phi = 0,9$$

$$\Phi M_n = 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2}\right)$$

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

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

$\Phi Mn > Mu$ Aman!

Maka digunakan 4D25

➤ Perencanaan Tulangan Lapangan Bawah

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

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

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

= 40 + 12 + (25/2)

= 64,5 mm

Tinggi efektif (d) = h-d'

= 800 - 66,5

= 735,5 mm

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

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

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

= $\frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(4,01378)}{0,85 \times 25}} \right)$

= 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

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

$$\rho_{\min 2} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\min \text{ use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\min} < \rho < \rho_{\max} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,01068 \times 400 \times 735,5 = 3143,48595 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

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

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

Spasi antar tulangan

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

$$= \frac{400 - (2 \times 40) - (2 \times 12) - (7 \times 25)}{7 - 1} = 20,17 \text{ mm} < 25 \text{ mm (Tidak Memenuhi!)}$$

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

$$\text{baris pertama (n1)} = 1 \text{ buah (sisi dalam)}$$

$$\text{baris kedua (n2)} = 6 \text{ buah (sisi luar)}$$

Analisis kapasitas momen

$$\text{Tinggi efektif baru (d)} = 728,35714 \text{ mm}$$

$$a = \frac{A_s \times f_y}{0,85 \times f'_c \times b}$$

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

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

$$\begin{aligned}\epsilon t &= \frac{(d - c)}{c} \times 0,003 \\ &= \frac{(728,35714 - 199,74659)}{199,74659} \times 0,003 \\ &= 0,00793922 > 0,005, \text{ Terkendali Tarik } \Phi = 0,9\end{aligned}$$

$$\begin{aligned}\Phi Mn &= 0,9 \times As \times fy \times \left(d - \frac{a}{2}\right) \\ &= 0,9 \times 3436,11696 \times 420 \times \left(728,35714 - \frac{169,7846}{2}\right) \\ &= 835,76573 \times 10^6 \text{ Nmm} = 835,76573 \text{ kNm}\end{aligned}$$

$\Phi Mn > Mu$ Aman!

Maka digunakan 7D25

➤ Perencanaan Tulangan Transversal

Menghitung nilai Mpr balok

$$\begin{aligned}Mpr- &= Ast \times 1 \times fy \times \left(d - \frac{a}{2}\right) \\ &= 10 \times \frac{1}{4} \times \pi \times 25^2 \times 1 \times 420 \times \left(713,9 - \frac{242,54943}{2}\right) \\ &= 1221,79787 \times 10^6 \text{ Nmm} = 1221,79787 \text{ kNm}\end{aligned}$$

$$\begin{aligned}Mpr+ &= Ast \times 1 \times fy \times \left(d - \frac{a}{2}\right) \\ &= 7 \times \frac{1}{4} \times \pi \times 25^2 \times 1 \times 420 \times \left(728,35714 - \frac{169,7846}{2}\right) \\ &= 928,628592 \times 10^6 \text{ Nmm} = 928,628592 \text{ kNm}\end{aligned}$$

$$Ln = 9,6 \text{ m}$$

$$Vg = 366,185 \text{ kN (dari ETABS)}$$

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

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

$$\begin{aligned}
 V_{u1} &= V_s \text{ ways} + V_g \\
 &= 224,00276 \text{ kN} + 366,185 \text{ kN} \\
 &= 590,18776 \text{ kN}
 \end{aligned}$$

$$\begin{aligned}
 V_{u2} &= V_{2E} \\
 &= 378,8 \text{ kN}
 \end{aligned}$$

$V_u \text{ use} = 590,18776 \text{ kN}$ (gunakan nilai tegangan geser yang terbesar)

➤ Tulangan Transversal Tumpuan

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

$$\begin{aligned}
 V_c &= 0,17 \times \lambda \times \sqrt{f'_c} \times b \times d \\
 &= 0,17 \times 1 \times \sqrt{25} \times 400 \times 713,9 \\
 &= 242726 \text{ N} \\
 &= 242,726 \text{ kN}
 \end{aligned}$$

$$\begin{aligned}
 V_s &= \frac{V_u}{\phi} - V_c \\
 &= \frac{590,18776}{0,75} - 242,726 \\
 &= 544,191 \text{ kN}
 \end{aligned}$$

Memeriksa batasan dimensi penampang

$$V_s < 0,66 \times \sqrt{f'_c} \times b_w \times d$$

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

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

$$\begin{aligned}
 \text{Spasi} &= \frac{A_v \times f_y \times d}{V_s} \\
 &= \frac{226,19467 \times 280 \times 713,9}{544,191 \times 10^3} = 83,08573 \text{ mm}
 \end{aligned}$$

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

$$\text{Smaks 2} = d.1 \times 8 = 25 \times 8 = 200 \text{ mm}$$

$$S_{maks\ 3} = d.s \times 24 = 12 \times 24 = 288 \text{ mm}$$

$$S_{maks\ 4} = 300 \text{ mm}$$

Digunakan spasi terkecil yaitu 83,08573 mm = 50 mm

Maka digunakan tulangan 2d12-50

➤ Tulangan Transversal Lapangan

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

$$\begin{aligned} V_{e\ max} &= V_{sways} + V_g \\ &= 224,00276 \text{ kN} + 366,185 \text{ kN} \\ &= 590,18776 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_{e\ min} &= V_g - V_{sways} \\ &= 366,185 \text{ kN} - 224,00276 \text{ kN} \\ &= 142,18224 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_{e\ lapangan} &= \frac{Ln-2h}{Ln} (V_{e\ max} - V_{e\ min}) + V_{e\ min} \\ &= \frac{9,6-2(0,8)}{9,6} (590,18776 - 142,18224) + 142,18224 \\ &= 515,52017 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_c &= 0,17 \times \lambda \times \sqrt{f'_c} \times b_w \times d \\ &= 0,17 \times 1 \times \sqrt{25} \times 400 \times 713,9 \\ &= 242726 \text{ N} \\ &= 242,726 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_s &= \frac{V_u}{\phi} - V_c \\ &= \frac{515,52}{0,75} - 242,726 \\ &= 444,634 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{Spasi} &= \frac{A_v \times f_y \times d}{V_s} \\ &= \frac{226,19467 \times 280 \times 713,9}{444,634 \times 10^3} = 101,68921 \text{ mm} \end{aligned}$$

$$S_{maks\ 1} = \frac{d}{4} = \frac{716,92857}{4} = 178,475\text{ mm}$$

$$S_{maks\ 2} = d.l \times 8 = 25 \times 8 = 200\text{ mm}$$

$$S_{maks\ 3} = d.s \times 24 = 12 \times 24 = 288\text{ mm}$$

$$S_{maks\ 4} = 300\text{ mm}$$

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: $f_y = 420\text{ MPa}$

Mutu Baja sengkang: $f_{ys} = 280\text{ MPa}$

Mutu Beton: $f'_c = 25\text{ MPa}$

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)

$P_u = 0\text{ kN-m}$ (dari ETABS)

$$A_g \times \frac{f'_c}{10} = (400 \times 700) \times \frac{25}{10}$$

$$= 700.000\text{ N}$$

$$= 700\text{ kN} > P_u\text{ Aman!}$$

B. Desain Tulangan Lentur

➤ Perencanaan Tulangan Tumpuan Atas

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

$$\text{Momen Nominal } (M_n) = \frac{M_u}{\phi} = \frac{553,0314}{0,9} = 614,479 \text{ kN-m}$$

$$d' = c_c + d_s + (d_l/2)$$

$$= 40 + 12 + (25/2)$$

$$= 64,5 \text{ mm}$$

Tinggi efektif (d) = $h - d'$

$$= 700 - 64,5$$

$$= 635,5 \text{ mm}$$

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

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

$$\rho = \frac{0,85 \times F'_c}{F_y} \left(1 - \sqrt{1 - \frac{2k}{0,85 F'_c}} \right)$$

$$= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(3,80379)}{0,85 \times 25}} \right)$$

$$= 0,01006$$

$$\rho_{\text{maks}} = 0,429 \times \frac{0,85 \times f'_c \times \beta_1}{f_y}$$

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

$$= 0,0184496$$

$$\rho_{\text{min 1}} = \frac{\sqrt{F'_c}}{4 \times f_y} = \frac{\sqrt{25}}{4 \times 420} = 0,002976$$

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$\rho_{\text{min use}} = 0,00333$ (terbesar)

$\rho_{\text{min}} < \rho < \rho_{\text{maks}}$ (Aman!)

$$A_s = \rho \times b \times d$$

$$= 0,01006 \times 400 \times 635,5 = 2556,22569 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

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

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

Spasi antar tulangan

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

$$= \frac{400 - (2 \times 40) - (2 \times 12) - (6 \times 25)}{6 - 1} = 29,2 \text{ mm} < 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f_c \times b}$$

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

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

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

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

$$= 0,00813 > 0,005 \text{ Terkendali Tarik} \quad \Phi = 0,9$$

$$\Phi M_n = 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2}\right)$$

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

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

$\Phi Mn > Mu$ Aman!

Maka digunakan 6D25

➤ Perencanaan Tulangan Tumpuan Bawah

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

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

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

$$= 40 + 12 + (25/2)$$

$$= 64,5 \text{ mm}$$

$$\text{Tinggi efektif (d)} = h - d'$$

$$= 700 - 64,5$$

$$= 635,5 \text{ mm}$$

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

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

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

$$= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(2,53739)}{0,85 \times 25}} \right)$$

$$= 0,006453$$

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

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

$$= 0,0184496$$

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

$$\rho_{\min 2} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\min \text{ use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\min} < \rho < \rho_{\max} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,006453 \times 400 \times 635,5 = 1640,32846 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

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

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

Spasi antar tulangan

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

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

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'_c \times b}$$

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

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

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

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

$$= 0,0137 > 0,005, \text{ Terkendali Tarik } \Phi = 0,9$$

$$\Phi M_n = 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2} \right)$$

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

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

$\Phi Mn > Mu$ Aman!

Maka digunakan 4D25

➤ Perencanaan Tulangan Lapangan Atas

$$\text{Momen Ultimet (Mu)} = 250,1975 \text{ kN-m (dari ETABS)}$$

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

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

$$= 40 + 12 + (25/2)$$

$$= 64,5 \text{ mm}$$

$$\text{Tinggi efektif (d) = h-d'}$$

$$= 700 - 64,5$$

$$= 635,5 \text{ mm}$$

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

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

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

$$= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(1,72087)}{0,85 \times 25}} \right)$$

$$= 0,004278$$

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

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

$$= 0,0184496$$

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

$$\rho_{\min 2} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\min \text{ use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\min} < \rho < \rho_{\max} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,0184496 \times 400 \times 635,5 = 1087,51799 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

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

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

Spasi antar tulangan

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

$$= \frac{400 - (2 \times 40) - (2 \times 12) - (3 \times 25)}{3 - 1} = 110,5 \text{ mm} > 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'c \times b}$$

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

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

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

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

$$= 0,01927 > 0,005, \text{ Terkendali Tarik } \Phi = 0,9$$

$$\begin{aligned}
 Mn &= 0,9 \times As \times fy \times \left(d - \frac{a}{2}\right) \\
 &= 0,9 \times 1472,6216 \times 420 \times \left(635,5 - \frac{72,76483}{2}\right) \\
 &= 333,49937 \times 10^6 \text{ Nmm} = 333,49937 \text{ kNm}
 \end{aligned}$$

$\Phi Mn > Mu$ Aman!

Maka digunakan 3D25

➤ Perencanaan Tulangan Lapangan Atas

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

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

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

$$= 40 + 12 + (25/2)$$

$$= 64,5 \text{ mm}$$

$$\text{Tinggi efektif (d)} = h - d'$$

$$= 700 - 64,5$$

$$= 635,5 \text{ mm}$$

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

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

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

$$= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(2,535276)}{0,85 \times 25}}\right)$$

$$= 0,00645$$

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

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

$$= 0,0184496$$

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

$$\rho_{\min 2} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\min \text{ use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\min} < \rho < \rho_{\max} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,00645 \times 400 \times 635,5 = 1638,8632 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

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

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

Spasi antar tulangan

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

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

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'c \times b}$$

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

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

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

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

$$= 0,013703 > 0,005, \text{ Terkendali Tarik } \Phi = 0,9$$

$$\begin{aligned}\Phi Mn &= 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2}\right) \\ &= 0,9 \times 1963,4954 \times 420 \times \left(635,5 - \frac{97,01978}{2}\right) \\ &= 435,6648 \times 10^6 \text{ Nmm} = 435,6648 \text{ kNm}\end{aligned}$$

$$\Phi Mn > Mu \text{ Aman!}$$

Maka digunakan 4D25

➤ Perencanaan Tulangan Transversal

Menghitung nilai Mpr balok

$$\begin{aligned}\text{Mpr-} &= A_{st} \times 1 \times f_y \times \left(d - \frac{a}{2}\right) \\ &= 6 \times \frac{1}{4} \times \pi \times 25^2 \times 1 \times 420 \times \left(635,5 - \frac{145,52966}{2}\right) \\ &= 696,10459 \times 10^6 \text{ Nmm} = 696,10459 \text{ kNm}\end{aligned}$$

$$\begin{aligned}\text{Mpr+} &= A_{st} \times 1 \times f_y \times \left(d - \frac{a}{2}\right) \\ &= 4 \times \frac{1}{4} \times \pi \times 25^2 \times 1 \times 420 \times \left(635,5 - \frac{97,01978}{2}\right) \\ &= 484,072 \times 10^6 \text{ Nmm} = 484,072 \text{ kNm}\end{aligned}$$

$$L_n = 9,6 \text{ m}$$

$$V_g = 178,14 \text{ kN (dari ETABS)}$$

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

$$V_{s \text{ ways}} = \frac{(M_{pr-}) + (M_{pr+})}{L_n} = \frac{696,10459 + 484,072}{9,6} = 112,93506 \text{ kN}$$

$$\begin{aligned}V_{u1} &= V_{s \text{ ways}} + V_g \\ &= 112,93506 \text{ kN} + 178,14 \text{ kN} \\ &= 301,08366 \text{ kN}\end{aligned}$$

$$\begin{aligned} V_{u2} &= V_{2E} \\ &= 194,1162 \text{ kN} \end{aligned}$$

$$V_{u \text{ use}} = 301,08366 \text{ kN (gunakan nilai tegangan geser yang terbesar)}$$

➤ Tulangan Transversal Tumpuan

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

$$\begin{aligned} V_c &= 0,17 \times \lambda \times \sqrt{f'_c} \times b_w \times d \\ &= 0,17 \times 1 \times \sqrt{25} \times 400 \times 635,5 \end{aligned}$$

$$= 216070 \text{ N}$$

$$= 216,07 \text{ kN}$$

$$\begin{aligned} V_s &= \frac{V_u}{\phi} - V_c \\ &= \frac{301,08366}{0,75} - 216,07 \end{aligned}$$

$$= 185,37488 \text{ kN}$$

Memeriksa batasan dimensi penampang

$$V_s < 0,66 \times \sqrt{f'_c} \times b_w \times d$$

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

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

$$\begin{aligned} \text{Spasi} &= \frac{A_v \times f_y \times d}{V_s} \\ &= \frac{226,19467 \times 280 \times 635,5}{185,37488 \times 10^3} = 217,12262 \text{ mm} \end{aligned}$$

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

$$\text{Smaks 2} = d.l \times 8 = 25 \times 8 = 200 \text{ mm}$$

$$\text{Smaks 3} = d.s \times 24 = 12 \times 24 = 288 \text{ mm}$$

$$\text{Smaks 4} = 300 \text{ mm}$$

Digunakan spasi terkecil yaitu 158,875 mm = 150 mm

Maka digunakan tulangan 2d12-150

➤ Tulangan Transversal Lapangan

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

$$\begin{aligned} V_{e \text{ max}} &= V_{\text{sways}} + V_g \\ &= 122,93506 \text{ kN} + 178,1486 \text{ kN} \\ &= 301,08366 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_{e \text{ min}} &= V_g - V_{\text{sways}} \\ &= 178,1486 \text{ kN} - 122,93506 \text{ kN} \\ &= 55,21354 \text{ N} \end{aligned}$$

$$\begin{aligned} V_{e \text{ lapangan}} &= \frac{L_n - 2h}{L_n} (V_{e \text{ max}} - V_{e \text{ min}}) + V_{e \text{ min}} \\ &= \frac{9,6 - 2(0,7)}{9,6} (301,08366 - 55,21354) + 55,21354 \\ &= 265,2276 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_c &= 0,17 \times \lambda \times \sqrt{f'_c} \times b_w \times d \\ &= 0,17 \times 1 \times \sqrt{25} \times 400 \times 635,5 \\ &= 21607 \text{ N} \\ &= 216,07 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_s &= \frac{V_u}{\phi} - V_c \\ &= \frac{265,2276}{0,75} - 216,07 \\ &= 137,5668 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{Spasi} &= \frac{A_v \times f_y \times d}{V_s} \\ &= \frac{226,19467 \times 280 \times 635,5}{137,5668 \times 10^3} = 292,57843 \text{ mm} \end{aligned}$$

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

$$\text{Smaks 2} = d.1 \times 8 = 25 \times 8 = 200 \text{ mm}$$

$$S_{maks\ 3} = d.s \times 24 = 12 \times 24 = 288 \text{ mm}$$

$$S_{maks\ 4} = 300 \text{ mm}$$

Digunakan spasi terkecil yaitu $158,875 \text{ mm} = 150 \text{ mm}$

Maka digunakan tulangan $2d12-150$

3. Balok Anak

Desain Balok Anak (300x550) mm

$$\text{Mutu Baja longitudinal: } f_y = 420 \text{ MPa}$$

$$\text{Mutu Baja sengkang: } f_{ys} = 280 \text{ MPa}$$

$$\text{Mutu Beton: } f'_c = 25 \text{ MPa}$$

Ukuran Struktur:

$$b \text{ balok} = 300 \text{ mm}$$

$$h \text{ balok} = 550 \text{ mm}$$

$$\text{selimut beton} = 40 \text{ mm}$$

$$\text{diameter tulangan pokok (d.l)} = 19 \text{ mm}$$

$$\text{diameter Sengkang (d.s)} = 8 \text{ mm}$$

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

$$P_u = 0 \text{ kN-m (dari ETABS)}$$

$$A_g \times \frac{f'_c}{10} = (300 \times 550) \times \frac{25}{10}$$

$$= 412.500 \text{ N}$$

$$= 412,5 \text{ kN} > P_u \text{ Aman!}$$

B. Desain Tulangan Lentur

➤ Perencanaan Tulangan Tumpuan Atas

$$\text{Momen Ultimet (Mu)} = 324,8168 \text{ kN-m (dari ETABS)}$$

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

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

$$= 40 + 8 + (19/2)$$

$$= 57,5 \text{ mm}$$

$$\text{Tinggi efektif (d)} = h - d'$$

$$= 550 - 57,5$$

$$= 492,5 \text{ mm}$$

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

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

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

$$= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(4,95977813)}{0,85 \times 25}} \right)$$

$$= 0,01365041$$

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

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

$$= 0,0184496$$

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

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\text{min use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\text{min}} < \rho < \rho_{\text{maks}} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,01365041 \times 300 \times 492,5 = 2016,84826 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

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

$$A_s \text{ use} = 8 \times \frac{1}{4} \times \pi \times 19^2 = 2268,23 \text{ mm}^2$$

Spasi antar tulangan

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

$$= \frac{300 - (2 \times 40) - (2 \times 8) - (8 \times 19)}{8 - 1} = 7,4285 \text{ mm} < 25 \text{ mm (Tidak$$

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

$$a = \frac{A_s \times f_y}{0,85 \times f'_c \times b}$$

$$a = \frac{2268,23 \times 420}{0,85 \times 25 \times 300} = 149,4363 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{149,4363}{0,85} = 175,8074 \text{ mm}$$

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

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

$$= 0,005123 > 0,005, \text{ Terkendali Tarik } \Phi = 0,9$$

$$\Phi M_n = 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2} \right)$$

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

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

$\Phi Mn > Mu$ Aman!

Maka digunakan 8D19

➤ Perencanaan Tulangan Tumpuan Bawah

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

Momen Nominal (Mn) = $\frac{Mu}{\phi} = \frac{188,8119}{0,9} = 209,791$ 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) = $\frac{Mn}{bd^2}$

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

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

= $\frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(2,88305)}{0,85 \times 25}} \right)$

= 0,00740653

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

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

= 0,0184496

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

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

$\rho_{min use} = 0,00333$ (terbesar)

$\rho_{min} < \rho < \rho_{maks}$ (Aman!)

$$A_s = \rho \times b \times d$$

$$= 0,00740653 \times 300 \times 492,5 = 1094,31532 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

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

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

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkan} - n D_{tul}}{n - 1}$$
$$= \frac{300 - (2 \times 40) - (2 \times 8) - (4 \times 19)}{4 - 1} = 42,67 \text{ mm} > 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'_c \times b}$$

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

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

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

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

$$= 0,001380 > 0,005, \text{ Terkendali Tarik } \Phi = 0,9$$

$$\Phi M_n = 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2}\right)$$

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

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

$\Phi Mn > Mu$ Aman!

Maka digunakan 4D19

➤ Perencanaan Tulangan Lapangan Atas

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

$$\text{Momen Nominal (Mn)} = \frac{M_u}{\phi} = \frac{101,353}{0,9} = 112,6144 \text{ kN-m}$$

$$\begin{aligned} d' &= cc + d.s + (d.l/2) \\ &= 40 + 8 + (19/2) \\ &= 57,5 \text{ mm} \end{aligned}$$

$$\begin{aligned} \text{Tinggi efektif (d)} &= h - d' \\ &= 550 - 57,5 \\ &= 492,5 \text{ mm} \end{aligned}$$

$$\begin{aligned} \text{Koefisien (k)} &= \frac{M_n}{bd^2} \\ &= \frac{112,6144 \times 10^6}{300 \times 492,5^2} = 1,5476 \end{aligned}$$

$$\begin{aligned} \rho &= \frac{0,85 f'c}{f_y} \left(1 - \sqrt{1 - \frac{2k}{0,85 f'c}} \right) \\ &= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(1,5476)}{0,85 \times 25}} \right) \end{aligned}$$

$$= 0,00382972$$

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

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

$$= 0,0184496$$

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

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$\rho_{min\ use} = 0,00333$ (terbesar)

$\rho_{min} < \rho < \rho_{maks}$ (Aman!)

$$A_s = \rho \times b \times d$$

$$= 0,0038972 \times 300 \times 492,5 = 565,8408 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

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

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

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkan} - n D_{tul}}{n - 1}$$
$$= \frac{300 - (2 \times 40) - (2 \times 8) - (2 \times 19)}{2 - 1} = 166 \text{ mm} > 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'_c \times b}$$

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

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

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

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

$$= 0,03062 > 0,005, \text{ Terkendali Tarik } \Phi = 0,9$$

$$\Phi M_n = 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2}\right)$$

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

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

$\Phi Mn > Mu$ Aman!

Maka digunakan 2D13

➤ Perencanaan Tulangan Lapangan Atas

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

Momen Nominal (M_n) = $\frac{M_u}{\phi} = \frac{173,4244}{0,9} = 192,6938$ kN-m

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

$$= 40 + 8 + (19/2)$$

$$= 57,5 \text{ mm}$$

Tinggi efektif (d) = $h - d'$

$$= 550 - 57,5$$

$$= 492,5 \text{ mm}$$

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

$$= \frac{192,6938 \times 10^6}{300 \times 492,5^2} = 2,648097$$

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

$$= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(2,648097)}{0,85 \times 25}} \right)$$

$$= 0,006756$$

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

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

$$= 0,0184496$$

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

$$\rho_{\min 2} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\min \text{ use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\min} < \rho < \rho_{\max} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,006756 \times 300 \times 492,5 = 998,209148 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{998,209148}{\frac{1}{4} \times \pi \times 19^2} = 3,520663 \approx 4 \text{ buah}$$

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

Spasi antar tulangan

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

$$= \frac{300 - (2 \times 40) - (2 \times 8) - (4 \times 19)}{4 - 1} = 38,75 \text{ mm} > 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'c \times b}$$

$$a = \frac{1134,11495 \times 420}{0,85 \times 25 \times 300} = 74,718161 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{74,718161}{0,85} = 87,90372 \text{ mm}$$

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

$$= \frac{(492,5 - 87,90372)}{87,90372} \times 0,003$$

$$= 0,0130808 > 0,005, \text{ Terkendali Tarik } \Phi = 0,9$$

$$\begin{aligned}\Phi M_n &= 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2}\right) \\ &= 0,9 \times 420 \times \left(492,5 - \frac{74,718161}{2}\right) \\ &= 195,1168 \times 10^6 \text{ Nmm} = 195,1168 \text{ kNm}\end{aligned}$$

$\Phi M_n > M_u$ Aman!

Maka digunakan 4D19

➤ Perencanaan Tulangan Transversal

$$V_u \text{ Tumpuan} = 164,68 \text{ kN}$$

$$V_u \text{ Lapangan} = 105,1 \text{ kN}$$

1. Tulangan Transversal Tumpuan

$$A_v = 2 \times \frac{1}{4} \times \pi \times 8^2 = 100,531 \text{ mm}^2$$

$$V_c = 0,17 \times \lambda \times \sqrt{f'_c} \times b_w \times d$$

$$= 0,17 \times 1 \times \sqrt{25} \times 300 \times 476$$

$$= 121380 \text{ N}$$

$$= 121,380 \text{ kN}$$

$$V_s = \frac{V_u}{\phi} - V_c$$

$$= \frac{164,68}{0,75} - 121,380$$

$$= 98,1933 \text{ kN}$$

Memeriksa batasan dimensi penampang

$$V_s < 0,66 \times \sqrt{f'_c} \times b_w \times d$$

$$98,1933 < 0,66 \times \sqrt{25} \times 300 \times 476$$

$$98,1933 < 471,240 \text{ kN} \quad (\text{Aman!})$$

$$\text{Spasi} = \frac{A_v \times f_y \times d}{V_s}$$

$$= \frac{100,531 \times 280 \times 476}{98,1933 \times 10^3} = 141,1829 \text{ mm}$$

$$\text{Smaks 1} = \frac{d}{2} = \frac{476}{2} = 238 \text{ mm}$$

$$\text{Smaks 2} = 600 \text{ mm}$$

Digunakan spasi terkecil yaitu 141,1829 mm = 100 mm

Maka digunakan tulangan 2d8-100

2. Tulangan Transversal Lapangan

$$A_v = 2 \times \frac{1}{4} \times \pi \times 8^2 = 100,531 \text{ mm}^2$$

$$V_c = 0,17 \times \lambda \times \sqrt{f'_c} \times b_w \times d$$

$$= 0,17 \times 1 \times \sqrt{25} \times 300 \times 476$$

$$= 121380 \text{ N}$$

$$= 121,380 \text{ kN}$$

$$V_s = \frac{V_u}{\phi} - V_c$$

$$= \frac{105,126}{0,75} - 121,380$$

$$= 18,787 \text{ kN}$$

$$\text{Spasi} = \frac{A_v \times f_y \times d}{V_s}$$

$$= \frac{100,531 \times 280 \times 476}{18,787 \times 10^3} = 737,8868 \text{ mm}$$

$$\text{Smaks 1} = \frac{d}{2} = \frac{476}{2} = 238 \text{ mm}$$

$$\text{Smaks 2} = 600 \text{ mm}$$

Digunakan spasi terkecil yaitu 238 mm = 200 mm

Maka digunakan tulangan 2d8-200

4. Ring Balok

Desain Ring Balok (300x550) mm

Mutu Baja longitudinal: $f_y = 420$ MPa

Mutu Baja sengkang: $f_{ys} = 280$ 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)

$P_u = 0$ kN-m (dari ETABS)

$$A_g \times \frac{f'_c}{10} = (300 \times 550) \times \frac{25}{10}$$

$$= 412.500 \text{ N}$$

$$= 412,5 \text{ kN} > P_u \text{ Aman!}$$

B. Desain Tulangan Lentur

➤ Perencanaan Tulangan Tumpuan Atas

Momen Ultimet (M_u) = 129,8298 kN-m (dari ETABS)

Momen Nominal (M_n) = $\frac{M_u}{\phi} = \frac{129,8298}{0,9} = 144,25533$ kN-m

$d' = c_c + d.s + (d.l/2)$

$$= 40 + 8 + (19/2)$$

$$= 57,5 \text{ mm}$$

Tinggi efektif (d) = $h - d'$

$$= 550 - 57,5$$

$$= 492,5 \text{ mm}$$

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

$$= \frac{144,25533 \times 10^6}{300 \times 492,5^2} = 1,982431$$

$$\begin{aligned} \rho &= \frac{0,85 f'c}{f_y} \left(1 - \sqrt{1 - \frac{2k}{0,85 f'c}} \right) \\ &= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(1,982431)}{0,85 \times 25}} \right) \\ &= 0,0049635 \end{aligned}$$

$$\begin{aligned} \rho_{\text{maks}} &= 0,429 \times \frac{0,85 \times f'c \times \beta_1}{f_y} \\ &= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420} \\ &= 0,0184496 \end{aligned}$$

$$\rho_{\text{min 1}} = \frac{\sqrt{F'c}}{4 \times f_y} = \frac{\sqrt{25}}{4 \times 420} = 0,002976$$

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\text{min use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\text{min}} < \rho < \rho_{\text{maks}} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,0049635 \times 300 \times 492,5 = 733,3636 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{733,3636}{\frac{1}{4} \times \pi \times 19^2} = 2,586558 \approx 3 \text{ buah}$$

$$A_s \text{ use} = 3 \times \frac{1}{4} \times \pi \times 19^2 = 850,5862 \text{ mm}^2$$

Spasi antar tulangan

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

$$= \frac{300 - (2 \times 40) - (2 \times 8) - (3 \times 19)}{3 - 1} = 73,5 \text{ mm} > 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'_c \times b}$$

$$a = \frac{850,5862 \times 420}{0,85 \times 25 \times 300} = 56,03862 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{56,03862}{0,85} = 65,9278 \text{ mm}$$

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

$$= \frac{(492,5 - 65,9278)}{65,9278} \times 0,003$$

$$= 0,0194108 > 0,005, \text{ Terkendali Tarik } \Phi = 0,9$$

$$\Phi M_n = 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2} \right)$$

$$= 0,9 \times 850,5862 \times 420 \times \left(492,5 - \frac{56,03862}{2} \right)$$

$$= 149,3405 \times 10^6 \text{ Nmm} = 149,3405 \text{ kNm}$$

$\Phi M_n > M_u$ Aman!

Maka digunakan 3D19

➤ Perencanaan Tulangan Tumpuan Bawah

Momen Ultimet (M_u) = 120,2108 kN-m (dari ETABS)

$$\text{Momen Nominal (} M_n \text{)} = \frac{M_u}{\phi} = \frac{120,2108}{0,9} = 133,5675 \text{ kN-m}$$

$$d' = c_c + d_s + (d_l/2)$$

$$= 40 + 8 + (19/2)$$

$$= 57,5 \text{ mm}$$

$$\text{Tinggi efektif (} d \text{)} = h - d'$$

$$= 550 - 57,5$$

$$= 492,5 \text{ mm}$$

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

$$= \frac{133,5675 \times 10^6}{300 \times 492,5^2} = 1,8355$$

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

$$= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(1,8355)}{0,85 \times 25}} \right)$$

$$= 0,004577$$

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

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

$$= 0,0184496$$

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

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\text{min use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\text{min}} < \rho < \rho_{\text{maks}} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,004577 \times 300 \times 492,5 = 676,3154 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{676,3154}{\frac{1}{4} \times \pi \times 19^2} = 2,38535 \approx 3 \text{ buah}$$

$$A_s \text{ use} = 3 \times \frac{1}{4} \times \pi \times 19^2 = 850,5862 \text{ mm}^2$$

Spasi antar tulangan

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

$$= \frac{300 - (2 \times 40) - (2 \times 8) - (3 \times 19)}{3 - 1} = 73,5 \text{ mm} > 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'_c \times b}$$

$$a = \frac{850,5862 \times 420}{0,85 \times 25 \times 300} = 56,0386 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{56,0386}{0,85} = 65,927789 \text{ mm}$$

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

$$= \frac{(492,5 - 65,927789)}{65,927789} \times 0,003$$

$$= 0,001941 > 0,005, \text{ **Terkendali Tarik** } \Phi = 0,9$$

$$\Phi M_n = 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2} \right)$$

$$= 0,9 \times 850,5862 \times 420 \times \left(492,5 - \frac{56,0386}{2} \right)$$

$$= 149,340568 \times 10^6 \text{ Nmm} = 149,34056 \text{ kNm}$$

$\Phi M_n > M_u$ Aman!

Maka digunakan 3D19

➤ Perencanaan Tulangan Lapangan Atas

$$\text{Momen Ultimet (Mu)} = 97,414 \text{ kN-m (dari ETABS)}$$

$$\text{Momen Nominal (Mn)} = \frac{M_u}{\phi} = \frac{97,414}{0,9} = 108,23778 \text{ kN-m}$$

$$d' = c_c + d.s + (d.l/2)$$

$$= 40 + 8 + (19/2)$$

$$= 57,5 \text{ mm}$$

$$\text{Tinggi efektif (d)} = h - d'$$

$$= 550 - 57,5$$

$$= 492,5 \text{ mm}$$

$$\begin{aligned} \text{Koefisien } (k) &= \frac{Mn}{bd^2} \\ &= \frac{108,23778 \times 10^6}{300 \times 492,5^2} = 1,48746 \end{aligned}$$

$$\begin{aligned} \rho &= \frac{0,85 f'c}{f_y} \left(1 - \sqrt{1 - \frac{2k}{0,85 f'c}} \right) \\ &= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(1,48746)}{0,85 \times 25}} \right) \\ &= 0,003675 \end{aligned}$$

$$\begin{aligned} \rho_{\text{maks}} &= 0,429 \times \frac{0,85 \times f'c \times \beta_1}{f_y} \\ &= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420} \\ &= 0,0184496 \end{aligned}$$

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

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\text{min use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\text{min}} < \rho < \rho_{\text{maks}} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,003675 \times 300 \times 492,5 = 542.9872 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{542.9872}{\frac{1}{4} \times \pi \times 19^2} = 1,9151 \approx 2 \text{ buah}$$

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

Spasi antar tulangan

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

$$= \frac{300 - (2 \times 40) - (2 \times 8) - (2 \times 19)}{2 - 1} = 166 \text{ mm} > 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'_c \times b}$$

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

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

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

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

$$= 0,03062 > 0,005, \text{ **Terkendali Tarik** } \Phi = 0,9$$

$$\Phi M_n = 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2} \right)$$

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

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

$\Phi M_n > M_u$ Aman!

Maka digunakan 2D19

➤ Perencanaan Tulangan Lapangan Atas

Momen Ultimet (M_u) = 120,2077 kN-m (dari ETABS)

$$\text{Momen Nominal (Mn)} = \frac{M_u}{\phi} = \frac{120,2077}{0,9} = 133,5641 \text{ kN-m}$$

$$d' = c_c + d.s + (d.l/2)$$

$$= 40 + 8 + (19/2)$$

$$= 57,5 \text{ mm}$$

$$\text{Tinggi efektif (d)} = h - d'$$

$$= 550 - 57,5$$

$$= 492,5 \text{ mm}$$

$$\begin{aligned} \text{Koefisien } (k) &= \frac{Mn}{bd^2} \\ &= \frac{133,5641 \times 10^6}{300 \times 492,5^2} = 1,83551 \end{aligned}$$

$$\begin{aligned} \rho &= \frac{0,85 f'c}{f_y} \left(1 - \sqrt{1 - \frac{2k}{0,85 f'c}} \right) \\ &= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(1,83551)}{0,85 \times 25}} \right) \\ &= 0,004577 \end{aligned}$$

$$\begin{aligned} \rho_{\text{maks}} &= 0,429 \times \frac{0,85 \times f'c \times \beta_1}{f_y} \\ &= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420} \\ &= 0,0184496 \end{aligned}$$

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

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\text{min use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\text{min}} < \rho < \rho_{\text{maks}} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,004577 \times 300 \times 492,5 = 676,2972 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{676,2972}{\frac{1}{4} \times \pi \times 19^2} = 2,385286 \approx 3 \text{ buah}$$

$$A_s \text{ use} = 3 \times \frac{1}{4} \times \pi \times 19^2 = 850,5862 \text{ mm}^2$$

Spasi antar tulangan

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

$$= \frac{300 - (2 \times 40) - (2 \times 8) - (3 \times 19)}{3 - 1} = 73,5 \text{ mm} > 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

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

$$a = \frac{850,5862 \times 420}{0,85 \times 25 \times 300} = 56,03862 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{56,03862}{0,85} = 65,9278 \text{ mm}$$

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

$$= \frac{(492,5 - 65,9278)}{65,9278} \times 0,003$$

$$= 0,01941 > 0,005, \text{ **Terkendali Tarik** } \Phi = 0,9$$

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

$$= 0,9 \times 850,5862 \times 420 \times \left(492,5 - \frac{56,03862}{2} \right)$$

$$= 149,34056 \times 10^6 \text{ Nmm} = 149,34056 \text{ kNm}$$

$\Phi Mn > Mu$ Aman!

Maka digunakan 3D19

➤ Perencanaan Tulangan Transversal

Menghitung nilai Mpr balok

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

$$= 3 \times \frac{1}{4} \times \pi \times 19^2 \times 1 \times 420 \times \left(492,5 - \frac{56,038621}{2} \right)$$

$$= 165,9339 \times 10^6 \text{ Nmm} = 165,9339 \text{ kNm}$$

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

$$= 3 \times \frac{1}{4} \times \pi \times 19^2 \times 420 \times \left(492,5 - \frac{56,0386}{2} \right)$$

$$= 165,9339 \times 10^6 \text{ Nmm} = 165,933 \text{ kNm}$$

$$L_n = 9,6 \text{ m}$$

$$V_g = 22,9789 \text{ kN (dari ETABS)}$$

$$V_{2E} = 25,4954 \text{ kN (akibat beban } 1,2D + 2,0E + 1,0L)$$

$$V_{s \text{ ways}} = \frac{(M_{pr-}) + (M_{pr+})}{L_n} = \frac{165,9339 + 165,933}{9,6} = 34,2132 \text{ kN}$$

$$V_{u1} = V_{s \text{ ways}} + V_g$$

$$= 34,2132 \text{ kN} + 22,9789 \text{ kN}$$

$$= 57,1921 \text{ kN}$$

$$V_{u2} = V_{2E}$$

$$= 25,4954 \text{ kN}$$

$$V_{u \text{ use}} = 57,1921 \text{ kN (gunakan nilai tegangan geser yang terbesar)}$$

➤ Tulangan Transversal Tumpuan

$$A_v = 2 \times \frac{1}{4} \times \pi \times 8^2 = 100,5309 \text{ mm}^2$$

$$V_c = 0,17 \times \lambda \times \sqrt{f'_c} \times b_w \times d$$

$$= 0,17 \times 1 \times \sqrt{25} \times 300 \times 492,5$$

$$= 125587,5 \text{ N}$$

= 125,5875 kN (nilai V_c sudah lebih besar dari nilai V_u , maka digunakan spasi maks terkecil)

$$S_{\text{maks } 1} = \frac{d}{4} = \frac{492,5}{4} = 123,125 \text{ mm}$$

$$S_{\text{maks } 2} = d.l \times 8 = 19 \times 8 = 152 \text{ mm}$$

$$S_{\text{maks } 3} = d.s \times 24 = 8 \times 24 = 192 \text{ mm}$$

$$S_{\text{maks } 4} = 300 \text{ mm}$$

Digunakan spasi terkecil yaitu 123,125 mm = 100 mm

Maka digunakan tulangan 2d8-100

➤ Tulangan Transversal Lapangan

$$A_v = 2 \times \frac{1}{4} \times \pi \times 8^2 = 100,5309 \text{ mm}^2$$

$$\begin{aligned} V_{e \text{ max}} &= V_{\text{sways}} + V_g \\ &= 34,2132 \text{ kN} + 22,9789 \text{ kN} \\ &= 57,1921 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_{e \text{ min}} &= V_g - V_{\text{sways}} \\ &= 22,9789 \text{ kN} - 34,2132 \text{ kN} \\ &= -11,2343 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_{e \text{ lapangan}} &= \frac{L_n - 2h}{L_n} (V_{e \text{ max}} - V_{e \text{ min}}) + V_{e \text{ min}} \\ &= \frac{9,7 - 2(0,55)}{9,7} (57,1921 - (-11,2343)) \\ &\quad + (-11,2343) \\ &= 49,4323 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_c &= 0,17 \times \lambda \times \sqrt{f'c} \times b_w \times d \\ &= 0,17 \times 1 \times \sqrt{25} \times 300 \times 492,5 \\ &= 125587,5 \text{ N} \end{aligned}$$

= 125,5875 kN (nilai V_c sudah lebih besar dari nilai V_u , maka digunakan spasi maks terkecil)

$$S_{\text{maks 1}} = \frac{d}{4} = \frac{492,5}{4} = 123,125 \text{ mm}$$

$$S_{\text{maks 2}} = d.l \times 8 = 19 \times 8 = 152 \text{ mm}$$

$$S_{\text{maks 3}} = d.s \times 24 = 8 \times 24 = 192 \text{ mm}$$

$$S_{\text{maks 4}} = 300 \text{ mm}$$

Digunakan spasi terkecil yaitu 123,125 mm = 100 mm

Maka digunakan tulangan 2d8-100

5. Sloof

Desain Sloof (250 x450) mm

Mutu Baja longitudinal: $f_y = 420$ MPa

Mutu Baja sengkang: $f_{ys} = 280$ 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)

$P_u = 0$ kN-m (dari ETABS)

$$A_g \times \frac{f'_c}{10} = (250 \times 450) \times \frac{25}{10}$$

$$= 281250 \text{ N}$$

$$= 281,25 \text{ kN} > P_u \text{ Aman!}$$

B. Desain Tulangan Lentur

➤ Perencanaan Tulangan Tumpuan Atas

Momen Ultimet (M_u) = 40,4504 kN-m (dari ETABS)

$$\text{Momen Nominal (Mn)} = \frac{M_u}{\phi} = \frac{40,4504}{0,9} = 44,94488 \text{ kN-m}$$

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

$$= 40 + 8 + (13/2)$$

$$= 54,5 \text{ mm}$$

$$\text{Tinggi efektif (d)} = h - d'$$

$$= 450 - 54,5$$

$$= 395,5 \text{ mm}$$

$$\begin{aligned} \text{Koefisien } (k) &= \frac{Mn}{bd^2} \\ &= \frac{44,94488 \times 10^6}{250 \times 395,5^2} = 1,149336 \end{aligned}$$

$$\begin{aligned} \rho &= \frac{0,85x f'c}{f_y} \left(1 - \sqrt{1 - \frac{2k}{0,85 F'c}} \right) \\ &= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(1,149336)}{0,85 \times 25}} \right) \\ &= 0,0028148 \end{aligned}$$

$$\begin{aligned} \rho_{\text{maks}} &= 0,429 \times \frac{0,85 \times f'c \times \beta_1}{f_y} \\ &= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420} \\ &= 0,0184496 \end{aligned}$$

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

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\text{min use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\text{min}} < \rho < \rho_{\text{maks}} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,0028148 \times 250 \times 395,5 = 278,3149 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{278,3149}{\frac{1}{4} \times \pi \times 13^2} = 2,09681 \approx 3 \text{ buah}$$

$$A_s \text{ use} = 3 \times \frac{1}{4} \times \pi \times 13^2 = 398,19687 \text{ mm}^2$$

Spasi antar tulangan

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

$$= \frac{250 - (2 \times 40) - (2 \times 8) - (3 \times 13)}{3 - 1} = 57,5 \text{ mm} < 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'_c \times b}$$

$$a = \frac{398,19687 \times 420}{0,85 \times 25 \times 250} = 31,48097 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{31,48097}{0,85} = 37,036444 \text{ mm}$$

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

$$= \frac{(395,5 - 37,036444)}{37,036444} \times 0,003$$

$$= 0,029036 > 0,005, \text{ **Terkendali Tarik** } \Phi = 0,9$$

$$\Phi M_n = 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2}\right)$$

$$= 0,9 \times 398,19687 \times 420 \times \left(395,5 - \frac{31,48097}{2}\right)$$

$$= 57,1608 \times 10^6 \text{ Nmm} = 57,1608 \text{ kNm}$$

$\Phi M_n > M_u$ Aman!

Maka digunakan 3D19

➤ Perencanaan Tulangan Tumpuan Bawah

$$\text{Momen Ultimet (Mu)} = 16,326 \text{ kN-m (dari ETABS)}$$

$$\text{Momen Nominal (Mn)} = \frac{M_u}{\phi} = \frac{16,326}{0,9} = 18,14 \text{ kN-m}$$

$$d' = c_c + d.s + (d.l/2)$$

$$= 40 + 8 + (13/2)$$

$$= 54,5 \text{ mm}$$

$$\text{Tinggi efektif (d)} = h - d'$$

$$= 450 - 54,5$$

$$= 395,5 \text{ mm}$$

$$\begin{aligned} \text{Koefisien } (k) &= \frac{Mn}{bd^2} \\ &= \frac{18,14 \times 10^6}{250 \times 395,5^2} = 0,463878 \end{aligned}$$

$$\begin{aligned} \rho &= \frac{0,85 f'c}{f_y} \left(1 - \sqrt{1 - \frac{2k}{0,85 f'c}} \right) \\ &= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(0,463878)}{0,85 \times 25}} \right) \\ &= 0,0011168 \end{aligned}$$

$$\begin{aligned} \rho_{\text{maks}} &= 0,429 \times \frac{0,85 \times f'c \times \beta_1}{f_y} \\ &= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420} \\ &= 0,0184496 \end{aligned}$$

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

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\text{min use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\text{min}} < \rho < \rho_{\text{maks}} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,0011168 \times 250 \times 395,5 = 110,42344 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{110,42344}{\frac{1}{4} \times \pi \times 13^2} = 0,83192 \approx 2 \text{ buah}$$

$$A_s \text{ use} = 2 \times \frac{1}{4} \times \pi \times 13^2 = 265,46458 \text{ mm}^2$$

Spasi antar tulangan

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

$$= \frac{250 - (2 \times 40) - (2 \times 8) - (2 \times 13)}{2 - 1} = 128 \text{ mm} > 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'_c \times b}$$

$$a = \frac{265,46458 \times 420}{0,85 \times 25 \times 250} = 20,9873 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{20,9873}{0,85} = 24,69096 \text{ mm}$$

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

$$= \frac{(395,5 - 24,69096)}{24,69096} \times 0,003$$

$$= 0,045054 > 0,005, \text{ **Terkendali Tarik** } \Phi = 0,9$$

$$\Phi M_n = 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2} \right)$$

$$= 0,9 \times 265,46458 \times 420 \times \left(395,5 - \frac{20,9873}{2} \right)$$

$$= 38,6333697 \times 10^6 \text{ Nmm} = 38,6333697 \text{ kNm}$$

$$\Phi M_n > M_u \text{ **Aman!**}$$

Maka digunakan 2D13

➤ Perencanaan Tulangan Lapangan Atas

Momen Ultimet (Mu) = 10,6349 kN-m (dari ETABS)

$$\text{Momen Nominal (Mn)} = \frac{M_u}{\phi} = \frac{10,6349}{0,9} = 11,81655 \text{ kN-m}$$

$$d' = c_c + d.s + (d.l/2)$$

$$= 40 + 8 + (13/2)$$

$$= 54,5 \text{ mm}$$

$$\text{Tinggi efektif (d)} = h - d'$$

$$= 450 - 54,5$$

$$= 492,5 \text{ mm}$$

$$\begin{aligned} \text{Koefisien } (k) &= \frac{Mn}{bd^2} \\ &= \frac{11,81655 \times 10^6}{250 \times 395,5^2} = 0,30217 \end{aligned}$$

$$\begin{aligned} \rho &= \frac{0,85 \times f'c}{f_y} \left(1 - \sqrt{1 - \frac{2k}{0,85 f'c}} \right) \\ &= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(0,30217)}{0,85 \times 25}} \right) \\ &= 0,0007246 \end{aligned}$$

$$\begin{aligned} \rho_{\text{maks}} &= 0,429 \times \frac{0,85 \times f'c \times \beta_1}{f_y} \\ &= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420} \\ &= 0,0184496 \end{aligned}$$

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

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\text{min use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\text{min}} < \rho < \rho_{\text{maks}} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,0007246 \times 250 \times 395,5 = 71,6500 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{71,6500}{\frac{1}{4} \times \pi \times 13^2} = 0,53981 \approx 2 \text{ buah}$$

$$A_s \text{ use} = 2 \times \frac{1}{4} \times \pi \times 13^2 = 265,464 \text{ mm}^2$$

Spasi antar tulangan

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

$$= \frac{250 - (2 \times 40) - (2 \times 8) - (2 \times 13)}{2 - 1} = 128 \text{ mm} > 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'_c \times b}$$

$$a = \frac{265,464 \times 420}{0,85 \times 25 \times 250} = 20,9873 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{20,9873}{0,85} = 24,6909 \text{ mm}$$

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

$$= \frac{(395,5 - 24,6909)}{24,6909} \times 0,003$$

$$= 0,045054 > 0,005, \text{ **Terkendali Tarik** } \Phi = 0,9$$

$$\Phi M_n = 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2} \right)$$

$$= 0,9 \times 265,464 \times 420 \times \left(395,5 - \frac{20,9873}{2} \right)$$

$$= 38,633697 \times 10^6 \text{ Nmm} = 38,633697 \text{ kNm}$$

$\Phi M_n > M_u$ Aman!

Maka digunakan 2D13

➤ Perencanaan Tulangan Lapangan Atas

Momen Ultimet (M_u) = 15,9292 kN-m (dari ETABS)

$$\text{Momen Nominal (} M_n \text{)} = \frac{M_u}{\phi} = \frac{15,9292}{0,9} = 17,6991 \text{ kN-m}$$

$$d' = c_c + d.s + (d.l/2)$$

$$= 40 + 8 + (13/2)$$

$$= 54,5 \text{ mm}$$

$$\begin{aligned} \text{Tinggi efektif (d)} &= h-d' \\ &= 450 - 54,5 \\ &= 395,5 \text{ mm} \end{aligned}$$

$$\begin{aligned} \text{Koefisien (k)} &= \frac{Mn}{bd^2} \\ &= \frac{17,6991 \times 10^6}{250 \times 395,5^2} = 0,45264 \end{aligned}$$

$$\begin{aligned} \rho &= \frac{0,85 \times f'c}{f_y} \left(1 - \sqrt{1 - \frac{2k}{0,85 f'c}} \right) \\ &= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(0,45264)}{0,85 \times 25}} \right) \\ &= 0,0010893 \end{aligned}$$

$$\begin{aligned} \rho_{\text{maks}} &= 0,429 \times \frac{0,85 \times f'c \times \beta_1}{f_y} \\ &= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420} \\ &= 0,0184496 \end{aligned}$$

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

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\text{min use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\text{min}} < \rho < \rho_{\text{maks}} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,0010893 \times 250 \times 395,5 = 107,7101 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{107,7101}{\frac{1}{4} \times \pi \times 13^2} = 0,8114 \approx 2 \text{ buah}$$

$$A_s \text{ use} = 2 \times \frac{1}{4} \times \pi \times 13^2 = 265,46458 \text{ mm}^2$$

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{senggang} - n D_{tul}}{n - 1}$$
$$= \frac{250 - (2 \times 40) - (2 \times 8) - (2 \times 13)}{2 - 1} = 128 \text{ mm} > 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'_c \times b}$$

$$a = \frac{265,464 \times 420}{0,85 \times 25 \times 250} = 20,9873 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{20,9873}{0,85} = 24,6909 \text{ mm}$$

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

$$= \frac{(395,5 - 24,6909)}{24,6909} \times 0,003$$

$$= 0,045054 > 0,005, \text{ Terkendali Tarik } \Phi = 0,9$$

$$M_n = 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2}\right)$$

$$= 0,9 \times 265,464 \times 420 \times \left(395,5 - \frac{20,9873}{2}\right)$$

$$= 38633697 \times 10^6 \text{ Nmm} = 38,633697 \text{ kNm}$$

$\Phi M_n > M_u$ Aman!

Maka digunakan 2D13

➤ Perencanaan Tulangan Transversal

Menghitung nilai Mpr balok

$$M_{pr} = A_{st} \times 1 \times f_y \times \left(d - \frac{a}{2}\right)$$

$$= 2 \times \frac{1}{4} \times \pi \times 16^2 \times 1 \times 420 \times \left(394 - \frac{31,7914}{2}\right)$$

$$= 63858796,1 \times 10^6 \text{ Nmm} = 63,8588 \text{ kNm}$$

$$M_{pr+} = A_{st} \times 1 \times f_y \times \left(d - \frac{a}{2}\right)$$

$$= 2 \times \frac{1}{4} \times \pi \times 16^2 \times 420 \times \left(394 - \frac{31,7914}{2}\right)$$

$$= 63858796,1 \times 10^6 \text{ Nmm} = 63,8588 \text{ kNm}$$

$$L_n = 9,6 \text{ m}$$

$$V_g = 12,8415 \text{ kN (dari ETABS)}$$

$$V_{2E} = 15,539 \text{ kN (akibat beban } 1,2D + 2,0E + 1,0L)$$

$$V_{s \text{ ways}} = \frac{(M_{pr-}) + (M_{pr+})}{L_n} = \frac{63,8588 + 63,8588}{9,6} = 13,0992 \text{ kN}$$

$$V_{u1} = V_{s \text{ ways}} + V_g$$

$$= 13,0992 \text{ kN} + 12,8415 \text{ kN}$$

$$= 25,9407 \text{ kN}$$

$$V_{u2} = V_{2E}$$

$$= 15,539 \text{ kN}$$

$$V_{u \text{ use}} = 25,9407 \text{ kN (gunakan nilai tegangan geser yang terbesar)}$$

➤ Tulangan Transversal Tumpuan

$$A_v = 2 \times \frac{1}{4} \times \pi \times 8^2 = 100,5309 \text{ mm}^2$$

$$V_c = 0,17 \times \lambda \times \sqrt{f'_c} \times b_w \times d$$

$$= 0,17 \times 1 \times \sqrt{25} \times 250 \times 394$$

$$= 83725 \text{ N} = 83,725 \text{ kN (nilai } V_c \text{ sudah lebih besar dari nilai}$$

V_u , maka digunakan nilai spasi maks terkecil)

$$S_{\text{maks } 1} = \frac{d}{4} = \frac{394}{4} = 98,5 \text{ mm}$$

$$S_{\text{maks } 2} = d.l \times 8 = 16 \times 8 = 128 \text{ mm}$$

$$S_{\text{maks } 3} = d.s \times 24 = 8 \times 24 = 192 \text{ mm}$$

Smaks 4 = 300 mm

Digunakan spasi terkecil yaitu 98,5 mm = 50 mm

Maka digunakan tulangan 2d8-50

➤ Tulangan Transversal Lapangan

$$A_v = 2 \times \frac{1}{4} \times \pi \times 8^2 = 100,5309 \text{ mm}^2$$

$$\begin{aligned} V_{e \text{ max}} &= V_{\text{sways}} + V_g \\ &= 13,0992 \text{ kN} + 12,8415 \text{ kN} \\ &= 25,9407 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_{e \text{ min}} &= V_g - V_{\text{sways}} \\ &= 12,8415 \text{ kN} - 13,0994 \text{ kN} \\ &= -0,2579 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_{e \text{ lapangan}} &= \frac{L_n - 2h}{L_n} (V_{e \text{ max}} - V_{e \text{ min}}) + V_{e \text{ min}} \\ &= \frac{9,75 - 2(0,45)}{9,75} (25,9407 - (-0,2579)) \\ &\quad + (-0,2579) \\ &= 23,5224 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_c &= 0,17 \times \lambda \times \sqrt{f'_c} \times b_w \times d \\ &= 0,17 \times 1 \times \sqrt{25} \times 250 \times 394 \\ &= 83,725 \text{ N} \\ &= 83,725 \text{ kN} \text{ (nilai } V_c \text{ sudah lebih besar dari nilai } V_u \text{, maka} \\ &\text{digunakan nilai spasi maks terkecil)} \end{aligned}$$

$$S_{\text{maks 1}} = \frac{d}{4} = \frac{394}{4} = 98,5 \text{ mm}$$

$$S_{\text{maks 2}} = d.l \times 8 = 16 \times 8 = 128 \text{ mm}$$

$$S_{\text{maks 3}} = d.s \times 24 = 8 \times 24 = 192 \text{ mm}$$

$$S_{\text{maks 4}} = 300 \text{ mm}$$

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: $f_y = 420$ MPa

Mutu Baja sengkang: $f_{ys} = 280$ 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)

$P_u = 0$ kN-m (dari ETABS)

$$\begin{aligned} A_g \times \frac{f'_c}{10} &= (250 \times 600) \times \frac{25}{10} \\ &= 375000 \text{ N} \\ &= 375 \text{ kN} > P_u \text{ Aman!} \end{aligned}$$

B. Desain Tulangan Lentur

➤ Perencanaan Tulangan Tumpuan Atas

Momen Ultimet (M_u) = 239,0537 kN-m (dari ETABS)

Momen Nominal (M_n) = $\frac{M_u}{\phi} = \frac{239,0537}{0,9} = 265,61522$ kN-m

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

= 40 + 8 + (16/2)

= 56 mm

Tinggi efektif (d) = $h - d'$

= 600 - 56

$$= 544 \text{ mm}$$

$$\begin{aligned} \text{Koefisien } (k) &= \frac{Mn}{bd^2} \\ &= \frac{265,61522 \times 10^6}{250 \times 544^2} = 3,5902 \end{aligned}$$

$$\begin{aligned} \rho &= \frac{0,85 f'c}{f_y} \left(1 - \sqrt{1 - \frac{2k}{0,85 f'c}} \right) \\ &= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(3,5902)}{0,85 \times 25}} \right) \\ &= 0,0094 \end{aligned}$$

$$\begin{aligned} \rho_{\text{maks}} &= 0,429 \times \frac{0,85 \times f'c \times \beta_1}{f_y} \\ &= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420} \\ &= 0,0184496 \end{aligned}$$

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

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\text{min use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\text{min}} < \rho < \rho_{\text{maks}} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,0094 \times 250 \times 544 = 1281,9474 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{1281,9474}{\frac{1}{4} \times \pi \times 16^2} = 6,3759 \approx 7 \text{ buah}$$

$$A_s \text{ use} = 7 \times \frac{1}{4} \times \pi \times 16^2 = 1407,4335 \text{ mm}^2$$

Spasi antar tulangan

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

$$= \frac{250 - (2 \times 40) - (2 \times 8) - (7 \times 16)}{7 - 1} = 7 \text{ mm} < 25 \text{ mm (Tidak Memenuhi!)}$$

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

baris pertama (n_1) = 4 buah

baris kedua (n_2) = 3 buah

Analisis kapasitas momen

Tinggi efektif = 526,4286 mm

$$a = \frac{A_s \times f_y}{0,85 \times f'_c \times b}$$

$$a = \frac{1407,433 \times 420}{0,85 \times 25 \times 250} = 111,27 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{111,27}{0,85} = 130,9059 \text{ mm}$$

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

$$= \frac{(526,4286 - 130,9059)}{130,9059} \times 0,003$$

$$= 0,00906 > 0,005, \text{ **Terkendali Tarik** } \Phi = 0,9$$

$$\Phi M_n = 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2} \right)$$

$$= 0,9 \times 1407,4335 \times 420 \times \left(526,4286 - \frac{111,27}{2} \right)$$

$$= 250,4668 \times 10^6 \text{ Nmm} = 250,4668 \text{ kNm}$$

$\Phi M_n > M_u$ Aman!

Maka digunakan 7D16

➤ Perencanaan Tulangan Tumpuan Bawah

Momen Ultimet (M_u) = 182,0667 kN-m (dari ETABS)

$$\text{Momen Nominal (} M_n \text{)} = \frac{M_u}{\phi} = \frac{182,0667}{0,9} = 202,29633 \text{ kN-m}$$

$$d' = c_c + d_s + (d_l/2)$$

$$= 40 + 8 + (16/2)$$

$$= 56 \text{ mm}$$

$$\text{Tinggi efektif (} d \text{)} = h - d'$$

$$= 600 - 56$$

$$= 544 \text{ mm}$$

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

$$= \frac{202,29633 \times 10^6}{250 \times 544^2} = 2,7343$$

$$\rho = \frac{0,85 \times f'_c}{f_y} \left(1 - \sqrt{1 - \frac{2k}{0,85 f'_c}} \right)$$

$$= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(2,7343)}{0,85 \times 25}} \right)$$

$$= 0,00699$$

$$\rho_{\text{maks}} = 0,429 \times \frac{0,85 \times f'_c \times \beta_1}{f_y}$$

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

$$= 0,0184496$$

$$\rho_{\text{min 1}} = \frac{\sqrt{f'_c}}{4 \times f_y} = \frac{\sqrt{25}}{4 \times 420} = 0,002976$$

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\text{min use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\text{min}} < \rho < \rho_{\text{maks}} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,00699 \times 250 \times 544 = 951,1373 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{951,1373}{\frac{1}{4} \times \pi \times 16^2} = 4,7305 \approx 5 \text{ buah}$$

$$\text{As use} = 5 \times \frac{1}{4} \times \pi \times 16^2 = 1005,3096 \text{ mm}^2$$

Spasi antar tulangan

$$s_1 = \frac{b - 2c_c - 2d_{sengkan} - n D_{tul}}{n - 1}$$
$$= \frac{250 - (2 \times 40) - (2 \times 8) - (5 \times 16)}{5 - 1} = 18,5 \text{ mm} < 25 \text{ mm (Tidak}$$

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

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

$$a = \frac{1005,3096 \times 420}{0,85 \times 25 \times 250} = 79,4786 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{79,4786}{0,85} = 93,5042 \text{ mm}$$

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

$$= \frac{(535,8 - 93,5042)}{93,5042} \times 0,003$$

$$= 0,01412 > 0,005, \text{ Terkendali Tarik } \Phi = 0,9$$

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

$$= 0,9 \times 1005,3096 \times 420 \times \left(535,8 - \frac{79,4786}{2} \right)$$

$$= 188,5065 \times 10^6 \text{ Nmm} = 188,5065 \text{ kNm}$$

$\Phi Mn > Mu$ Aman!

Maka digunakan 3D16

➤ Perencanaan Tulangan Lapangan Atas

Momen Ultimet (M_u) = 100,4865 kN-m (dari ETABS)

$$\text{Momen Nominal (Mn)} = \frac{M_u}{\phi} = \frac{100,4865}{0,9} = 111,65167 \text{ kN-m}$$

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

$$= 40 + 10 + (16/2)$$

$$= 56 \text{ mm}$$

$$\text{Tinggi efektif (d)} = h - d'$$

$$= 600 - 56$$

$$= 544 \text{ mm}$$

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

$$= \frac{111,65167 \times 10^6}{250 \times 544^2} = 1,5091$$

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

$$= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(1,5091)}{0,85 \times 25}} \right)$$

$$= 0,003731$$

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

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

$$= 0,0184496$$

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

$$\rho_{\min 2} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\min \text{ use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\min} < \rho < \rho_{\max} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,003731 \times 250 \times 544 = 507,3776 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{507,3776}{\frac{1}{4} \times \pi \times 16^2} = 2,5235 \approx 3 \text{ buah}$$

$$A_s \text{ use} = 3 \times \frac{1}{4} \times \pi \times 16^2 = 603,1858 \text{ mm}^2$$

Spasi antar tulangan

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

$$= \frac{250 - (2 \times 40) - (2 \times 8) - (3 \times 16)}{3 - 1} = 53 \text{ mm} > 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'c \times b}$$

$$a = \frac{603,1858 \times 420}{0,85 \times 16 \times 250} = 47,6872 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{47,6872}{0,85} = 56,1025 \text{ mm}$$

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

$$= \frac{(544 - 56,1025)}{56,1025} \times 0,003$$

$$= 0,026089 > 0,005, \text{ Terkendali Tarik } \Phi = 0,9$$

$$\begin{aligned}\Phi M_n &= 0,9 \times A_s \times F_y \times \left(d - \frac{a}{2}\right) \\ &= 0,9 \times 603,1858 \times 420 \times \left(844 - \frac{47,6872}{2}\right) \\ &= 118,5978 \times 10^6 \text{ Nmm} = 118,5978 \text{ kNm}\end{aligned}$$

$\Phi M_n > M_u$ Aman!

Maka digunakan 3D16

➤ Perencanaan Tulangan Lapangan Atas

Momen Ultimet (M_u) = 137,58 kN-m (dari ETABS)

$$\text{Momen Nominal (Mn)} = \frac{M_u}{\phi} = \frac{137,58}{0,9} = 152,86667 \text{ kN-m}$$

$$\begin{aligned}d' &= c_c + d.s + (d.l/2) \\ &= 40 + 8 + (16/2) \\ &= 56 \text{ mm}\end{aligned}$$

$$\begin{aligned}\text{Tinggi efektif (d)} &= h - d' \\ &= 500 - 56 \\ &= 544 \text{ mm}\end{aligned}$$

$$\begin{aligned}\text{Koefisien (k)} &= \frac{M_n}{bd^2} \\ &= \frac{152,86667 \times 10^6}{250 \times 544^2} = 2,0662\end{aligned}$$

$$\begin{aligned}\rho &= \frac{0,85 \times f'_c}{f_y} \left(1 - \sqrt{1 - \frac{2k}{0,85 \times f'_c}}\right) \\ &= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(2,0662)}{0,85 \times 25}}\right) \\ &= 0,005185\end{aligned}$$

$$\begin{aligned}\rho_{\text{maks}} &= 0,429 \times \frac{0,85 \times f'_c \times \beta_1}{f_y} \\ &= 0,429 \times \frac{0,85 \times 25 \times 0,85}{420}\end{aligned}$$

$$= 0,0184496$$

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

$$\rho_{\min 2} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\min \text{ use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\min} < \rho < \rho_{\max} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,005185 \times 250 \times 644 = 705,1953 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{705,1953}{\frac{1}{4} \times \pi \times 16^2} = 3,5073 \approx 4 \text{ buah}$$

$$A_{s \text{ use}} = 4 \times \frac{1}{4} \times \pi \times 16^2 = 804,2477 \text{ mm}^2$$

Spasi antar tulangan

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

$$= \frac{250 - (2 \times 40) - (2 \times 8) - (4 \times 16)}{4 - 1} = 30 \text{ mm} > 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'c \times b}$$

$$a = \frac{804,2477 \times 420}{0,85 \times 25 \times 250} = 63,2477 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{63,2477}{0,85} = 74,8034 \text{ mm}$$

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

$$= \frac{(544 - 74,8034)}{74,8034} \times 0,003$$

$$= 0,01882 > 0,005, \text{ Terkendali Tarik } \Phi = 0,9$$

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

$$= 0,9 \times 804,2477 \times 420 \times \left(544 - \frac{63,2477}{2}\right)$$

$$= 155,7142 \times 10^6 \text{ Nmm} = 155,7142 \text{ kNm}$$

$\Phi Mn > Mu$ Aman!

Maka digunakan 4D16

➤ Perencanaan Tulangan Transversal

$$Vu \text{ Tumpuan} = 102,5 \text{ kN}$$

$$Vu \text{ Lapangan} = 74,1718 \text{ kN}$$

1. Tulangan Transversal Tumpuan

$$Av = 2 \times \frac{1}{4} \times \pi \times 8^2 = 100,531 \text{ mm}^2$$

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

$$= 0,17 \times 1 \times \sqrt{25} \times 250 \times 544$$

$$= 115600 \text{ N}$$

$$= 115,600 \text{ kN}$$

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

$$= \frac{102,4521}{0,75} - 115,600$$

$$= 21,0028 \text{ kN}$$

Memeriksa batasan dimensi penampang

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

$$21,0028 < 0,66 \times \sqrt{25} \times 250 \times 544$$

$$21,0028 < 448,800 \text{ kN} \quad (\text{Aman!})$$

$$\begin{aligned} \text{Spasi} &= \frac{A_v \times f_y \times d}{V_s} \\ &= \frac{100,531 \times 280 \times 544}{21,00282 \times 10^3} = 729,0873 \text{ mm} \end{aligned}$$

$$\text{Smaks 1} = \frac{d}{2} = \frac{544}{2} = 272 \text{ mm}$$

$$\text{Smaks 2} = 600 \text{ mm}$$

Digunakan spasi terkecil yaitu 272 mm = 250 mm

Maka digunakan tulangan 2d8-250

➤ Tulangan Transversal Lapangan

$$A_v = 2 \times \frac{1}{4} \times \pi \times 8^2 = 100,531 \text{ mm}^2$$

$$\begin{aligned} V_c &= 0,17 \times \lambda \times \sqrt{f'_c} \times b_w \times d \\ &= 0,17 \times 1 \times \sqrt{25} \times 250 \times 544 \end{aligned}$$

$$= 111866,1 \text{ N}$$

= 111,8661 kN (nilai V_c sudah lebih besar dari nilai V_u ,
maka digunakan nilai spasi maks terkecil)

$$\text{Smaks 1} = \frac{d}{2} = \frac{544}{2} = 272 \text{ mm}$$

$$\text{Smaks 2} = 600 \text{ mm}$$

Digunakan spasi terkecil yaitu 272 mm = 250 mm

Maka digunakan tulangan 2d8-250

7. Balok Kantilever

Desain Balok Kantilever (400x600) mm

Mutu Baja longitudinal: $f_y = 420 \text{ MPa}$

Mutu Baja sengkang: $f_{ys} = 280 \text{ MPa}$

Mutu Beton: $f'c = 25 \text{ MPa}$

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)

$P_u = 0 \text{ kN-m}$ (dari ETABS)

$$\begin{aligned} A_g \times \frac{f'c}{10} &= (400 \times 600) \times \frac{25}{10} \\ &= 600.000 \text{ N} \\ &= 600 \text{ kN} > P_u \text{ Aman!} \end{aligned}$$

D. Desain Tulangan Lentur

- Perencanaan Tulangan Tumpuan Atas

Momen Ultimet (M_u) = 177,6695 kN-m (dari ETABS)

$$\text{Momen Nominal (Mn)} = \frac{M_u}{\phi} = \frac{177,6695}{0,9} = 197,4105 \text{ kN-m}$$

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

$$= 40 + 12 + (25/2)$$

$$= 64,5 \text{ mm}$$

$$\text{Tinggi efektif (d)} = h - d'$$

$$= 600 - 64,5$$

$$= 535,5 \text{ mm}$$

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

$$= \frac{197,4105 \times 10^6}{400 \times 535,5^2} = 1,72104$$

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

$$= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(1,72104)}{0,85 \times 25}} \right)$$

$$= 0,004278$$

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

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

$$= 0,0184496$$

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

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\text{min use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\text{min}} < \rho < \rho_{\text{maks}} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,004278 \times 400 \times 535,5 = 916,4829 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{916,4829}{\frac{1}{4} \times \pi \times 25^2} = 1,86704 \approx 2 \text{ buah}$$

$$A_s \text{ use} = 2 \times \frac{1}{4} \times \pi \times 25^2 = 981,7477 \text{ mm}^2$$

Spasi antar tulangan

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

$$= \frac{400 - (2 \times 40) - (2 \times 12) - (2 \times 25)}{2 - 1} = 246 \text{ mm} > 29 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'c \times b}$$

$$a = \frac{981,7477 \times 420}{0,85 \times 25 \times 400} = 48,50989 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{48,50989}{0,85} = 57,0704 \text{ mm}$$

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

$$= \frac{(535,5 - 57,0704)}{57,0704} \times 0,003$$

$$= 0,0050021 \quad \text{Terkendali Tarik} \quad \Phi = 0,9$$

$$\begin{aligned} \Phi Mn &= 0,9 \times A_s \times f_y \times \left(d - \frac{a}{2}\right) \\ &= 0,9 \times 981,7477 \times 420 \times \left(535,5 - \frac{48,50989}{2}\right) \end{aligned}$$

$$= 189,7233 \times 10^6 \text{ Nmm} = 189,7233 \text{ kNm}$$

$\Phi Mn > Mu$ Aman!

Maka digunakan 2D25

➤ Perencanaan Tulangan Tumpuan Bawah

Momen Ultimet (M_u) = 224,367 kN-m (dari ETABS)

$$\text{Momen Nominal (Mn)} = \frac{M_u}{\phi} = \frac{224,367}{0,9} = 249,29667 \text{ kN-m}$$

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

$$= 40 + 12 + (25/2)$$

$$= 64,5 \text{ mm}$$

$$\text{Tinggi efektif (d)} = h - d'$$

$$= 600 - 64,5$$

$$= 535,5 \text{ mm}$$

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

$$= \frac{249,29667 \times 10^6}{400 \times 535,5^2} = 2,1734$$

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

$$= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(2,1734)}{0,85 \times 25}} \right)$$

$$= 0,00547$$

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

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

$$= 0,0184496$$

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

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\text{min use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\text{min}} < \rho < \rho_{\text{maks}} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,00547 \times 400 \times 535,5 = 1171,7761 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{1171,7761}{\frac{1}{4} \times \pi \times 25^2} = 2,3871 \approx 3 \text{ buah}$$

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

Spasi antar tulangan

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

$$= \frac{400 - (2 \times 40) - (2 \times 12) - (3 \times 25)}{3 - 1} = 110,5 \text{ mm} > 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'c \times b}$$

$$a = \frac{1472,6216 \times 420}{0,85 \times 25 \times 400} = 72,7648 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{72,7648}{0,85} = 85,6057 \text{ mm}$$

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

$$= \frac{(535,5 - 85,6057)}{85,6057} \times 0,003$$

$$= 0,015766 > 0,005, \text{ **Terkendali Tarik** } \Phi = 0,9$$

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

$$= 0,9 \times 1472,6216 \times 420 \times \left(535,5 - \frac{72,7648}{2} \right)$$

$$= 277,834277 \times 10^6 \text{ Nmm} = 277,834277 \text{ kNm}$$

$\Phi Mn > Mu$ Aman!

Maka digunakan 3D25

➤ Perencanaan Tulangan Lapangan Atas

Momen Ultimet (M_u) = 177,6695 kN-m (dari ETABS)

$$\text{Momen Nominal (} Mn \text{)} = \frac{M_u}{\phi} = \frac{177,6695}{0,9} = 197,4105 \text{ kN-m}$$

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

$$= 40 + 12 + (25/2)$$

$$= 64,5 \text{ mm}$$

$$\text{Tinggi efektif (} d \text{)} = h - d'$$

$$= 600 - 64,5$$

$$= 535,5 \text{ mm}$$

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

$$= \frac{197,4105 \times 10^6}{400 \times 535,5^2} = 1,72104$$

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

$$= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(1,72104)}{0,85 \times 25}} \right)$$

$$= 0,004278$$

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

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

$$= 0,0184496$$

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

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\text{min use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\text{min}} < \rho < \rho_{\text{maks}} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,004278 \times 400 \times 535,5 = 916,4829 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{916,4829}{\frac{1}{4} \times \pi \times 25^2} = 1,86704 \approx 2 \text{ buah}$$

$$A_s \text{ use} = 2 \times \frac{1}{4} \times \pi \times 25^2 = 981,7477 \text{ mm}^2$$

Spasi antar tulangan

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

$$= \frac{400 - (2 \times 40) - (2 \times 12) - (2 \times 25)}{2 - 1} = 246 \text{ mm} > 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'c \times b}$$

$$a = \frac{981,7477 \times 420}{0,85 \times 25 \times 400} = 48,50989 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{48,50989}{0,85} = 57,0704 \text{ mm}$$

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

$$= \frac{(535,5 - 57,0704)}{57,0704} \times 0,003$$

$$= 0,0161 > 0,005, \text{ **Terkendali Tarik** } \Phi = 0,9$$

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

$$= 0,9 \times 981,7477 \times 420 \times \left(535,5 - \frac{48,50989}{2}\right)$$

$$= 189,7233 \times 10^6 \text{ Nmm} = 189,7233 \text{ kNm}$$

$\Phi Mn > Mu$ Aman!

Maka digunakan 2D25

➤ Perencanaan Tulangan Lapangan Atas

Momen Ultimet (M_u) = 224,367 kN-m (dari ETABS)

$$\text{Momen Nominal (Mn)} = \frac{M_u}{\phi} = \frac{224,367}{0,9} = 249,2967 \text{ kN-m}$$

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

$$= 40 + 12 + (25/2)$$

$$= 64,5 \text{ mm}$$

$$\text{Tinggi efektif (d)} = h - d'$$

$$= 600 - 64,5$$

$$= 535,5 \text{ mm}$$

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

$$= \frac{249,2967 \times 10^6}{400 \times 535,5^2} = 2,1734$$

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

$$= \frac{0,85 \times 25}{420} \left(1 - \sqrt{1 - \frac{2(2,1734)}{0,85 \times 25}} \right)$$

$$= 0,00547$$

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

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

$$= 0,0184496$$

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

$$\rho_{\text{min 2}} = \frac{1,4}{f_y} = \frac{1,4}{420} = 0,00333$$

$$\rho_{\text{min use}} = 0,00333 \text{ (terbesar)}$$

$$\rho_{\text{min}} < \rho < \rho_{\text{maks}} \text{ (Aman!)}$$

$$A_s = \rho \times b \times d$$

$$= 0,00547 \times 400 \times 535,5 = 1171,7762 \text{ mm}^2$$

Hitung Jumlah tulangan yang dibutuhkan

$$n = \frac{1171,7762}{\frac{1}{4} \times \pi \times 25^2} = 2,38712 \approx 3 \text{ buah}$$

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

Spasi antar tulangan

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

$$= \frac{400 - (2 \times 40) - (2 \times 12) - (3 \times 25)}{3 - 1} = 110,5 \text{ mm} > 25 \text{ mm (Memenuhi!)}$$

Analisis kapasitas momen

$$a = \frac{A_s \times f_y}{0,85 \times f'c \times b}$$

$$a = \frac{1472,6216 \times 420}{0,85 \times 25 \times 400} = 72,7648 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{72,7648}{0,85} = 85,6057 \text{ mm}$$

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

$$= \frac{(535,5 - 85,6057)}{85,6057} \times 0,003$$

$$= 0,015766 > 0,005, \text{ **Terkendali Tarik** } \Phi = 0,9$$

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

$$= 0,9 \times 1472,6216 \times 420 \times \left(535,5 - \frac{72,7648}{2}\right)$$

$$= 277834277 \times 10^6 \text{ Nmm} = 277,834277 \text{ kNm}$$

$\Phi Mn > Mu$ Aman!

Maka digunakan 3D25

➤ Perencanaan Tulangan Transversal

Menghitung nilai Mpr balok

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

$$= 2 \times \frac{1}{4} \times \pi \times 25^2 \times 1 \times 420 \times \left(535,5 - \frac{48,50988}{2}\right)$$

$$= 210,8037 \times 10^6 \text{ Nmm} = 210,8037 \text{ kNm}$$

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

$$= 3 \times \frac{1}{4} \times \pi \times 25^2 \times 420 \times \left(535,5 - \frac{72,7648}{2}\right)$$

$$= 308,70475 \times 10^6 \text{ Nmm} = 308,70475 \text{ kNm}$$

$$Ln = 9,6 \text{ m}$$

$$Vg = 146,1674 \text{ kN (dari ETABS)}$$

$$V_{2E} = 146,7416 \text{ kN (akibat beban } 1,2D + 2,0E + 1,0L)$$

$$V_{s \text{ ways}} = \frac{(M_{pr-}) + (M_{pr+})}{Ln} = \frac{210,8037 + 308,70475}{9,6} = 54,1155 \text{ kN}$$

$$\begin{aligned} V_{u1} &= V_{s \text{ ways}} + V_g \\ &= 54,1155 \text{ kN} + 146,1674 \text{ kN} \\ &= 200,2829 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_{u2} &= V_{2E} \\ &= 146,7416 \text{ kN} \end{aligned}$$

$$V_{u \text{ use}} = 200,2829 \text{ kN (gunakan nilai tegangan geser yang terbesar)}$$

➤ Tulangan Transversal Tumpuan

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

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

$$= 0,17 \times 1 \times \sqrt{25} \times 400 \times 535,5$$

$$= 182070 \text{ N}$$

$$= 182,070 \text{ kN}$$

$$\begin{aligned} V_s &= \frac{V_u}{\phi} - V_c \\ &= \frac{200,2829}{0,75} - 182,070 \\ &= 84,9738 \text{ kN} \end{aligned}$$

Memeriksa batasan dimensi penampang

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

$$71,3764 < 0,66 \times \sqrt{25} \times 400 \times 545,5$$

$$71,3764 < 706,86 \text{ kN (Aman!)}$$

$$\begin{aligned} \text{Spasi} &= \frac{A_v \times f_y \times d}{V_s} \\ &= \frac{226,19467 \times 280 \times 525,5}{84,9738 \times 10^3} = 399,1303 \text{ mm} \end{aligned}$$

$$\text{Smaks 1} = \frac{d}{4} = \frac{535,5}{4} = 133,875 \text{ mm}$$

$$\text{Smaks 2} = d.l \times 8 = 25 \times 8 = 200 \text{ mm}$$

$$\text{Smaks 3} = d.s \times 24 = 12 \times 24 = 288 \text{ mm}$$

$$\text{Smaks 4} = 300 \text{ mm}$$

Digunakan spasi terkecil yaitu 133,875 mm = 100 mm

Maka digunakan tulangan 2d12-100

➤ Tulangan Transversal Lapangan

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

$$\begin{aligned} V_{e \text{ max}} &= V_{s \text{ ways}} + V_g \\ &= 54,1155 \text{ kN} + 146,9174 \text{ kN} \\ &= 201,0329 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_{e \text{ min}} &= V_g - V_{s \text{ ways}} \\ &= 146,1674 \text{ kN} - 54,1155 \text{ kN} \\ &= 92,8019 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_{e \text{ lapangan}} &= \frac{L_n - 2h}{L_n} (V_{e \text{ max}} - V_{e \text{ min}}) + V_{e \text{ min}} \\ &= \frac{9,6 - 2(0,6)}{9,6} (201,0329 - 92,8019) + 92,8019 \\ &= 186,754 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_c &= 0,17 \times \lambda \times \sqrt{f'c} \times b_w \times d \\ &= 0,17 \times 1 \times \sqrt{25} \times 400 \times 535,5 \\ &= 182070 \text{ N} \\ &= 182,070 \text{ kN} \end{aligned}$$

$$V_s = \frac{V_u}{\phi} - V_c$$

$$= \frac{186,754}{0,75} = 182,070$$

$$= 66,9353 \text{ kN}$$

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

$$= \frac{226,19467 \times 280 \times 535,5}{66,9353 \times 10^3} = 506,6925 \text{ mm}$$

$$\text{Smaks 1} = \frac{d}{4} = \frac{535,5}{4} = 133,875 \text{ mm}$$

$$\text{Smaks 2} = d.l \times 8 = 25 \times 8 = 200 \text{ mm}$$

$$\text{Smaks 3} = d.s \times 24 = 12 \times 24 = 288 \text{ mm}$$

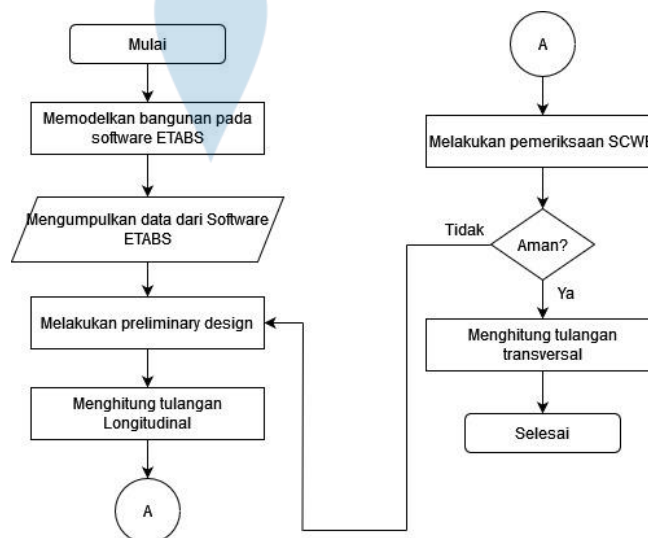
$$\text{Smaks 4} = 300 \text{ mm}$$

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 dilakukan analisis preliminary 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

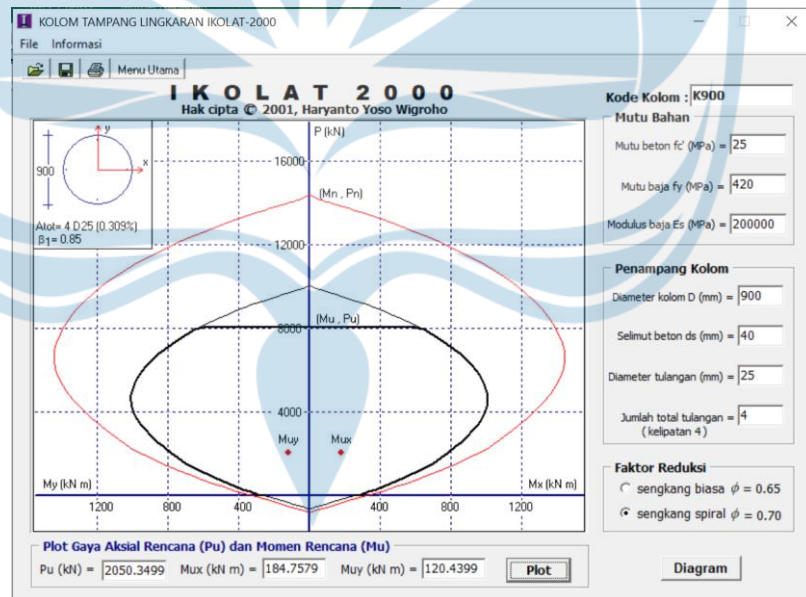
$Mu_2 = 120,4399 \text{ kNm}$ (dari ETABS)

$Mu_3 = 184,7579 \text{ kNm}$ (dari ETABS)

$Mpr_{kiri} = 1221,798 \text{ kNm}$

$Mpr_{kanan} = 928,6286 \text{ kNm}$

Diagram interaksi kolom jika menggunakan tulangan 4D25



Gambar 2.25 Nilai Mu_2 dan Mu_3 pada diagram interaksi kolom Tipe 1

Pada gambar 2.25 menunjukkan nilai Mu_2 dan Mu_3 untuk interaksi kolom Tipe 1 Kolom harus memenuhi persyaratan Strong Coloum-Weak Beam (SCWB) berikut:

$$1,2 (Mpr_{kiri} + Mpr_{kanan}) \leq (Mnca + MnCb)$$

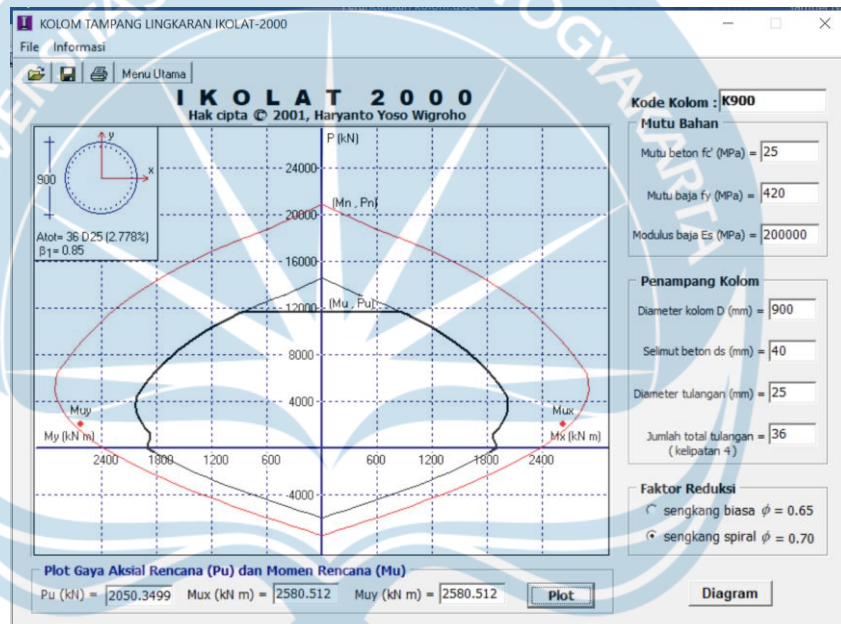
Dari diagram diatas dapat diketahui bahwa nilai M_{ncb} adalah sebesar 950 kNm

$$1,2 (1221,798 + 928,6286) \leq (0 + 950)$$

$$2580,512 \text{ kNm} \geq 950 \text{ (Tidak Aman!)}$$

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 M_{nc} pada diagram interaksi kolom Tipe 1

Pada gambar 2.26 Diagram IKOLAT diatas, didapatkan nilai M_{ncb} sebesar 2650 kNm > 2580,512 kNm (sudah memenuhi SCWB). Maka kolom tipe 1 menggunakan tulangan 36D25

B. Perencanaan Tulangan Transversal

- Tukangan Transversal daerah L_o

$$A_g = \frac{1}{4} \times \pi \times 900^2 = 636172,5 \text{ mm}^2$$

$$A_{ch} = \frac{1}{4} \times \pi \times (900 - (2 \times 40))^2 = 528101,7 \text{ mm}^2$$

Rasio Volumetrik tulangan spiral

$$\begin{aligned}\rho_s \text{ min} &= 0,45 \left(\frac{A_g}{A_{ch}} - 1 \right) \frac{F'_c}{F_{yt}} \\ &= 0,45 \left(\frac{636172,5}{528101,7} - 1 \right) \frac{25}{420} = 0,005481\end{aligned}$$

$$\begin{aligned}\text{Smaks 1} &= \frac{A_{st}}{bc \times \rho_s \text{ min}} \\ &= \frac{2 \times \frac{1}{4} \times \pi \times 13^2}{(900 - 2(40)) \times 0,005481} \\ &= 59,0607 \text{ mm}\end{aligned}$$

$$\text{Smaks 2} = d.l \times 8 = 25 \times 8 = 200 \text{ mm}$$

$$\text{Smaks 3} = d.s \times 24 = 13 \times 24 = 312 \text{ mm}$$

$$\text{Smaks 4} = 0,5 \times 900 = 450 \text{ mm}$$

$$\text{Smaks 5} = 300 \text{ mm}$$

Digunakan Smaks terkecil yaitu 59,0607 mm

$$\begin{aligned}V_{e1} &= \frac{\sum M \text{ prb atas} \times DF \text{ atas} + \sum M \text{ prb bawah} \times DF \text{ bawah}}{4,5} \\ &= \frac{(1221,798 + 928,6286) \times 0,5 + (1221,798 + 928,6286) \times 0,5}{4,5} \\ &= 573,4471 \text{ kN}\end{aligned}$$

$$V_{e2} = 56,6519 \text{ kN (dari ETABS)}$$

Digunakan V_e terbesar, yaitu 573,4471 kN

$$\begin{aligned}V_c &= 0,17 \times \lambda \times \sqrt{f'_c} \times b_w \times d \\ &= 0,17 \times 1 \times \sqrt{25} \times 621226 \quad \rightarrow 621226 \text{ adalah luas efektif kolom} \\ &= 528042 \text{ N} \\ &= 528,042 \text{ kN}\end{aligned}$$

$$V_s = \frac{V_u}{\phi} - V_c$$

$$= \frac{573,4471}{0,75} - 528,042$$

$$= 236,554 \text{ kN}$$

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

$$= \frac{132,7323 \times 420 \times 834,5}{236,554 \times 10^3}$$

$$= 196,6627 \text{ mm}$$

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

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

$$= 0,17 \times 1 \times \sqrt{25} \times 621226 \rightarrow 621226 \text{ adalah luas efektif kolom}$$

$$= 528042 \text{ N}$$

$$= 528,042 \text{ kN}$$

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

$$= \frac{573,4471}{0,75} - 528,042$$

$$= 236,554 \text{ kN}$$

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

$$= \frac{132,7323 \times 420 \times 834,5}{236,554 \times 10^3}$$

$$= 196,6627 \text{ mm}$$

Tulangan transversal yang digunakan D13-150

2.5.2 Perancangan kolom Tipe 2

Diameter = 750 mm

Selimit beton (cc) = 40 mm

Diameter tulangan utama (d.l) = 25 mm

Diameter tulangan sengkang (d.s) = 13 mm

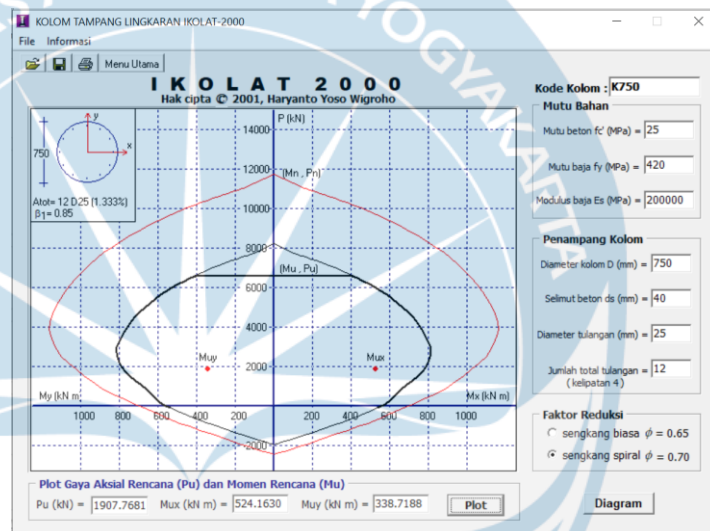
A. Perencanaan tulangan Longitudinal

- 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 Mu_2 dan Mu_3 kolom bawah pada diagram interaksi kolom Tipe 2

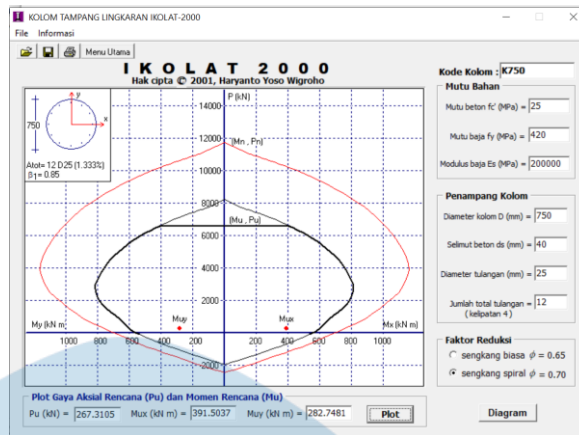
Pada gambar 2.27 menunjukkan nilai Mu_2 dan Mu_3 untuk interaksi kolom Tipe 2

- 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 diagram interaksi kolom Tipe 1. Kolom harus memenuhi persyaratan Strong Coloum-Weak Beam (SCWB) berikut:

$$1,2 (M_{pr_{kiri}} + M_{pr_{kanan}}) \leq (M_{nca} + M_{ncb})$$

Dari diagram diatas dapat diketahui bahwa nilai Mnca adalah sebesar 710 kNm dan Mncb sebesar 1000 kNm

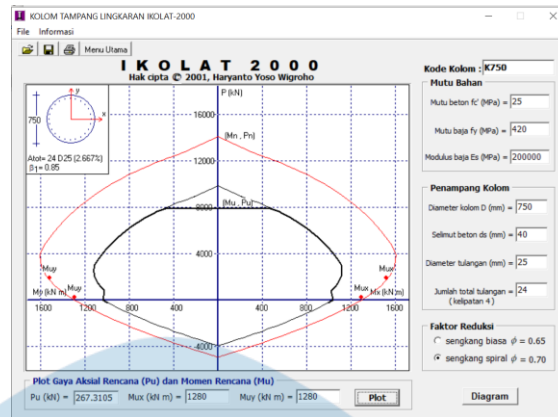
$$1,2 (M_{pr_{kiri}} + M_{pr_{kanan}}) \leq (M_{nca} + M_{ncb})$$

$$1,2 (1221,798 + 928,6286) \leq (710 + 1000)$$

$$2580,512 \text{ kNm} \geq 1710 \text{ (Tidak Aman!)}$$

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

$$A_g = \frac{1}{4} \times \pi \times 750^2 = 441786,4669 \text{ mm}^2$$

$$A_{ch} = \frac{1}{4} \times \pi \times (750 - (2 \times 40))^2 = 352565,2355 \text{ mm}^2$$

Rasio Volumetrik tulangan spiral

$$\begin{aligned} \rho_s \text{ min} &= 0,45 \left(\frac{A_g}{A_{ch}} - 1 \right) \frac{f'c}{f_{yt}} \\ &= 0,45 \left(\frac{441786,4669}{352565,2355} - 1 \right) \frac{25}{420} = 0,0067785 \end{aligned}$$

$$\begin{aligned} S_{maks 1} &= \frac{A_{st}}{bc \times \rho_s \text{ min}} \\ &= \frac{2 \times \frac{1}{4} \times \pi \times 13^2}{(750 - 2(40)) \times 0,0067785} \\ &= 58,4518 \text{ mm} \end{aligned}$$

$$S_{maks 2} = d.l \times 8 = 25 \times 8 = 20 \text{ mm}$$

$$S_{maks 3} = d.s \times 24 = 13 \times 24 = 312 \text{ mm}$$

$$S_{maks 4} = 0,5 \times 750 = 375 \text{ mm}$$

Smaks 5 = 300 mm

Digunakan Smaks terkecil yaitu 58,4518 mm

$$\begin{aligned} V_{e1} &= \frac{\Sigma M \text{ prb atas} \times DF \text{ atas} + \Sigma M \text{ prb bawah} \times DF \text{ bawah}}{4,5} \\ &= \frac{(1221,798+928,6286) \times 0,5 + (1221,798+928,6286) \times 0,5}{4,5} \\ &= 573,4471 \text{ kN} \end{aligned}$$

$$V_{e2} = 100,0382 \text{ kN (dari ETABS)}$$

Digunakan V_e terbesar, yaitu 573,4471 kN

$$\begin{aligned} V_c &= 0,17 \times \lambda \times \sqrt{f'c} \times b_w \times d \\ &= 0,17 \times 1 \times \sqrt{25} \times 428191,7 \quad \rightarrow 428191,7 \text{ adalah luas efektif kolom} \\ &= 363962,945 \text{ N} \\ &= 363,9629 \text{ kN} \end{aligned}$$

$$\begin{aligned} V_s &= \frac{V_u}{\phi} - V_c \\ &= \frac{573,4471}{0,75} - 363,9629 \\ &= 400,633 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{Spasi} &= \frac{A_v \times f_y \times d}{V_s} \\ &= \frac{132,7323 \times 420 \times 684,5}{400,633 \times 10^3} \\ &= 95,2402 \text{ mm} \end{aligned}$$

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

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

$$= 0,17 \times 1 \times \sqrt{25} \times 428191,7 \quad \rightarrow 428191,7 \quad \text{adalah luas efektif kolom}$$

$$= 363962,945 \text{ N}$$

$$= 363,9629 \text{ kN}$$

$$V_s = \frac{V_u}{\phi} - V_c$$

$$= \frac{573,4471}{0,75} - 363,9629$$

$$= 400,633 \text{ kN}$$

$$\text{Spasi} = \frac{A_v \times f_y \times d}{V_s}$$

$$= \frac{132,7323 \times 420 \times 684,5}{400,633 \times 10^3}$$

$$= 95,2402 \text{ mm}$$

Tulangan transversal yang digunakan D13-50