

BAB VI

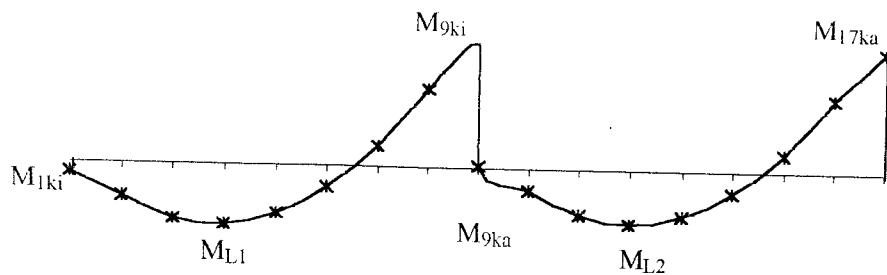
DESAIN STRUKTUR BETON BERTULANG

6.1 Desain Balok

Untuk perencanaan balok yang lebih ekonomis, maka digunakan metode redistribusi momen untuk memperkecil momen negatif tumpuan dan memperbesar momen positif lapangan yang relatif jauh lebih kecil, sehingga didapatkan distribusi yang lebih baik dari pemanfaatan kekuatan sepanjang bentang balok. Selain itu momen balok yang digunakan adalah momen aktual yang terjadi, yaitu momen di muka kolom, yang didapatkan dengan cara interpolasi.

6.1.1 Redistribusi Momen

Dalam perhitungan redistribusi momen ini diambil momen di muka kolom. Sebagai contoh dihitung bentang balok C tingkat 1, struktur 16 portal dengan 2 dinding geser.



$$M_{1ki} = 30,9790 \text{ KNm}$$

$$M_{9ka} = -8,527 \text{ KNm}$$

$$M_{1,1} = 194,852 \text{ KNm}$$

$$M_{1,2} = 174,700 \text{ KNm}$$

$$M_{9ka} = -408,073 \text{ KNm}$$

$$M_{17ka} = -395,09 \text{ KNm}$$

$$\Sigma M_{bi} = M_{1ki} + M_{9ki} + M_{9ka} + M_{17ka}$$

$$= 30,9790 + 408,073 + 8,527 + 395,09 = 842,669 \text{ KNm}$$

a. Untuk balok bentang kiri

Diambil $\Delta M_1 = 21\% \cdot 408,073 = 85,695 \text{ KNm}$ dan $\Delta M_2 = \Delta M_1 = 85,695 \text{ KNm}$.

Dimana nilai ΔM_1 dan $\Delta M_2 < 30\% \cdot M_{\text{mak}} = 122,4219 \text{ KNm}$ sehingga diperoleh :

$$M_{1ki}^* = M_{1ki} + \Delta M_1 = 30,974 + 85,695 = 116,674 \text{ KNm}$$

$$M_{9ki}^* = M_{9ki} - \Delta M_1 = 408,073 - 85,695 = 322,378 \text{ KNm}$$

$$M_{L1}^* = M_{L1} + \Delta M_1 = 194,852 + 85,695 = 280,548 \text{ KNm}$$

b. Untuk balok bentang kanan

Diambil $\Delta M_2 = 21\% \cdot 408,073 = 85,695 \text{ KNm}$ dan $\Delta M_3 = \Delta M_2 = 85,695 \text{ KNm}$

Dimana nilai ΔM_2 dan $\Delta M_3 < 30\% \cdot M_{\text{mak}} = 122,4219 \text{ KNm}$ sehingga diperoleh :

$$M_{9ka}^* = M_{9ka} + \Delta M_2 = 8,527 + 85,695 = 94,222 \text{ KNm}$$

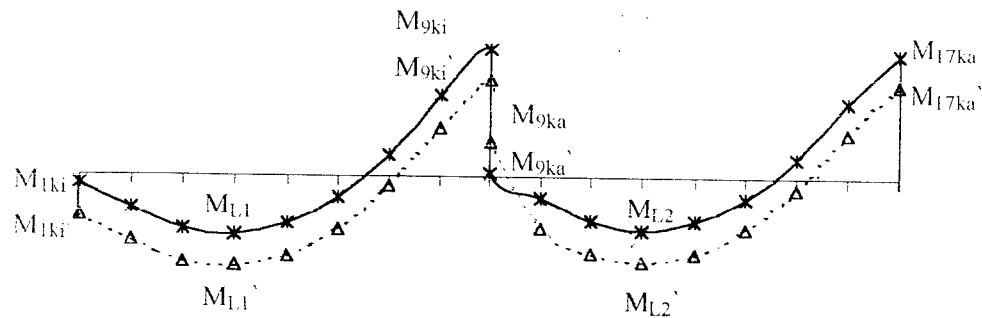
$$M_{17ka}^* = M_{17ka} - \Delta M_2 = 395,09 - 85,695 = 309,395 \text{ KNm}$$

$$M_{1,2}^* = M_{1,2} + \Delta M_2 = 174,700 + 85,695 = 260,395 \text{ KNm}$$

Sehingga $M_{bi}^* = M_{1ki}^* + M_{9ki}^* + M_{9ka}^* + M_{17ka}^*$

$$= 116,674 + 322,378 + 94,222 + 309,395$$

$$= 842,669 = M_{bi}$$



Gambar 6.1 Redistribusi momen balok C tingkat 1

$$M_{1ka}' = 116,674 \text{ KNm}$$

$$M_{1.1}' = 280,548 \text{ KNm}$$

$$M_{9ki}' = -322,378 \text{ KNm}$$

$$M_{9ka}' = -94,222 \text{ KNm}$$

$$M_{1.2}' = 260,395 \text{ KNm}$$

$$M_{17ki}' = -309,395 \text{ KNm}$$

Hasil redistribusi momen untuk balok-balok lain pada struktur 16 portal dengan dua dinding geser dapat dilihat pada tabel 6.1.

6.1.2 Desain Balok

Untuk contoh akan didesain bentang balok C1-2 tingkat 1, sedang untuk balok-balok yang lainnya dapat dilihat pada tabel 6.1. Momen tumpuan positif dan momen tumpuan negatif yang digunakan adalah momen pada sisi muka kolom yaitu momen sejarak $\frac{1}{2}$ tebal kolom dari titik pusat joint yang dapat diperoleh dengan cara interpolasi. Dalam perencanaan ini, ukuran balok yang digunakan adalah 40/80 untuk tingkat 1 hingga tingkat 10.

$$M_u^- = -322,378 \text{ KNm}$$

$$M_u^+ = 166,674 \text{ KNm}$$

a. Tulangan Tumpuan Negatif

$$\frac{\rho'}{\rho} = \frac{116,674}{322,378} = 0,3619 \text{ digunakan } \frac{\rho'}{\rho} = 0,5 \text{ (persyaratan gempa)}$$

ds diambil 100 mm, $d = 800 - 100 = 700$ mm

$$\frac{Mu}{bd^2} = \frac{322,378}{0,4 \cdot 0,7^2} = 1644,786$$

Dari tabel 4.1 untuk $f'_c = 30$ Mpa, $f_y = 400$ Mpa dan $\rho' = 0,5\rho$ didapat $\rho = 0,005473$

$$As = \rho \cdot b \cdot d = 0,005473 \cdot 400 \cdot 700 = 1532,357 \text{ mm}^2$$

Dipakai 5D20

$$As' = 0,5 As = 0,5 \cdot 1532,357 = 766,1786 \text{ mm}^2$$

Dipakai 3D20

b. Tulangan Tumpuan Positif

$$\frac{\rho'}{\rho} = \frac{322,378}{166,674} = 2,7631, \text{ dipakai } \frac{\rho'}{\rho} = 1$$

$$\frac{Mu}{bd^2} = \frac{166,674}{0,4 \cdot 0,7^2} = 595,2755$$

Dari tabel 4.1 untuk $\rho' = \rho$ didapat $\rho = 0,002067$

$$As = As' = \rho \cdot b \cdot d = 0,002067 \cdot 400 \cdot 700 = 578,643 \text{ mm}^2$$

Dipakai 2D20

Tulangan terpasang diambil berdasarkan nilai maksimum dari 2 jenis tulangan tumpuan yaitu : $As = 5D20$ dan $As' = 3D20$.

$$d_s = \frac{5 \cdot \left(\frac{20}{2} + 10 + 40 \right)}{5}$$

$$= 60 \text{ mm}$$

$$jbd = \frac{400 - 80 - 20 - 5 \cdot 20}{4}$$

$$= 50 \text{ mm} > 25 \text{ mm}$$

$$d' = \frac{20}{2} + 10 + 40 = 60 \text{ mm}$$

$$d = h - d_s = 800 - 60 = 740 \text{ mm}$$

$$A_s = 5.0,25 \cdot \pi \cdot 20^2 = 1570,79 \text{ mm}^2$$

$$A_{s'} = 3.0,25 \cdot \pi \cdot 20^2 = 942,48 \text{ mm}^2$$

$$A_{s1} = A_s - A_{s'}$$

$$= 1570,79 - 942,48$$

$$= 628,31 \text{ mm}^2$$

$$A_{s'} = A_{s2}$$

$$T = A_s \cdot f_y$$

$$= 1570,79 \cdot 400 = 628316 \text{ N}$$

$$C_c = 0,85 \cdot f_c' \cdot b \cdot a$$

$$C_c = 0,85 \cdot 30 \cdot 400 \cdot a = 10200 \cdot a$$

$$C_s = A_{s'} \cdot (f_y - 0,85 \cdot f_c')$$

$$C_s = 942,48 \cdot (400 - 0,85 \cdot 30) = 352958,76 \text{ N}$$

$$T = C_c + C_s$$

$$628316 = 10200 \cdot a + 352958,76$$

$$a = 26,996 \text{ mm}$$

$$M_{nak \ b} = M_{n1} + M_{n2}$$

$$\begin{aligned} M_{nak \ b} &= A_s l \cdot f_y \cdot \left(d - \frac{a}{2} \right) + C_s \cdot (d - d') \\ &= 628,31 \cdot 400 \cdot \left(740 - \frac{26,996}{2} \right) + 352958,76 \cdot (740 - 60) \\ &= 182,58 \text{ kNm} + 240,01 \text{ kNm} \\ &= 422,59 \text{ kNm} > M_u / \phi = 322,378 / 0,8 = 402,972 \text{ kNm} \end{aligned}$$

$$M_{kap \ b} = \phi_o \cdot M_{nak \ b}$$

$$M_{kap \ b} = 1,25 \cdot 422,59 = 528,238 \text{ kNm}$$

$$M_{nak \ b'} = 240,01 \text{ kNm}$$

$$M_{kap \ b'} = 1,25 \cdot 240,01 = 300,013 \text{ kNm}$$

c. Tulangan Lapangan

$$M_u = 280,548 \text{ kNm}$$

$$M_n = \frac{280,548}{0,8} = 350,685 \text{ kNm}$$

$$R_n = \frac{M_n}{bd^2} = \frac{350,685 \cdot 10^6}{400 \cdot 740^2} = 1,601$$

$$m = \frac{f_y}{0,85 \cdot f_c'} = \frac{400}{0,85 \cdot 30} = 15,69$$

$$\rho = \frac{1}{m} \left(1 - \sqrt{1 - \frac{2m \cdot R_n}{f_y}} \right)$$

$$= \frac{1}{15,69} \left(1 - \sqrt{1 - \frac{2 \cdot 15,69 \cdot 1,601}{400}} \right) = 0,004137$$

$$A_s = \rho \cdot b \cdot d = 0,004137 \cdot 400 \cdot 740 = 1224,485 \text{ mm}^2$$

Dipakai tulangan 4D20.

d. Gaya Geser Balok

$$V_D = 146,835 \text{ KN}$$

$$V_L = 32,165 \text{ KN}$$

$$V_E = 50,371 \text{ KN}$$

$$\begin{aligned} V_G &= 1,2 \cdot V_D + 1,6 \cdot V_L \\ &= 1,2 \cdot 146,835 + 1,6 \cdot 32,165 \\ &= 227,666 \text{ KN} \end{aligned}$$

$$l_n = 9 - \left(\frac{0,75 + 0,85}{2} \right) = 8,2 \text{ m}$$

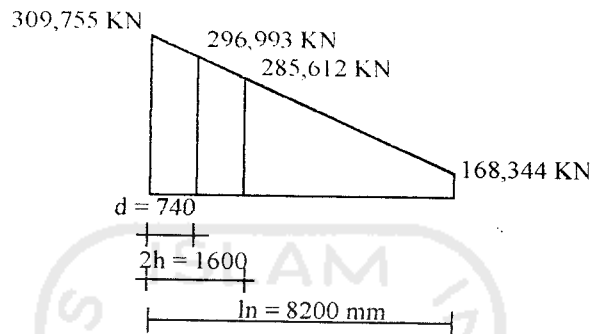
$$\begin{aligned} V_u &= 0,7 \cdot \frac{M_{kaph} + M_{kaph'}}{l_n} + 1,05 \cdot V_G \\ &= 0,7 \cdot \frac{528,238 + 300,013}{8,2} + 1,05 \cdot 227,666 \end{aligned}$$

$$= 309,755 \text{ KN}$$

tetapi tidak boleh lebih dari :

$$\begin{aligned} V_u &= 1,05 \left(V_D + V_L + \frac{4}{K} V_E \right) \\ &= 1,05 (146,385 + 32,165 + 4 \cdot 50,371) \\ &= 399,508 \text{ KN} > 318,238 \text{ KN} \quad (\text{memenuhi syarat}) \end{aligned}$$

$$1,05 \cdot V_G - 0,7 \cdot \frac{M_{kap} + M_{kap'}}{l_n} = 1,05 \cdot 227,666 - 0,7 \cdot \frac{528,238 + 300,013}{8,2} = 168,344 \text{ KN}$$



.Di dalam daerah sendi plastis :

$$V_{u\text{terpakai}} = 296,993 \text{ KN}$$

$$V_c = 0$$

$$V_s = \frac{V_u}{\phi} = \frac{296,993}{0,6} = 494,989 \text{ KN}$$

Di pakai sengkang ϕ 10 mm dengan mutu baja $f_y = 400 \text{ Mpa}$

$$s = \frac{A_v \cdot f_y \cdot d}{F_s} = \frac{2,025 \cdot \pi \cdot 10^2 \cdot 400 \cdot 740}{494,989 \cdot 10^3} = 93,932 \text{ mm} < d/4 = 185 \text{ mm}$$

Di pakai sengkang ϕ 10-90 mm.

Diluar daerah sendi plastis :

$$V_u = 318,238 - \frac{1,4 \cdot (309,755 - 168,344)}{8,2} = 285,612 \text{ KN}$$

$$V_c = \left(\frac{\sqrt{f_c'}}{6} \right) \cdot b \cdot d = \left(\frac{\sqrt{30}}{6} \right) \cdot 400 \cdot 740 = 270,210 \text{ KN}$$

$$V_s = \frac{V_u}{\phi} - V_c = \frac{285,612}{0,6} - 270,210 = 205,809 \text{ KN}$$

$$s = \frac{2,0,25 \cdot \pi \cdot 10^2 \cdot 400 \cdot 740}{205,809 \cdot 10^3} = 225,916 \text{ mm} > d/2 = 370 \text{ mm}$$

Di pakai sengkang ϕ 10-225 mm

Dengan cara yang sama dapat dihitung penulangan untuk balok-balok yang lain.

Hasil perhitungan penulangan balok dapat dilihat pada tabel 6.2.

Tabel 6.1 Redistribusi momen struktur 16 portal 2 dinding geser

| Section | No. Data | Momen Sebelum dan Sesudah Redistribusi | | | | | | | | | |
|---------|----------|--|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| | | 1C | 1C' | 3C | 3C' | 5C | 5C' | 7C | 7C' | 10C | 10C' |
| C1-1 | 1 | 30,979 | 116,674 | -5,541 | -81,397 | -43,177 | -105,904 | -90,536 | -139,748 | -78,545 | -63,597 |
| C1-2 | 2 | 110,724 | 196,419 | 80,577 | 156,433 | 55,483 | 118,210 | 21,467 | 70,679 | -7,277 | 7,671 |
| C1-3 | 3 | 178,639 | 264,334 | 158,052 | 233,908 | 142,521 | 205,248 | 122,497 | 171,709 | 57,597 | 42,649 |
| C1-4 | 4 | 194,852 | 280,548 | 183,825 | 259,681 | 177,857 | 240,584 | 171,826 | 221,038 | 95,715 | 80,766 |
| C1-5 | 5 | 159,364 | 245,059 | 157,896 | 233,752 | 161,491 | 224,219 | 169,452 | 218,664 | 107,076 | 92,127 |
| C1-6 | 6 | 72,174 | 157,869 | 80,266 | 156,122 | 93,424 | 156,151 | 115,377 | 164,589 | 91,680 | 76,732 |
| C1-7 | 7 | -66,718 | 18,977 | -49,067 | 26,789 | -26,345 | 36,382 | 9,600 | 58,812 | 49,528 | 34,580 |
| C1-8 | 8 | -257,312 | -171,616 | -230,101 | -154,245 | -197,816 | -135,089 | -147,878 | -98,666 | -19,380 | -34,328 |
| C1-9 | 9ki | -408,073 | -322,378 | -374,914 | -299,058 | -346,064 | -283,337 | -296,629 | -247,417 | -89,534 | -104,483 |
| C2-1 | 9ka | -8,527 | -94,222 | 18,935 | 94,791 | 8,699 | 71,426 | -37,512 | -86,725 | -46,217 | -31,269 |
| C2-2 | 10 | 71,755 | 157,451 | 94,625 | 170,481 | 91,490 | 154,217 | 58,975 | 108,187 | 15,215 | 0,267 |
| C2-3 | 11 | 149,079 | 234,774 | 164,568 | 240,424 | 163,974 | 226,701 | 142,958 | 192,170 | 72,229 | 57,281 |
| C2-4 | 12 | 174,700 | 260,395 | 182,809 | 258,665 | 184,756 | 247,483 | 175,239 | 224,451 | 102,486 | 87,538 |
| C2-5 | 13 | 148,620 | 234,315 | 149,349 | 225,204 | 153,837 | 216,564 | 155,819 | 205,031 | 105,987 | 91,039 |
| C2-6 | 14 | 70,838 | 156,533 | 64,186 | 140,042 | 71,216 | 133,943 | 84,696 | 133,908 | 82,732 | 67,784 |
| C2-7 | 15 | -58,646 | 27,049 | -72,678 | 3,178 | -63,107 | -0,380 | -38,128 | 11,084 | 32,720 | 17,772 |
| C2-8 | 16 | -239,832 | -154,136 | -261,243 | -185,388 | -249,131 | -186,404 | -212,653 | -163,441 | -44,049 | -58,997 |
| C2-9 | 17 | -395,090 | -309,395 | -421,422 | -345,566 | -418,181 | -355,454 | -378,554 | -329,342 | -124,568 | -139,516 |

Tabel 6.2 Tulangan longitudinal balok portal C struktur 16 portal 2 dinding geser

| Balok | Posisi | Momen Perlu (Mu) | | Tulangan Atas | | Tulangan Bawah | | Momen nak (KNm) | |
|--------|----------|-----------------------|-----------------------|---------------|--------|----------------|--------|-----------------|----------|
| | | Mu ⁻ (KNm) | Mu ⁺ (KNm) | As Perlu | Jumlah | As Perlu | Jumlah | Mnak, b | Mnak, b' |
| 1C1-2 | tumpuan | 322,378 | 116,674 | 1532,36 | 5D20 | 766,18 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 280,548 | - | 2D20 | 1224,49 | 4D20 | | |
| 1C2-3 | tumpuan | 309,395 | - | 1469,98 | 5D20 | 734,99 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 260,395 | - | 2D20 | 1133,71 | 4D20 | | |
| 3C1-2 | tumpuan | 299,058 | - | 1420,36 | 5D20 | 710,18 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 259,681 | - | 2D20 | 1130,50 | 4D20 | | |
| 3C2-3 | tumpuan | 345,566 | 94,791 | 1643,83 | 6D20 | 821,91 | 3D20 | 511,573 | 240,011 |
| | lapangan | - | 258,665 | - | 2D20 | 1125,93 | 4D20 | | |
| 5C1-2 | tumpuan | 283,337 | - | 1344,90 | 5D20 | 672,45 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 240,584 | - | 2D20 | 1044,92 | 4D20 | | |
| 5C2-3 | tumpuan | 355,454 | 71,426 | 1691,41 | 6D20 | 845,71 | 3D20 | 511,573 | 240,011 |
| | lapangan | - | 247,483 | - | 2D20 | 1075,79 | 4D20 | | |
| 7C1-2 | tumpuan | 247,417 | - | 1172,87 | 4D20 | 586,43 | 2D20 | 342,696 | 160,008 |
| | lapangan | - | 221,037 | - | 2D20 | 957,74 | 4D20 | | |
| 7C2-3 | tumpuan | 329,342 | - | 1565,83 | 5D20 | 782,92 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 224,451 | - | 2D20 | 972,94 | 4D20 | | |
| 10C1-2 | tumpuan | 104,482 | - | 492,84 | 2D20 | 246,42 | 2D16 | 168,912 | 102,405 |
| | lapangan | - | 92,127 | - | 2D20 | 393,15 | 2D20 | | |
| 10C2-3 | tumpuan | 139,516 | - | 658,90 | 3D20 | 329,45 | 2D16 | 259,951 | 102,405 |
| | lapangan | - | 91,039 | - | 2D20 | 388,45 | 2D20 | | |

Tabel 6.3 Tulangan longitudinal balok portal C struktur 15 portal 3 dinding geser

| Balok | Posisi | Momen Perlu (Mu) | | Tulangan Atas | | Tulangan Bawah | | Momen nak (KNm) | |
|-------|----------|-----------------------|-----------------------|---------------|--------|----------------|--------|-----------------|----------|
| | | Mu ⁻ (KNm) | Mu ⁺ (KNm) | As Perlu | Jumlah | As Perlu | Jumlah | Mnak, b | Mnak, b' |
| 1C1-2 | tumpuan | 303,328 | 76,061 | 1440,85 | 5D20 | 720,43 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 261,762 | - | 2D20 | 1139,85 | 4D20 | | |
| 1C2-3 | tumpuan | 289,465 | - | 1374,31 | 5D20 | 687,16 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 243,441 | - | 2D20 | 1057,70 | 4D20 | | |
| 3C1-2 | tumpuan | 273,656 | - | 1298,44 | 5D20 | 649,22 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 245,151 | - | 2D20 | 1065,35 | 4D20 | | |
| 3C2-3 | tumpuan | 321,248 | - | 1526,93 | 5D20 | 763,46 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 246,182 | - | 2D20 | 1069,96 | 4D20 | | |
| 5C1-2 | tumpuan | 254,933 | - | 1208,84 | 4D20 | 604,42 | 2D20 | 342,696 | 160,007 |
| | lapangan | - | 232,202 | - | 2D20 | 1007,48 | 4D20 | | |
| 5C2-3 | tumpuan | 329,405 | - | 1566,14 | 5D20 | 783,07 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 241,449 | - | 2D20 | 1048,79 | 4D20 | | |

Tabel 6.2 Tulangan longitudinal balok portal C struktur 16 portal 2 dinding geser

| Balok | Posisi | Momen Perlu (Mu) | | Tulangan Atas | | Tulangan Bawah | | Momen nak (KNm) | |
|--------|----------|-----------------------|-----------------------|---------------|--------|----------------|--------|-----------------|----------|
| | | Mu ⁻ (KNm) | Mu ⁺ (KNm) | As Perlu | Jumlah | As Perlu | Jumlah | Mnak, b | Mnak, b' |
| 1C1-2 | tumpuan | 322,378 | 116,674 | 1532,36 | 5D20 | 766,18 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 280,548 | - | 2D20 | 1224,49 | 4D20 | | |
| 1C2-3 | tumpuan | 309,395 | - | 1469,98 | 5D20 | 734,99 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 260,395 | - | 2D20 | 1133,71 | 4D20 | | |
| 3C1-2 | tumpuan | 299,058 | - | 1420,36 | 5D20 | 710,18 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 259,681 | - | 2D20 | 1130,50 | 4D20 | | |
| 3C2-3 | tumpuan | 345,566 | 94,791 | 1643,83 | 6D20 | 821,91 | 3D20 | 511,573 | 240,011 |
| | lapangan | - | 258,665 | - | 2D20 | 1125,93 | 4D20 | | |
| 5C1-2 | tumpuan | 283,337 | - | 1344,90 | 5D20 | 672,45 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 240,584 | - | 2D20 | 1044,92 | 4D20 | | |
| 5C2-3 | tumpuan | 355,454 | 71,426 | 1691,41 | 6D20 | 845,71 | 3D20 | 511,573 | 240,011 |
| | lapangan | - | 247,483 | - | 2D20 | 1075,79 | 4D20 | | |
| 7C1-2 | tumpuan | 247,417 | - | 1172,87 | 4D20 | 586,43 | 2D20 | 342,696 | 160,008 |
| | lapangan | - | 221,037 | - | 2D20 | 957,74 | 4D20 | | |
| 7C2-3 | tumpuan | 329,342 | - | 1565,83 | 5D20 | 782,92 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 224,451 | - | 2D20 | 972,94 | 4D20 | | |
| 10C1-2 | tumpuan | 104,482 | - | 492,84 | 2D20 | 246,42 | 2D16 | 168,912 | 102,405 |
| | lapangan | - | 92,127 | - | 2D20 | 393,15 | 2D20 | | |
| 10C2-3 | tumpuan | 139,516 | - | 658,90 | 3D20 | 329,45 | 2D16 | 259,951 | 102,405 |
| | lapangan | - | 91,039 | - | 2D20 | 388,45 | 2D20 | | |

Tabel 6.3 Tulangan longitudinal balok portal C struktur 15 portal 3 dinding geser

| Balok | Posisi | Momen Perlu (Mu) | | Tulangan Atas | | Tulangan Bawah | | Momen nak (KNm) | |
|-------|----------|-----------------------|-----------------------|---------------|--------|----------------|--------|-----------------|----------|
| | | Mu ⁻ (KNm) | Mu ⁺ (KNm) | As Perlu | Jumlah | As Perlu | Jumlah | Mnak, b | Mnak, b' |
| 1C1-2 | tumpuan | 303,328 | 76,061 | 1440,85 | 5D20 | 720,43 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 261,762 | - | 2D20 | 1139,85 | 4D20 | | |
| 1C2-3 | tumpuan | 289,465 | - | 1374,31 | 5D20 | 687,16 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 243,441 | - | 2D20 | 1057,70 | 4D20 | | |
| 3C1-2 | tumpuan | 273,656 | - | 1298,44 | 5D20 | 649,22 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 245,151 | - | 2D20 | 1065,35 | 4D20 | | |
| 3C2-3 | tumpuan | 321,248 | - | 1526,93 | 5D20 | 763,46 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 246,182 | - | 2D20 | 1069,96 | 4D20 | | |
| 5C1-2 | tumpuan | 254,933 | - | 1208,84 | 4D20 | 604,42 | 2D20 | 342,696 | 160,007 |
| | lapangan | - | 232,202 | - | 2D20 | 1007,48 | 4D20 | | |
| 5C2-3 | tumpuan | 329,405 | - | 1566,14 | 5D20 | 783,07 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 241,449 | - | 2D20 | 1048,79 | 4D20 | | |

Lanjutan tabel 6.3

| | | | | | | | | | |
|--------|----------|---------|---------|---------|------|--------|------|---------|---------|
| 7C1-2 | tumpuan | 234,679 | - | 1111,91 | 4D20 | 555,96 | 2D20 | 342,696 | 160,007 |
| | lapangan | - | 208,272 | - | 2D20 | 901,04 | 3D20 | | |
| 7C2-3 | tumpuan | 320,014 | - | 1520,99 | 5D20 | 760,50 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 211,343 | - | 2D20 | 914,67 | 3D20 | | |
| 10C1-2 | tumpuan | 101,048 | - | 476,57 | 2D20 | 238,29 | 2D14 | 168,912 | 102,405 |
| | lapangan | - | 90,833 | - | 2D20 | 387,57 | 2D20 | | |
| 10C2-3 | tumpuan | 104,165 | - | 491,34 | 2D20 | 245,67 | 2D14 | 168,912 | 102,405 |
| | lapangan | - | 89,980 | - | 2D20 | 383,89 | 2D20 | | |

Tabel 6.4 Tulangan longitudinal balok portal C struktur 16 portal 4 dinding geser

| Balok | Posisi | Momen Perlu (Mu) | | Tulangan Atas | | Tulangan Bawah | | Momen nak (KNm) | |
|--------|----------|-----------------------|-----------------------|---------------|--------|----------------|--------|-----------------|----------|
| | | Mu ⁻ (KNm) | Mu ⁺ (KNm) | As Perlu | Jumlah | As Perlu | Jumlah | Mnak, b | Mnak, b' |
| 1C1-2 | tumpuan | 297,432 | - | 1412,55 | 5D20 | 706,28 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 257,975 | - | 2D20 | 1122,84 | 4D20 | | |
| 1C2-3 | tumpuan | 283,297 | - | 1344,71 | 5D20 | 672,35 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 240,182 | - | 2D20 | 1043,12 | 4D20 | | |
| 3C1-2 | tumpuan | 274,487 | - | 1302,42 | 5D20 | 651,21 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 239,620 | - | 2D20 | 1040,61 | 4D20 | | |
| 5C1-3 | tumpuan | 322,584 | - | 1533,35 | 5D20 | 766,67 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 241,016 | - | 2D20 | 1046,85 | 4D20 | | |
| 6C1-2 | tumpuan | 260,502 | - | 1235,49 | 4D20 | 617,74 | 2D20 | 342,696 | 160,007 |
| | lapangan | - | 229,511 | - | 2D20 | 995,48 | 4D20 | | |
| 6C2-3 | tumpuan | 336,323 | - | 1599,39 | 5D20 | 799,70 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 238,964 | - | 2D20 | 1037,68 | 4D20 | | |
| 7C1-2 | tumpuan | 238,974 | - | 1132,46 | 4D20 | 566,23 | 2D20 | 342,696 | 160,007 |
| | lapangan | - | 209,452 | - | 2D20 | 906,28 | 3D20 | | |
| 7C2-3 | tumpuan | 326,651 | - | 1552,90 | 5D20 | 776,45 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 213,793 | - | 2D20 | 925,54 | 3D20 | | |
| 10C1-2 | tumpuan | 101,355 | - | 478,03 | 2D20 | 239,01 | 2D14 | 168,912 | 102,405 |
| | lapangan | - | 90,423 | - | 2D20 | 385,80 | 2D20 | | |
| 10C2-3 | tumpuan | 106,705 | - | 503,36 | 2D20 | 251,68 | 2D14 | 168,912 | 102,405 |
| | lapangan | - | 89,455 | - | 2D20 | 381,63 | 2D20 | | |

Tabel 6.5 Tulangan longitudinal balok portal C struktur 15 portal 5 dinding geser

| Balok | Posisi | Momen Perlu (Mu) | | Tulangan Atas | | Tulangan Bawah | | Momen nak (KNm) | |
|--------|----------|-----------------------|-----------------------|---------------|--------|----------------|--------|-----------------|----------|
| | | Mu ⁻ (KNm) | Mu ⁺ (KNm) | As Perlu | Jumlah | As Perlu | Jumlah | Mnak, b | Mnak, b' |
| 1C1-2 | tumpuan | 277,374 | - | 1316,28 | 5D20 | 658,14 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 239,240 | - | 2D20 | 1038,91 | 4D20 | | |
| 1C2-3 | tumpuan | 256,480 | - | 1216,24 | 4D20 | 608,12 | 2D20 | 342,696 | 160,007 |
| | lapangan | - | 221,972 | - | 2D20 | 961,90 | 4D20 | | |
| 3C1-2 | tumpuan | 257,056 | - | 1219,00 | 4D20 | 609,50 | 2D20 | 342,696 | 160,007 |
| | lapangan | - | 231,254 | - | 2D20 | 1003,26 | 4D20 | | |
| 3C2-3 | tumpuan | 292,498 | - | 1388,87 | 5D20 | 694,44 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 230,673 | - | 2D20 | 1000,66 | 4D20 | | |
| 5C1-2 | tumpuan | 256,350 | - | 1215,62 | 4D20 | 607,81 | 2D20 | 342,696 | 160,007 |
| | lapangan | - | 221,844 | - | 2D20 | 961,33 | 4D20 | | |
| 5C2-3 | tumpuan | 313,392 | - | 1489,16 | 5D20 | 744,58 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 227,271 | - | 2D20 | 985,50 | 4D20 | | |
| 7C1-2 | tumpuan | 342,634 | - | 1149,98 | 4D20 | 574,99 | 2D20 | 342,696 | 160,007 |
| | lapangan | - | 209,219 | - | 2D20 | 905,24 | 3D20 | | |
| 7C2-3 | tumpuan | 302,846 | - | 1438,54 | 5D20 | 719,27 | 3D20 | 422,601 | 240,011 |
| | lapangan | - | 208,673 | - | 2D20 | 902,82 | 3D20 | | |
| 10C1-2 | tumpuan | 107,595 | - | 497,68 | 2D20 | 239,84 | 2D16 | 168,912 | 102,405 |
| | lapangan | - | 98,550 | - | 2D20 | 420,87 | 2D20 | | |
| 10C2-3 | tumpuan | 141,396 | - | 695,76 | 3D20 | 347,88 | 2D16 | 168,912 | 102,405 |
| | lapangan | - | 95,938 | - | 2D20 | 409,59 | 2D20 | | |

Tabel 6.6 Tulangan geser balok portal C struktur 16 portal 2 dinding geser

| Balok | Sepanjang Daerah Sendi Plastis | | | | Di luar Daerah Sendi Plastis | | | | |
|--------|--------------------------------|------------|-----------|----------|------------------------------|------------|------------|-----------|----------|
| | Vu (KN) | Vs (KN) | S (mm) | Terpakai | Vu (KN) | Vc (KN) | Vs (KN) | S (mm) | Terpakai |
| 1C1-2 | 309,755 | 494,989 | 93,93 | D10-90 | 285,611 | 270,210 | 205,809 | 225,92 | D10-225 |
| 1C2-3 | 299,353 | 477,652 | 97,34 | D10-95 | 275,209 | 270,210 | 188,472 | 246,70 | D10-245 |
| 3C1-2 | 300,060 | 478,832 | 97,10 | D10-95 | 275,917 | 270,210 | 189,652 | 245,16 | D10-245 |
| 3C2-3 | 318,540 | 506,774 | 91,75 | D10-90 | 291,154 | 270,210 | 215,047 | 216,21 | D10-215 |
| 5C1-2 | 295,139 | 471,139 | 98,69 | D10-95 | 271,574 | 270,210 | 182,413 | 254,89 | D10-250 |
| 5C2-3 | 321,646 | 512,529 | 90,72 | D10-90 | 294,916 | 270,210 | 221,317 | 210,09 | D10-210 |
| 7C1-2 | 276,339 | 445,096 | 104,46 | D10-100 | 258,779 | 270,210 | 161,089 | 288,63 | D10-285 |
| 7C2-3 | 313,105 | 501,453 | 92,72 | D10-90 | 289,960 | 270,210 | 213,057 | 218,23 | D10-215 |
| 10C1-2 | 142,627 | 229,510 | 202,59 | D10-185 | 133,317 | 270,210 | 48,015 | 968,4 | D10-370 |
| 10C2-3 | 161,912 | 258,900 | 179,59 | D10-175 | 149,479 | 270,210 | 21,079 | 2205,8 | D10-370 |

Tabel 6.7 Tulangan geser balok portal C struktur 15 portal 3 dinding geser

| Balok | Sepanjang Daerah Sendi Plastis | | | | Di luar Daerah Sendi Plastis | | | | |
|--------|--------------------------------|---------|--------|----------|------------------------------|---------|---------|--------|----------|
| | Vu | Vs | S | Terpakai | Vu | Vc | Vs | S | Terpakai |
| | (KN) | (KN) | (mm) | | (KN) | (KN) | (KN) | (mm) | |
| 1C1-2 | 309,667 | 494,843 | 93,96 | D10-90 | 285,524 | 270,210 | 205,664 | 226,08 | D10-225 |
| 1C2-3 | 299,438 | 477,795 | 97,31 | D10-95 | 275,295 | 270,210 | 188,615 | 246,51 | D10-245 |
| 3C1-2 | 299,847 | 478,475 | 97,17 | D10-95 | 275,703 | 270,210 | 189,295 | 245,62 | D10-245 |
| 3C2-3 | 309,248 | 494,144 | 94,09 | D10-90 | 285,105 | 270,210 | 204,964 | 226,85 | D10-225 |
| 5C1-2 | 277,945 | 447,492 | 103,90 | D10-100 | 260,067 | 270,210 | 163,235 | 284,84 | D10-280 |
| 5C2-3 | 312,591 | 500,226 | 92,95 | D10-90 | 289,026 | 270,210 | 211,501 | 219,84 | D10-215 |
| 7C1-2 | 275,933 | 444,419 | 104,62 | D10-100 | 258,373 | 270,210 | 160,412 | 289,85 | D10-285 |
| 7C2-3 | 313,510 | 502,127 | 92,60 | D10-90 | 290,365 | 270,210 | 213,732 | 217,54 | D10-215 |
| 10C1-2 | 142,416 | 229,158 | 202,90 | D10-185 | 133,106 | 270,210 | 48,367 | 961,3 | D10-370 |
| 10C2-3 | 152,696 | 246,293 | 188,78 | D10-185 | 143,387 | 270,210 | 31,232 | 1488,7 | D10-370 |

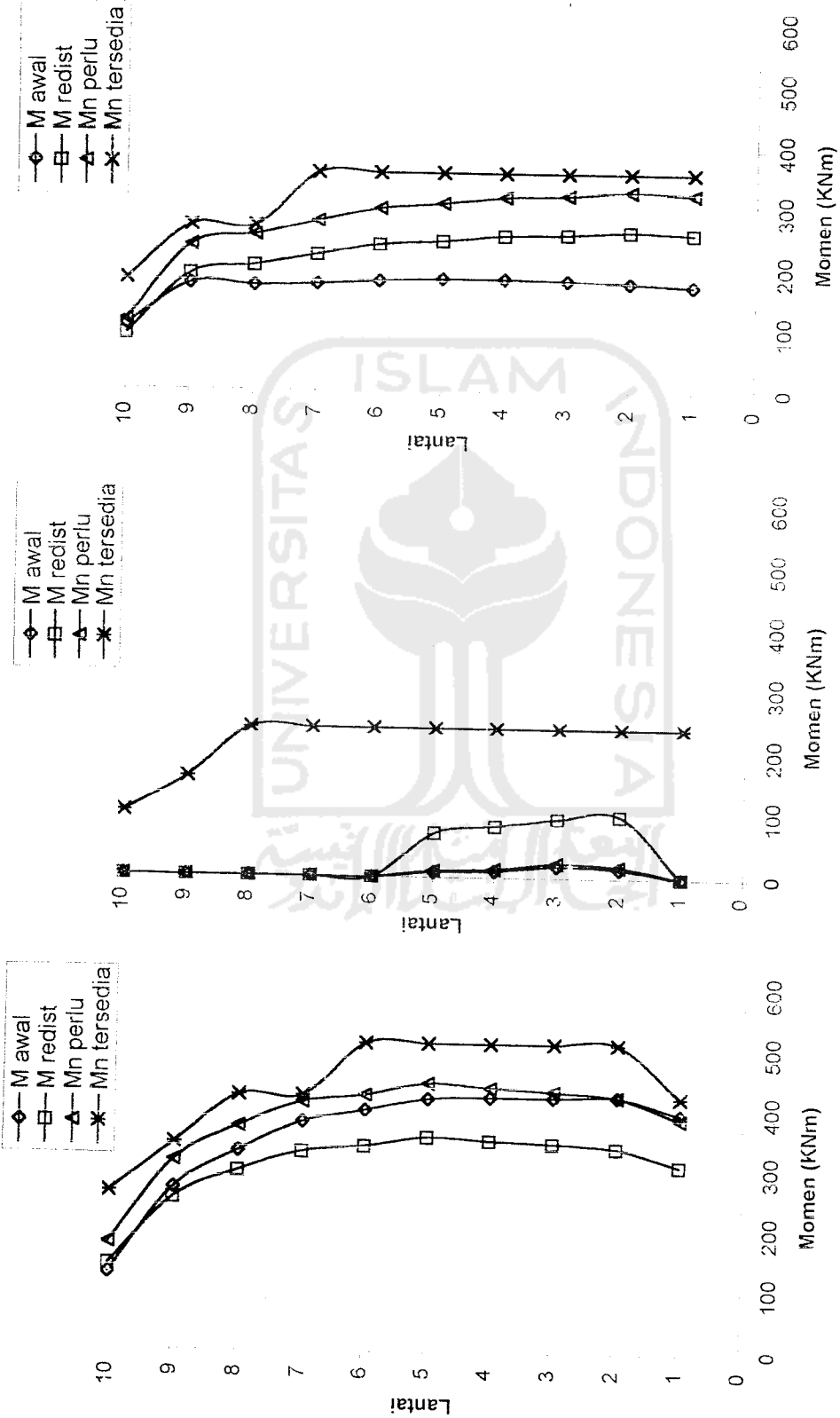
Tabel 6.8 Tulangan geser balok portal C struktur 16 portal 4 dinding geser

| Balok | Sepanjang Daerah Sendi Plastis | | | | Di luar Daerah Sendi Plastis | | | | |
|--------|--------------------------------|---------|--------|----------|------------------------------|---------|---------|--------|----------|
| | Vu | Vs | S | Terpakai | Vu | Vc | Vs | S | Terpakai |
| | (KN) | (KN) | (mm) | | (KN) | (KN) | (KN) | (mm) | |
| 1C1-2 | 309,618 | 494,761 | 93,98 | D10-90 | 285,475 | 270,210 | 205,582 | 226,17 | D10-225 |
| 1C2-3 | 299,489 | 477,880 | 97,30 | D10-95 | 275,346 | 270,210 | 188,700 | 246,40 | D10-245 |
| 3C1-2 | 299,728 | 478,278 | 97,21 | D10-95 | 275,585 | 270,210 | 189,098 | 245,88 | D10-240 |
| 3C2-3 | 309,378 | 494,360 | 94,05 | D10-90 | 285,234 | 270,210 | 205,181 | 226,61 | D10-225 |
| 5C1-2 | 277,756 | 447,177 | 103,98 | D10-100 | 259,878 | 270,210 | 162,920 | 285,39 | D10-285 |
| 5C2-3 | 312,772 | 500,526 | 92,89 | D10-90 | 289,207 | 270,210 | 211,801 | 219,52 | D10-215 |
| 7C1-2 | 276,296 | 445,025 | 104,48 | D10-100 | 258,737 | 270,210 | 161,018 | 288,76 | D10-285 |
| 7C2-3 | 313,778 | 502,573 | 92,51 | D10-90 | 290,633 | 270,210 | 214,178 | 217,09 | D10-215 |
| 10C1-2 | 142,010 | 228,482 | 203,50 | D10-185 | 132,700 | 270,210 | 49,043 | 948,1 | D10-370 |
| 10C2-3 | 153,105 | 246,974 | 188,26 | D10-185 | 143,795 | 270,210 | 30,551 | 1521,9 | D10-370 |

Tabel 6.9 Tulangan geser balok portal C struktur 15 portal 5 dinding geser

| Balok | Sepanjang Daerah Sendi Plastis | | | | Di luar Daerah Sendi Plastis | | | | |
|--------|--------------------------------|---------|--------|----------|------------------------------|---------|---------|--------|----------|
| | Vu | Vs | S | Terpakai | Vu | Vc | Vs | S | Terpakai |
| | (KN) | (KN) | (mm) | | (KN) | (KN) | (KN) | (mm) | |
| 1C1-2 | 310,293 | 495,886 | 93,76 | D10-90 | 286,150 | 270,210 | 206,706 | 224,94 | D10-225 |
| 1C2-3 | 281,750 | 453,446 | 102,54 | D10-100 | 263,433 | 270,210 | 168,845 | 275,37 | D10-275 |
| 3C1-2 | 284,303 | 457,702 | 101,58 | D10-100 | 265,986 | 270,210 | 173,100 | 268,61 | D10-265 |
| 3C2-3 | 307,738 | 491,628 | 94,57 | D10-90 | 283,595 | 270,210 | 202,448 | 229,67 | D10-225 |
| 5C1-2 | 280,313 | 451,439 | 102,99 | D10-100 | 262,435 | 270,210 | 167,182 | 278,11 | D10-275 |
| 5C2-3 | 310,230 | 496,290 | 93,69 | D10-90 | 286,665 | 270,210 | 207,564 | 224,01 | D10-220 |
| 7C1-2 | 279,435 | 450,255 | 103,26 | D10-100 | 261,875 | 270,210 | 166,249 | 279,67 | D10-275 |
| 7C2-3 | 310,008 | 496,291 | 93,69 | D10-90 | 286,863 | 270,210 | 207,896 | 223,65 | D10-220 |
| 10C1-2 | 138,775 | 223,090 | 208,42 | D10-185 | 129,465 | 270,210 | 54,435 | 854,1 | D10-370 |
| 10C2-3 | 156,340 | 252,366 | 185,24 | D10-185 | 147,031 | 270,210 | 25,159 | 1848,1 | D10-370 |

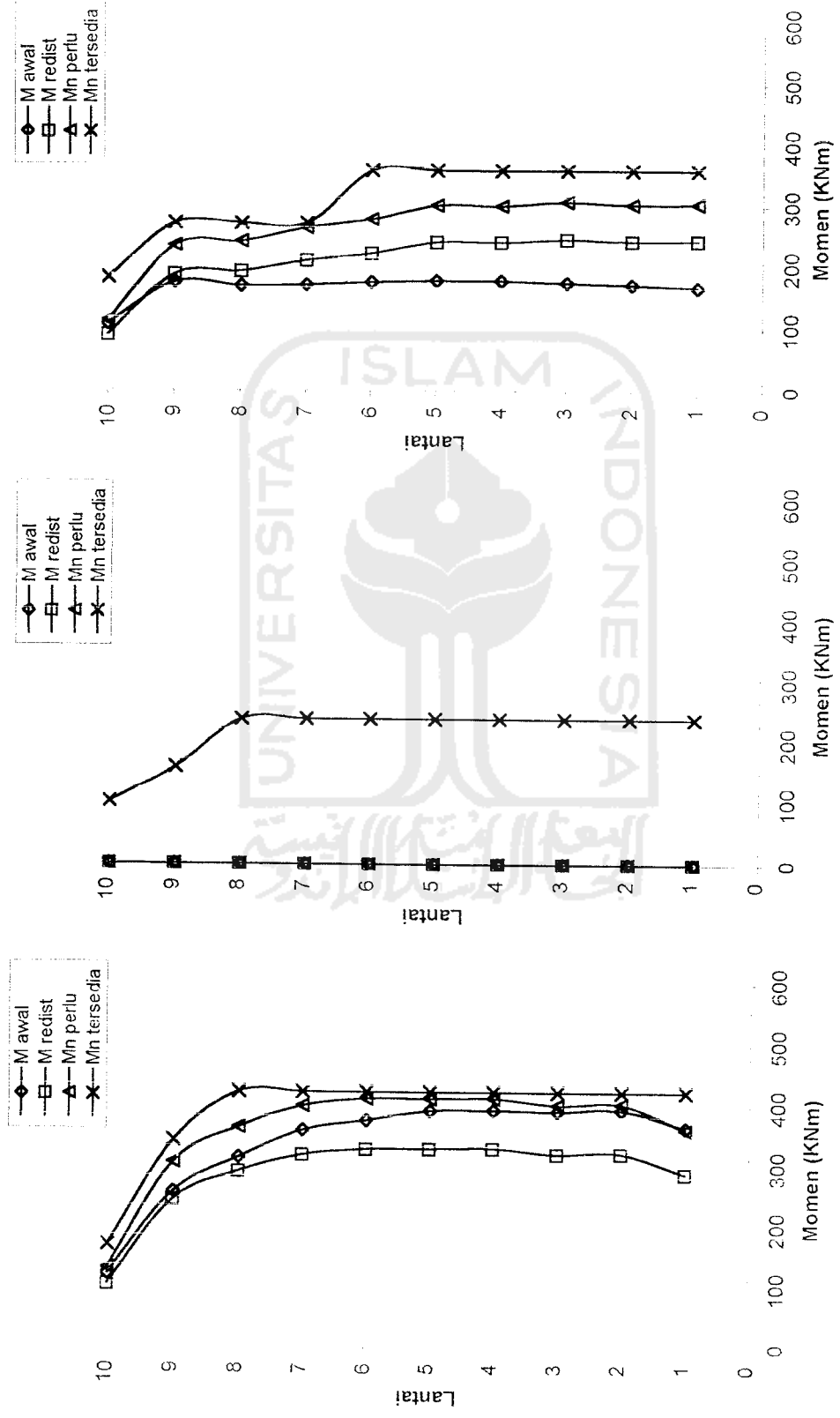




Gb.6.2 M. tump.(-) 16P-2DG

Gb.6.3 M. tump.(+) 16P-2DG

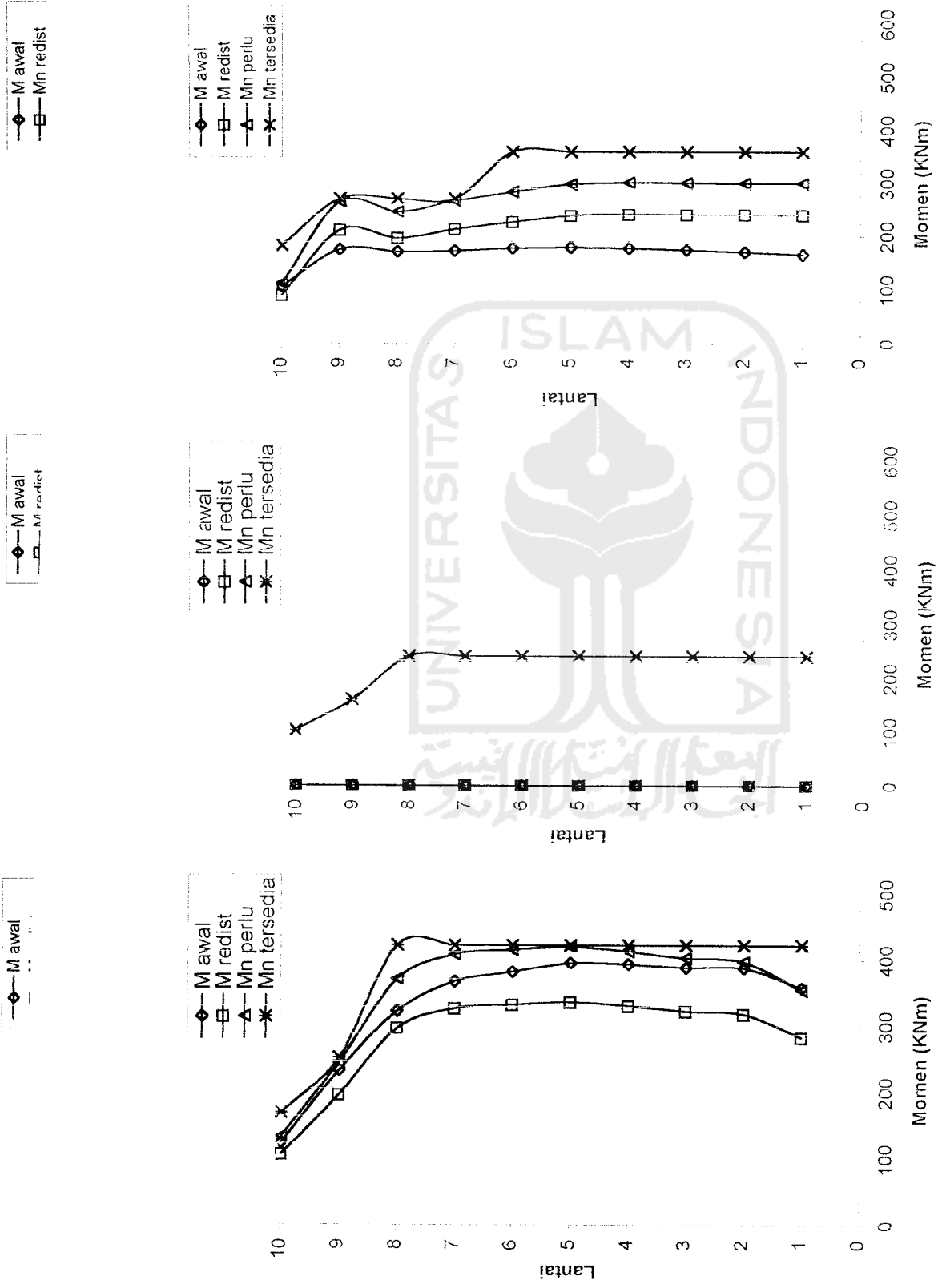
Gb.6.4 M. lapangan 16P-2DG



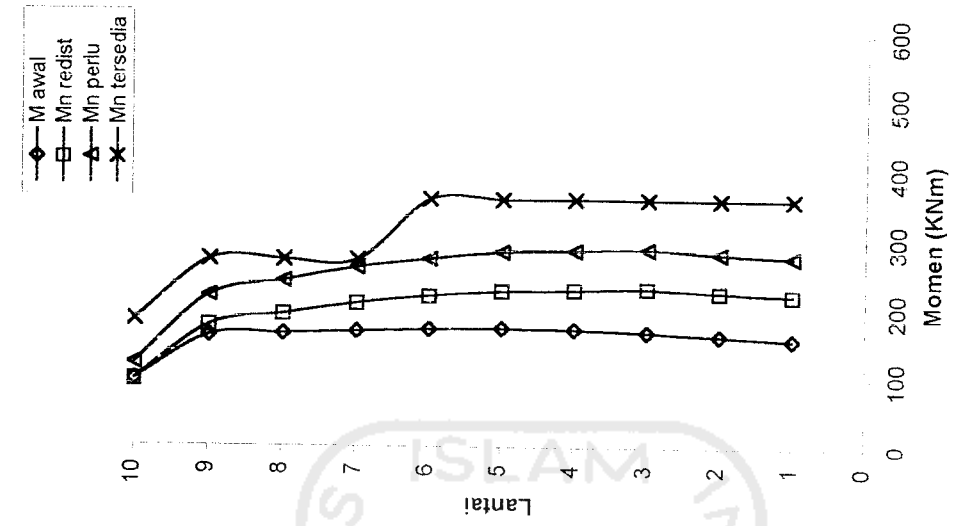
Gb.6.5 M. tump.(-) 15P-3DG

Gb.6.6 M. tump.(+) 15P-3DG

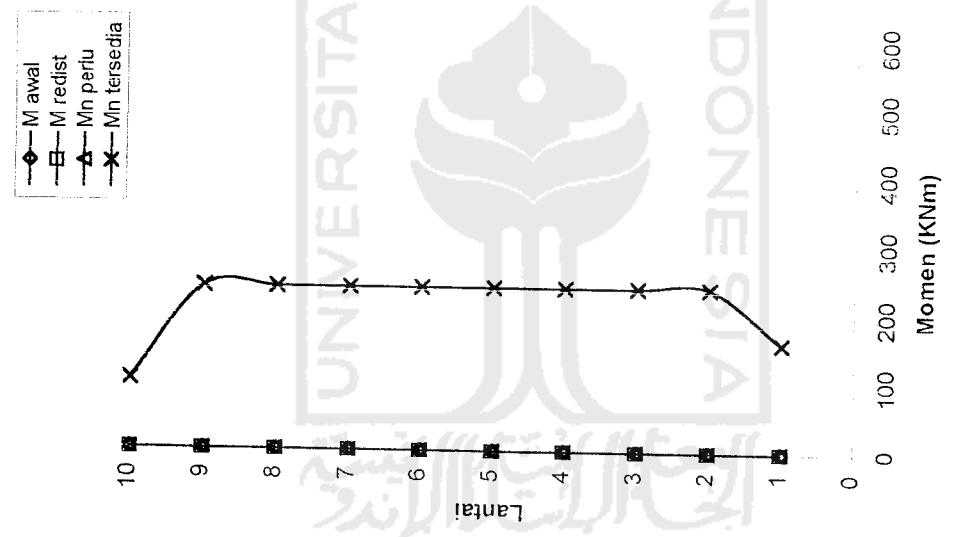
Gb.6.7 M. lapangan 15P-3DG



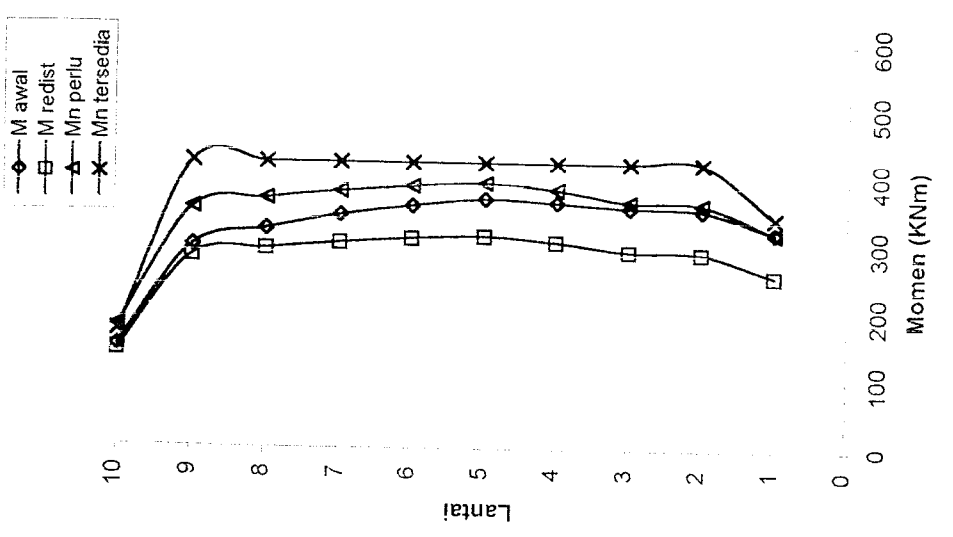
Gb.6.8 M. tump.(-) 16P-4DG Gb.6.9 M. tump.(+) 16P-4DG Gb.6.10 M. lapangan 16P-4DG



Gb.6.13 M. lapangan 15P-5DG



Gb.6.12 M. tump.(+) 15P-5DG



Gb.6.11 M. tump.(-) 15P-5DG

6.2 Desain Penulangan Kolom Akibat Beban Lentur dan Aksial

6.2.1 Momen Rencana dan Momen Maksimum Kolom

Momen rencana kolom dihitung berdasarkan pada anggapan bahwa sendi plastis terjadi pada muka ujung-ujung balok pada pertemuan antara balok dan kolom. Dalam hal ini momen kapasitas balok diperhitungkan sebagai momen rencana yang bekerja pada kolom setelah sebelumnya dikalikan dengan beberapa faktor. Momen rencana kolom dapat dihitung berdasarkan persamaan dibawah ini.

$$M_{u_k} = \frac{h}{l_n} \cdot 0.7 \cdot \omega_d \cdot \phi_c \cdot \alpha_k \cdot \left[\frac{l_{ki}}{l_n} M_{u_{bk}} h_{ki} + \frac{l_{ka}}{l_n} M_{u_{bk}} h_{ka} \right] \quad (6.1)$$

$$\text{dimana, } \alpha_k = \frac{M_{u_{bk}} k_{i+\text{atas dan bawah}}}{M_{u_{bk}} k_{i+\text{atas dan bawah}} + M_{u_{bk}} k_{i+\text{atas dan bawah}}} \quad (6.2)$$

h = tinggi kolom dari titik pertemuan ke titik pertemuan

h_n = tinggi bersih kolom

l_{ki} = bentang balok sebelah kiri diukur dari titik pertemuan ke titik pertemuan

l_{nki} = bentang bersih balok sebelah kiri

l_{ka} = bentang balok sebelah kanan

l_{nka} = bentang bersih balok sebelah kanan

M_{nak} = momen lentur nominal aktual balok

Menurut Pedoman Perencanaan Ketahanan Gempa untuk Rumah dan Gedung 1987, gaya aksial dan momen rencana untuk kolom harus diperhitungkan terhadap 30 % arah tegak lurus nya. Dalam tugas akhir ini, 30 % arah tegak lurus dari sumbu

utama yang ditinjau dijumlahkan secara aljabar agar dapat memudahkan perhitungan dengan tetap menggunakan rumus-rumus uniaksial (Gideon 1994).

1. Momen rencana kolom

Momen rencana kolom lantai 1 interior

$$\phi_0 = 1,25 \text{ untuk } f_y \leq 400 \text{ Mpa}$$

$$K = 1$$

$$\omega_d = 1,09$$

$$l_{bx} = 4,00 \text{ m}$$

$$l_{nbx} = 3,6 \text{ m}$$

$$l_{bx}/l_{nbx} = 4/3,6 = 1,111$$

$$l_{by} = 9,00 \text{ m}$$

$$l_{nby} = 8,15 \text{ m}$$

$$l_{by}/l_{nby} = 9/8,15 = 1,1043 \text{ m}$$

$$h_{kolom} = 5,25 \text{ m}$$

$$h_{nkolom} = 4,6 \text{ m}$$

$$h_k/h_{nk} = 5,25/4,6 = 1,1413 \text{ m}$$

Contoh hitungan kolom interior lantai 1,

$$M_{E,k} \text{ lantai 1 atas} = 312,88 \text{ kNm}$$

$$M_{F,k} \text{ lantai 2 bawah} = 245,074 \text{ kNm}$$

Nilai distribusi momen kolom portal α_k menurut Gideon (1994)

$$\text{Adalah } \alpha_{katas} = \frac{312,88}{245,074 + 312,88} = 0,5601$$



$$\text{Momen perlu kolom } M_{uk} = \frac{h}{h_u} \cdot 0,7 \cdot \omega_d \cdot \phi_D \cdot \alpha_s \left[\frac{l_{kx}}{l_{ekx}} \cdot M_{maks} \cdot b_{kx} + \frac{l_{ky}}{l_{eky}} \cdot 30\% \cdot M_{maks} \cdot b_{ky} \right]$$

$$M_{ukx} \text{ lt 1 atas} = 1,1413 \cdot 0,7 \cdot 1,09 \cdot 1,25 \cdot 0,561 \cdot [1,111 \cdot 422,601 + 1,1043 \cdot 0,3 \cdot 511,573] \\ = 389,437 \text{ kNm}$$

$$M_{uky} \text{ lt 1 atas} = 1,1413 \cdot 0,7 \cdot 1,09 \cdot 1,25 \cdot 0,561 \cdot [1,111 \cdot 0,3 \cdot 422,601 + 1,1043 \cdot 501,573]$$

Khusus untuk kolom lantai 1 dimana sendi plastis dimungkinkan terjadi maka $\alpha_{kbawah} = 0$. Untuk itu momen rencana kolom lantai 1 dihitung berdasarkan gaya gempa yang diperoleh dari hasil SAP90.

$$M_{uklt1-bawah-x} = 334,388 + 0,3 \cdot 365,013 = 443,892 \text{ kNm}$$

$$M_{uklt1-bawah-y} = 0,3 \cdot 334,388 + 365,013 = 465,329 \text{ kNm}$$

Perhitungan momen rencana kolom lainnya dihitung dengan cara yang sama dan hasilnya ditabelkan pada tabel 6.10. Apabila momen rencana kolom setelah dihitung hasilnya melebihi momen maksimum maka yang digunakan dalam perhitungan adalah momen maksimum sebagai berikut,

2. Momen maksimum kolom

a. Momen maksimum kolom 1 atas dan bawah arah x

$$M_{uk1-x-atas} = 1,05 \cdot (2,238 + 0,697 + 4 \cdot (334,388 + 0,3 \cdot 365,023)) = 1867,488 \text{ kNm}$$

$$M_{uk1-x-bawah} = 1,05 \cdot (2,238 + 0,697 - 4 \cdot (334,388 + 0,3 \cdot 365,023)) = -1861,2296 \text{ kNm}$$

b. Momen maksimum kolom 1 atas dan bawah arah y

$$M_{uk1-y-atas} = 1,05 \cdot (0 + 0 + 4 \cdot (0,3 \cdot 334,388 + 365,023)) = 1954,425 \text{ kNm}$$

$$M_{uk1-y-bawah} = 1,05 \cdot (0 + 0 - 4 \cdot (0,3 \cdot 334,388 + 365,023)) = -1954,425 \text{ kNm}$$

Perhitungan momen maksimum lainnya dihitung dengan cara yang sama dan hasilnya ditabelkan pada tabel 6.14.

struktur

Tabel 6.10 Momen rencana kolom struktur 16 portal 2 dinding geser

| Lantai | Kolom | $M_{E,k}$ | | α_{ka} | α_{kb} | $M_{nak,bs}$ (kNm) | | $M_{nak,bv}$ (kNm) | | $M_{u,ks}$ (kNm) | | $M_{u,kv}$ (kNm) | |
|--------|-------|-----------|---------|---------------|---------------|--------------------|---------|--------------------|---------|------------------|----------|------------------|----------|
| | | Atas | Bawah | | | Kiri | Kanan | Kiri | Kanan | Atas | Bawah | Atas | Bawah |
| 1 | 2 | 211,321 | - | 0,476 | ~ | 412,035 | 422,601 | 422,601 | 422,601 | 624,357 | 443,892* | 624,461 | 465,329* |
| | 3 | 119,063 | - | 0,509 | ~ | 332,080 | 422,601 | 422,601 | ~ | 541,732 | 380,435* | 396,396 | 332,247* |
| 3 | 2 | 223,011 | 221,795 | 0,512 | 0,498 | 332,080 | 412,035 | 422,601 | 511,573 | 775,757 | 753,639 | 870,788 | 845,960 |
| | 3 | 114,652 | 115,763 | 0,506 | 0,502 | 332,080 | 332,080 | 511,573 | ~ | 612,369 | 607,247 | 528,910 | 524,486 |
| 5 | 2 | 206,606 | 199,874 | 0,533 | 0,480 | 332,080 | 332,080 | 422,601 | 511,573 | 740,776 | 666,977 | 877,650 | 790,215 |
| | 3 | 109,675 | 103,522 | 0,545 | 0,476 | 332,080 | 332,080 | 511,573 | ~ | 657,296 | 574,879 | 564,072 | 493,344 |
| 7 | 2 | 160,275 | 145,867 | 0,573 | 0,426 | 252,126 | 332,080 | 342,696 | 422,601 | 685,294 | 508,978 | 778,088 | 577,897 |
| | 3 | 91,809 | 83,636 | 0,598 | 0,460 | 252,126 | 252,126 | 422,601 | ~ | 556,204 | 427,639 | 496,873 | 382,022 |
| 10 | 2 | 44,384 | 30,502 | 1,000 | 0,239 | 168,912 | 168,912 | 168,912 | 259,951 | 569,929 | 136,448 | 633,320 | 151,625 |
| | 3 | 23,775 | 15,122 | 1,000 | 0,231 | 168,912 | 168,912 | 259,951 | ~ | 509,897 | 117,812 | 433,213 | 100,094 |

Ket * : $M_{E,k,l,1 \text{ bawah } X} = M_{E,b-X} + 0,3 M_{E,b-Y}$

struktur

Tabel 6.11 Momen rencana kolom struktur 15 portal 3 dinding geser

| Lantai | Kolom | $M_{E,k}$ | | α_{ka} | α_{kb} | $M_{nak,bs}$ (kNm) | | $M_{nak,bv}$ (kNm) | | $M_{u,ks}$ (kNm) | | $M_{u,kv}$ (kNm) | |
|--------|-------|-----------|---------|---------------|---------------|--------------------|---------|--------------------|---------|------------------|----------|------------------|----------|
| | | Atas | Bawah | | | Kiri | Kanan | Kiri | Kanan | Atas | Bawah | Atas | Bawah |
| 1 | 2 | 182,38 | - | 0,478 | - | 412,035 | 412,035 | 422,601 | 422,601 | 621,276 | 428,983* | 625,657 | 414,583* |
| | 3 | 102,949 | - | 0,512 | - | 422,601 | 422,601 | 422,601 | - | 600,623 | 379,028* | 415,301 | 301,476* |
| 3 | 2 | 196,58 | 188,83 | 0,521 | 0,496 | 332,08 | 412,035 | 422,601 | 422,601 | 768,095 | 730,938 | 817,170 | 777,639 |
| | 3 | 98,199 | 98,625 | 0,508 | 0,499 | 332,08 | 332,08 | 422,601 | - | 594,540 | 584,461 | 464,471 | 456,596 |
| 5 | 2 | 175,676 | 169,965 | 0,532 | 0,479 | 342,696 | 332,08 | 342,696 | 422,601 | 709,531 | 639,047 | 749,361 | 674,920 |
| | 3 | 93,336 | 88,137 | 0,544 | 0,476 | 332,08 | 332,08 | 422,601 | - | 635,715 | 556,169 | 493,530 | 431,775 |
| 7 | 2 | 136,523 | 124,187 | 0,574 | 0,426 | 252,126 | 252,126 | 342,696 | 422,601 | 618,457 | 458,492 | 759,077 | 562,740 |
| | 3 | 78,222 | 71,214 | 0,600 | 0,460 | 252,126 | 252,126 | 422,601 | - | 557,572 | 427,537 | 498,095 | 381,930 |
| 10 | 2 | 35,599 | 23,917 | 1,000 | 0,227 | 168,912 | 168,912 | 168,912 | 168,912 | 537,573 | 121,973 | 525,468 | 119,226 |
| | 3 | 19,091 | 11,814 | 1,000 | 0,218 | 168,912 | 168,912 | 168,912 | - | 477,541 | 104,171 | 325,360 | 70,974 |

Ket * : $M_{E,k,l,1 \text{ bawah } X} = M_{E,b-X} + 0,3 M_{E,b-Y}$

Tabel 6.12 Momen rencana kolom struktur 16 portal 4 dinding geser

| Lantai | Kolom | $M_{E,k}$ | | α_{ka} | α_{kb} | $M_{nak,bx}$ (kNm) | | $M_{nak,by}$ (kNm) | | $M_{u,kx}$ (kNm) | | $M_{u,ky}$ (kNm) | |
|--------|-------|-----------|---------|---------------|---------------|--------------------|---------|--------------------|---------|------------------|----------|------------------|----------|
| | | Atas | Bawah | | | Kiri | Kanan | Kiri | Kanan | Atas | Bawah | Atas | Bawah |
| 1 | 2 | 174,164 | - | 0,475 | - | 412,035 | 412,035 | 422,601 | 422,601 | 617,792 | 430,354* | 622,148 | 402,728* |
| | 3 | 98,430 | - | 0,508 | - | 412,035 | 412,035 | 422,601 | - | 583,356 | 402,055* | 408,445 | 300,386* |
| 3 | 2 | 184,196 | 185,18 | 0,505 | 0,502 | 332,080 | 412,035 | 422,601 | 422,601 | 745,210 | 740,265 | 792,823 | 787,562 |
| | 3 | 94,700 | 97,118 | 0,499 | 0,507 | 332,080 | 332,080 | 422,601 | - | 583,830 | 593,338 | 456,103 | 463,531 |
| 5 | 2 | 176,282 | 172,702 | 0,525 | 0,487 | 332,080 | 332,080 | 342,696 | 422,601 | 690,996 | 641,928 | 736,029 | 683,764 |
| | 3 | 93,479 | 89,814 | 0,535 | 0,485 | 332,080 | 332,080 | 422,601 | - | 625,503 | 566,874 | 485,602 | 440,086 |
| 7 | 2 | 142,479 | 130,583 | 0,569 | 0,432 | 252,126 | 252,126 | 342,696 | 422,601 | 612,947 | 465,544 | 752,314 | 571,396 |
| | 3 | 81,387 | 75,004 | 0,593 | 0,468 | 252,126 | 252,126 | 422,601 | - | 551,530 | 434,951 | 492,697 | 388,554 |
| 10 | 2 | 38,110 | 25,566 | 1,000 | 0,226 | 168,912 | 168,912 | 168,912 | 168,912 | 537,573 | 121,643 | 525,468 | 118,904 |
| | 3 | 20,331 | 12,504 | 1,000 | 0,216 | 168,912 | 168,912 | 168,912 | - | 477,541 | 103,248 | 325,360 | 70,346 |

Ket * : $M_{E,k \text{ tr.1 bawah } X} = M_{E,b-X} + 0,3 M_{E,b-Y}$

Tabel 6.13 Momen rencana kolom struktur 15 portal 5 dinding geser

| Lantai | Kolom | $M_{E,k}$ | | α_{ka} | α_{kb} | $M_{nak,bx}$ (kNm) | | $M_{nak,by}$ (kNm) | | $M_{u,kx}$ (kNm) | | $M_{u,ky}$ (kNm) | |
|--------|-------|-----------|---------|---------------|---------------|--------------------|---------|--------------------|---------|------------------|----------|------------------|----------|
| | | Atas | Bawah | | | Kiri | Kanan | Kiri | Kanan | Atas | Bawah | Atas | Bawah |
| 1 | 2 | 138,427 | - | 0,467 | - | 412,035 | 412,035 | 422,601 | 342,696 | 593,846 | 414,666* | 566,905 | 343,728* |
| | 3 | 78,216 | - | 0,498 | - | 412,035 | - | 342,601 | - | 309,139 | 378,617* | 278,121 | 257,716* |
| 3 | 2 | 151,880 | 156,885 | 0,493 | 0,516 | 422,601 | 422,601 | 342,696 | 422,601 | 783,152 | 819,585 | 737,517 | 771,826 |
| | 3 | 77,631 | 82,743 | 0,483 | 0,523 | 332,080 | 332,080 | 422,601 | - | 565,960 | 612,617 | 442,143 | 478,592 |
| 5 | 2 | 153,613 | 152,570 | 0,517 | 0,496 | 332,080 | 412,034 | 342,034 | 422,601 | 741,981 | 712,556 | 743,106 | 713,636 |
| | 3 | 81,384 | 79,668 | 0,527 | 0,496 | 332,080 | 332,080 | 422,601 | - | 615,235 | 579,206 | 477,631 | 449,660 |
| 7 | 2 | 129,059 | 110,657 | 0,559 | 0,421 | 252,126 | 332,080 | 342,696 | 422,601 | 668,560 | 503,050 | 759,088 | 571,167 |
| | 3 | 73,878 | 75,553 | 0,583 | 0,508 | 252,126 | 252,126 | 422,601 | - | 542,223 | 472,246 | 484,383 | 421,871 |
| 10 | 2 | 39,605 | 25,762 | 1,000 | 0,240 | 259,951 | 259,951 | 168,912 | 168,912 | 762,599 | 183,027 | 592,975 | 142,316 |
| | 3 | 22,153 | 9,065 | 1,000 | 0,159 | 168,912 | 168,912 | 168,912 | - | 477,541 | 75,935 | 325,360 | 51,736 |

Ket * : $M_{E,k \text{ tr.1 bawah } X} = M_{E,b-X} + 0,3 M_{E,b-Y}$

Tabel 6.14 Momen maksimum kolom struktur 16 portal 2 dinding geser

| Lantai | Kolom | $M_{D,kx}$ (kNm) | $M_{D,ky}$ (kNm) | $M_{L,kx}$ (kNm) | $M_{L,ky}$ (kNm) | $M_{E,kx}$ (kNm) | $M_{E,ky}$ (kNm) | Mu_{kx} (kNm) | | Mu_{ky} (kNm) | |
|--------|-------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|-----------------|-----------|-----------------|-----------|
| | | | | | | | | Atas | Bawah | Atas | Bawah |
| 1 | 2 | 2,283 | 0,000 | 0,697 | 0,000 | 334,388 | 365,023 | 1867,488 | -1861,230 | 1954,425 | -1954,425 |
| | 3 | 0,440 | 70,784 | 0,137 | 15,732 | 308,528 | 239,689 | 598,432 | -1597,220 | 1486,281 | -1304,597 |
| 3 | 2 | 11,979 | 0,000 | 2,078 | 0,000 | 237,712 | 223,011 | 1294,144 | -1264,624 | 1236,163 | -1236,163 |
| | 3 | 0,606 | 118,747 | 0,062 | 26,673 | 209,514 | 115,763 | 1026,522 | -1025,119 | 902,883 | -597,501 |
| 5 | 2 | 17,231 | 0,000 | 29,414 | 0,000 | 200,696 | 206,606 | 1152,224 | -1054,270 | 1120,622 | -1120,622 |
| | 3 | 0,520 | 108,593 | 0,168 | 24,553 | 178,406 | 109,675 | 888,218 | -886,773 | 825,230 | -545,623 |
| 7 | 2 | 20,187 | 0,000 | 34,269 | 0,000 | 143,812 | 160,274 | 863,134 | -748,777 | 854,354 | -854,354 |
| | 3 | 0,518 | 106,047 | 0,236 | 24,087 | 131,172 | 91,809 | 667,393 | -665,810 | 687,515 | -414,234 |
| 10 | 2 | 24,312 | 0,000 | 43,936 | 0,000 | 36,669 | 44,384 | 281,594 | -138,273 | 232,616 | -232,616 |
| | 3 | 2,019 | 94,604 | 0,108 | 20,717 | 26,682 | 23,775 | 144,254 | -139,788 | 254,561 | -12,387 |

Tabel 6.15 Momen maksimum kolom struktur 15 portal 3 dinding geser

| Lantai | Kolom | $M_{D,kx}$ (kNm) | $M_{D,ky}$ (kNm) | $M_{L,kx}$ (kNm) | $M_{L,ky}$ (kNm) | $M_{E,kx}$ (kNm) | $M_{E,ky}$ (kNm) | Mu_{kx} (kNm) | | Mu_{ky} (kNm) | |
|--------|-------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|-----------------|-----------|-----------------|-----------|
| | | | | | | | | Atas | Bawah | Atas | Bawah |
| 1 | 2 | 5,813 | 0,000 | 1,257 | 0,000 | 334,734 | 314,163 | 1809,152 | -1794,305 | 1741,249 | -1741,249 |
| | 3 | 1,905 | 70,873 | 0,417 | 15,757 | 317,127 | 206,338 | 1594,357 | -1589,481 | 1357,161 | -1175,238 |
| 3 | 2 | 15,342 | 0,000 | 3,702 | 0,000 | 250,225 | 190,58 | 1311,072 | -1271,080 | 1115,720 | -1115,720 |
| | 3 | 4,912 | 119,069 | 1,120 | 26,760 | 217,361 | 98,625 | 1043,517 | -1030,850 | 841,220 | -534,979 |
| 5 | 2 | 23,069 | 0,000 | 4,998 | 0,000 | 210,348 | 175,676 | 1134,284 | -1075,343 | 1002,878 | -1002,878 |
| | 3 | 7,544 | 109,025 | 1,715 | 24,670 | 185,381 | 93,336 | 905,926 | -886,482 | 765,971 | -485,212 |
| 7 | 2 | 27,315 | 0,000 | 5,908 | 0,000 | 150,973 | 136,523 | 840,990 | -771,221 | 763,623 | -763,623 |
| | 3 | 27,315 | 106,613 | 2,139 | 24,241 | 136,376 | 78,222 | 702,266 | -640,412 | 637,763 | -362,969 |
| 10 | 2 | 21,83 | 0,000 | 4,814 | 0,000 | 41,817 | 35,599 | 248,462 | -192,510 | 202,205 | -202,205 |
| | 3 | 7,739 | 95,327 | 1,796 | 20,920 | 28,321 | 19,091 | 153,015 | -132,991 | 237,926 | 6,193 |

Tabel 6.16 Momen maksimum kolom struktur 16 portal 4 dinding geser

| Lantai | Kolom | $M_{D,kx}$ (kNm) | $M_{D,ky}$ (kNm) | $M_{L,kx}$ (kNm) | $M_{L,ky}$ (kNm) | $M_{E,kx}$ (kNm) | $M_{E,ky}$ (kNm) | Mu_{kx} (kNm) | | Mu_{ky} (kNm) | |
|--------|-------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|-----------------|-----------|-----------------|-----------|
| | | | | | | | | Atas | Bawah | Atas | Bawah |
| 1 | 2 | 5,304 | 0,000 | 1,154 | 0,000 | 340,149 | 300,683 | 1814,267 | -1800,705 | 1691,456 | -1691,456 |
| | 3 | 1,752 | 70,895 | 0,385 | 15,761 | 342,790 | 197,549 | 1690,874 | -1686,386 | 1352,610 | -1170,632 |
| 3 | 2 | 13,502 | 0,000 | 2,930 | 0,000 | 185,180 | 257,753 | 1119,778 | -1085,271 | 1315,889 | -1315,889 |
| | 3 | 4,159 | 119,170 | 0,965 | 26,781 | 222,845 | 97,118 | 1063,698 | -1652,937 | 841,929 | -535,432 |
| 5 | 2 | 20,359 | 0,000 | 4,433 | 0,000 | 215,801 | 176,283 | 1154,512 | -1102,449 | 1012,298 | -1012,298 |
| | 3 | 6,477 | 109,139 | 1,495 | 27,707 | 93,479 | 190,032 | 640,423 | -623,682 | 1059,606 | -772,230 |
| 7 | 2 | 24,161 | 0,000 | 2,256 | 0,000 | 154,674 | 142,479 | 856,892 | -801,416 | 793,301 | -793,301 |
| | 3 | 8,128 | 106,769 | 1,872 | 24,273 | 139,734 | 81,387 | 699,930 | -678,930 | 655,484 | -380,296 |
| 10 | 2 | 18,852 | 0,000 | 4,915 | 0,000 | 43,824 | 38,110 | 257,035 | -207,124 | 215,280 | -215,280 |
| | 3 | 6,378 | 95,405 | 1,514 | 20,936 | 28,236 | 20,331 | 152,495 | -135,922 | 243,126 | 1,190 |

Tabel 6.17 Momen maksimum kolom struktur 15 portal 5 dinding geser

| Lantai | Kolom | $M_{D,kx}$ (kNm) | $M_{D,ky}$ (kNm) | $M_{L,kx}$ (kNm) | $M_{L,ky}$ (kNm) | $M_{E,kx}$ (kNm) | $M_{E,ky}$ (kNm) | Mu_{kx} (kNm) | | Mu_{ky} (kNm) | |
|--------|-------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|-----------------|-----------|-----------------|-----------|
| | | | | | | | | Atas | Bawah | Atas | Bawah |
| 1 | 2 | 2,017 | 0,000 | 0,472 | 0,000 | 342,359 | 241,021 | 1744,208 | -1738,981 | 1443,661 | -1443,661 |
| | 3 | 1,137 | 70,218 | 0,259 | 15,624 | 331,101 | 158,386 | 1591,656 | -1588,725 | 1172,543 | -992,274 |
| 3 | 2 | 0,567 | 0,000 | 0,262 | 0,000 | 268,907 | 156,885 | 1327,955 | -1326,214 | 997,740 | -997,740 |
| | 3 | 1,921 | 116,698 | 0,508 | 26,280 | 228,560 | 82,743 | 1066,759 | -1061,658 | 785,633 | -485,379 |
| 5 | 2 | 1,173 | 0,000 | 0,472 | 0,000 | 224,512 | 153,613 | 1138,230 | -1134,776 | 928,060 | -928,060 |
| | 3 | 3,185 | 105,833 | 0,822 | 24,024 | 194,990 | 81,384 | 925,709 | -917,294 | 723,850 | -451,150 |
| 7 | 2 | 1,499 | 0,000 | 0,584 | 0,000 | 159,984 | 129,059 | 836,734 | -832,360 | 743,628 | -743,628 |
| | 3 | 4,090 | 103,551 | 1,047 | 23,654 | 143,436 | 73,878 | 700,911 | -696,124 | 624,582 | -357,452 |
| 10 | 2 | 7,289 | 0,000 | 1,207 | 0,000 | 50,325 | 39,604 | 270,187 | -252,345 | 229,746 | -229,746 |
| | 3 | 2,462 | 109,910 | 0,743 | 23,614 | 30,709 | 22,153 | 160,256 | -153,525 | 271,936 | 8,464 |

6.2.2 Gaya aksial rencana dan maksimum kolom

Gaya aksial kolom dihitung sama seperti pada perhitungan momen rencana yaitu 100% sumbu utama + 30 % arah tegak lurus sumbu utama.

1. Gaya aksial rencana kolom

Persamaan (3.104) dapat juga ditulis dalam bentuk,

$$N_{uk} = 1,05 \cdot N_{gk} + 0,7 \cdot R_v \cdot \frac{\phi_0}{l_b} \cdot [\Sigma(M_{nak-bxki} - M_{nak-bxka}) + 0,3 \cdot \Sigma(M_{nak-byki} - M_{nak-byka})]$$

$M_{nak-bki}$ = momen nominal aktual balok sebelah kiri yang masuk ke dalam kolom

$M_{nak-bka}$ = momen nominal aktual balok sebelah kanan yang masuk ke dalam kolom

Dimana,

$$\phi_0 = 1,25 \text{ untuk } f_y \leq 400 \text{ Mpa}$$

$$l_{b-x} = 4,00 \text{ m}$$

$$l_{b-y} = 9,00 \text{ m}$$

$$\frac{\phi}{l_{b-x}} = \frac{1,25}{4,00} = 0,3125$$

$$\frac{\phi}{l_{b-y}} = \frac{1,25}{9,00} = 0,1389$$

$$R_v = 1,1 - 0,025 \cdot 9 = 0,875$$

a. Gaya aksial rencana kolom interior lantai 1 arah x

$$N_{gk} = N_{DK} + N_{LK} + \Sigma \text{ berat sendiri kolom}$$

$$= 3793,60 + 726,17 + 268,92 = 4788,69 \text{ kN}$$

$$N_{u,k1-x \max} = (1,05 \cdot 4788,69) + 0,7 \cdot 0,875 \cdot 0,3125 \cdot [(422,6009 - 240,0112) + 0,3 \cdot (422,6009 - 240,0112)] = 5073,5579 \text{ kN}$$

$$N_{u,k1-x \min} = (1,05 \cdot 4788,69) - 0,7 \cdot 0,875 \cdot 0,3125 \cdot [(422,6009 - 240,0112) + 0,3 \cdot (422,6009 - 240,0112)] = 4982,6911 \text{ kN}$$

b. Gaya aksial rencana kolom interior lantai 1 arah y

$$N_{u,k1-y \max} = (1,05 \cdot 4788,69) + 0,7 \cdot 0,875 \cdot 0,1385 \cdot [0,3 \cdot (422,6009 - 240,0112) + (422,6009 - 240,0112)] = 5048,317 \text{ kN}$$

$$N_{u,k1-y \min} = (1,05 \cdot 4788,69) - 0,7 \cdot 0,875 \cdot 0,1385 \cdot [0,3 \cdot (422,6009 - 240,0112) + (422,6009 - 240,0112)] = 5007,932 \text{ kN}$$

2. Gaya aksial maksimum kolom

a. Gaya aksial maksimum kolom interior lantai 1 arah x

$$N_{u,k-x \text{ atas}} = 1,05 \cdot (4788,69 + 4 \cdot (27,04 + 0,3 \cdot (-0,2205))) = 5141,415 \text{ kN}$$

$$N_{u,k-x \text{ bawah}} = 1,05 \cdot (4788,69 - 4 \cdot (27,04 + 0,3 \cdot (-0,2205))) = 4914,834 \text{ kN}$$

b. Gaya aksial maksimum kolom interior lantai 1 arah y

$$N_{u,k-y \text{ atas}} = 1,05 \cdot (4788,69 + 4 \cdot (0,3 \cdot 27,04 + (-0,2205))) = 5061,269 \text{ kN}$$

$$N_{u,k-y \text{ bawah}} = 1,05 \cdot (4788,69 - 4 \cdot (0,3 \cdot 27,04 + (-0,2205))) = 4994,980 \text{ kN}$$

Gaya aksial rencana dan maksimum kolom lainnya dihitung dengan cara yang sama dan ditabelkan pada tabel 6.18 dan 6.22.

Tabel 6.18 Gaya aksial rencana kolom struktur 16 portal 2 dinding geser

| Lantai | Kolom | N _{Gk} (kN) | M _{mak,bx} (kNm) | | M _{mak,by} (kNm) | | N _{u,kx} (kN) | | N _{u,ky} (kN) | |
|--------|-------|-------------------------|---------------------------|---------|---------------------------|---------|------------------------|----------|------------------------|----------|
| | | | Negatif | Positif | Negatif | Positif | Maks | Min | Maks | Min |
| 1 | 2 | 4810,110 | 422,601 | 240,011 | 422,601 | 240,011 | 5096,049 | 5005,182 | 5070,808 | 5030,423 |
| | 3 | 2983,540 | 422,601 | 240,011 | 422,601 | 240,011 | 3178,150 | 3087,284 | 3152,910 | 3112,524 |
| 3 | 2 | 3724,900 | 412,034 | 320,015 | 511,573 | 240,011 | 3946,249 | 3876,041 | 3938,049 | 3895,543 |
| | 3 | 2335,040 | 332,080 | 240,011 | 511,573 | 240,011 | 2486,906 | 2416,678 | 2478,698 | 2436,186 |
| 5 | 2 | 2701,110 | 332,080 | 240,011 | 511,573 | 240,011 | 2873,178 | 2799,153 | 2864,526 | 2819,716 |
| | 3 | 1705,280 | 332,080 | 240,011 | 511,573 | 240,011 | 1827,556 | 1753,532 | 1818,904 | 1774,094 |
| 7 | 2 | 1715,110 | 332,080 | 240,011 | 422,601 | 240,011 | 1832,988 | 1768,743 | 1821,303 | 1786,589 |
| | 3 | 1081,830 | 252,126 | 160,007 | 422,601 | 240,011 | 1168,055 | 1103,788 | 1156,360 | 1121,640 |
| 10 | 2 | 268,890 | 168,912 | 102,405 | 259,951 | 102,405 | 307,222 | 257,447 | 299,591 | 271,273 |
| | 3 | 174,720 | 168,912 | 143,367 | 259,951 | 102,405 | 199,383 | 167,529 | 199,518 | 176,377 |

Tabel 6.19 Gaya aksial rencana kolom struktur 15 portal 3 dinding geser

| Lantai | Kolom | N _{Gk} (kN) | M _{mak,bx} (kNm) | | M _{mak,by} (kNm) | | N _{u,kx} (kN) | | N _{u,ky} (kN) | |
|--------|-------|-------------------------|---------------------------|---------|---------------------------|---------|------------------------|----------|------------------------|----------|
| | | | Negatif | Positif | Negatif | Positif | Maks | Min | Maks | Min |
| 1 | 2 | 4844,210 | 412,035 | 320,015 | 422,601 | 240,011 | 5114,518 | 5058,323 | 5104,302 | 5073,933 |
| | 3 | 2997,450 | 422,601 | 240,011 | 422,601 | 240,011 | 3192,756 | 3101,889 | 3167,515 | 3127,130 |
| 3 | 2 | 3757,800 | 412,035 | 320,015 | 422,601 | 240,011 | 3975,393 | 3915,987 | 3964,593 | 3932,488 |
| | 3 | 2348,110 | 332,080 | 240,011 | 422,601 | 240,011 | 2495,229 | 2435,802 | 2484,420 | 2452,310 |
| 5 | 2 | 2729,340 | 342,696 | 160,008 | 422,601 | 336,016 | 2910,311 | 2821,303 | 2879,210 | 2846,027 |
| | 3 | 1716,400 | 332,080 | 240,011 | 422,601 | 336,016 | 1827,397 | 1777,043 | 1813,046 | 1791,030 |
| 7 | 2 | 1734,840 | 252,126 | 160,008 | 422,601 | 336,016 | 1847,415 | 1795,749 | 1832,687 | 1810,101 |
| | 3 | 1089,830 | 252,126 | 160,008 | 422,601 | 336,016 | 1170,154 | 1118,489 | 1155,426 | 1132,840 |
| 10 | 2 | 268,720 | 168,912 | 102,405 | 168,912 | 102,405 | 301,069 | 263,243 | 290,562 | 273,750 |
| | 3 | 176,230 | 168,912 | 102,405 | 168,912 | 102,405 | 203,954 | 166,129 | 193,447 | 176,636 |

Tabel 6.20 Gaya aksial rencana kolom struktur 16 portal 4 dinding geser

| Lantai | Kolom | N _{Gk} (kN) | M _{mak,bx} (kNm) | | M _{mak,by} (kNm) | | N _{u,kx} (kN) | | N _{u,ky} (kN) | |
|--------|-------|-------------------------|---------------------------|---------|---------------------------|---------|------------------------|----------|------------------------|----------|
| | | | Negatif | Positif | Negatif | Positif | Maks | Min | Maks | Min |
| 1 | 2 | 4849,680 | 412,035 | 320,015 | 422,601 | 240,011 | 5120,262 | 5064,066 | 5110,045 | 5079,676 |
| | 3 | 2993,870 | 412,035 | 320,015 | 422,601 | 240,011 | 3171,661 | 3115,466 | 3161,445 | 3131,076 |
| 3 | 2 | 3763,970 | 412,035 | 320,015 | 422,601 | 240,011 | 3981,872 | 3922,465 | 3971,072 | 3938,967 |
| | 3 | 2345,030 | 332,080 | 240,011 | 422,601 | 240,011 | 2491,995 | 2432,568 | 2481,186 | 2449,076 |
| 5 | 2 | 2736,050 | 332,080 | 240,011 | 422,601 | 240,011 | 2904,172 | 2841,533 | 2892,779 | 2858,933 |
| | 3 | 1714,200 | 332,080 | 240,011 | 422,601 | 240,011 | 1831,229 | 1768,591 | 1819,836 | 1785,990 |
| 7 | 2 | 1741,680 | 252,126 | 160,008 | 422,601 | 240,011 | 1860,897 | 1796,631 | 1849,203 | 1814,483 |
| | 3 | 1088,770 | 252,126 | 160,008 | 422,601 | 240,011 | 1175,342 | 1111,075 | 1163,647 | 1128,927 |
| 10 | 2 | 273,080 | 168,912 | 102,405 | 168,912 | 102,405 | 305,647 | 267,821 | 295,140 | 278,328 |
| | 3 | 176,670 | 168,912 | 102,405 | 168,912 | 102,405 | 204,416 | 166,591 | 193,909 | 177,098 |

Tabel 6.21 Gaya aksial rencana kolom struktur 15 portal 5 dinding geser

| Lantai | Kolom | N_{Gk} (kN) | $M_{nak,by}$ (kNm) | | $M_{nak,bv}$ (kNm) | | N_{ukx} (kN) | | N_{uky} (kN) | |
|--------|-------|------------------|--------------------|---------|--------------------|---------|----------------|----------|----------------|----------|
| | | | Negatif | Positif | Negatif | Positif | Maks | Min | Maks | Min |
| | | | | | | | | | | |
| 1 | 2 | 4676,690 | 412,035 | 320,015 | 422,601 | 240,011 | 4938,622 | 4882,427 | 4928,406 | 4898,037 |
| | 3 | 2966,100 | 412,035 | 320,015 | 342,696 | 160,007 | 3142,509 | 3086,301 | 3132,295 | 3101,915 |
| 3 | 2 | 3597,550 | 422,601 | 240,011 | 422,601 | 160,007 | 3830,314 | 3724,541 | 3805,969 | 3753,923 |
| | 3 | 2320,270 | 332,080 | 240,011 | 422,601 | 240,011 | 2465,997 | 2406,570 | 2455,188 | 2423,078 |
| 5 | 2 | 2590,170 | 412,035 | 320,015 | 422,601 | 240,011 | 2750,988 | 2688,369 | 2739,603 | 2705,763 |
| | 3 | 1696,070 | 332,080 | 240,011 | 422,601 | 240,011 | 1812,193 | 1749,554 | 1800,800 | 1766,954 |
| 7 | 2 | 1628,960 | 332,080 | 240,011 | 422,601 | 240,011 | 1742,531 | 1678,285 | 1730,845 | 1696,131 |
| | 3 | 1080,940 | 252,126 | 160,008 | 422,601 | 336,016 | 1160,820 | 1109,154 | 1146,092 | 1123,506 |
| 10 | 2 | 249,590 | 259,951 | 102,405 | 168,912 | 102,405 | 300,897 | 223,242 | 273,131 | 244,813 |
| | 3 | 178,510 | 168,912 | 102,405 | 168,912 | 102,405 | 206,348 | 168,523 | 195,841 | 179,030 |

Tabel 6.22 Gaya aksial maksimum kolom struktur 16 portal 2 dinding geser

| Lantai | Kolom | N_{Gk} (kN) | $N_{E,kx}$ (kN) | $N_{E,ky}$ (kN) | $N_{u,kx}$ (kN) | | $N_{u,ky}$ (kN) | |
|--------|-------|------------------|--------------------|--------------------|-----------------|----------|-----------------|----------|
| | | | | | Atas | Bawah | Atas | Bawah |
| | | | | | | | | |
| 1 | 2 | 4810,110 | 27,040 | -0,221 | 5163,906 | 4937,325 | 5083,760 | 5017,471 |
| | 3 | 2983,540 | -2,638 | -371,670 | 2653,333 | 3612,101 | 1568,379 | 4697,055 |
| 3 | 2 | 3724,900 | 31,460 | -0,078 | 4043,179 | 3779,111 | 3950,457 | 3871,833 |
| | 3 | 2335,040 | -5,227 | -270,510 | 2088,996 | 2814,588 | 1309,064 | 3594,520 |
| 5 | 2 | 2701,110 | 29,520 | -0,031 | 2960,111 | 2712,220 | 2873,233 | 2799,098 |
| | 3 | 1705,280 | -1,621 | -172,130 | 1566,852 | 2014,236 | 1065,556 | 2515,532 |
| 7 | 2 | 1715,110 | 22,620 | 0,053 | 1895,936 | 1705,795 | 1829,590 | 1772,141 |
| | 3 | 1081,830 | 0,590 | -85,760 | 1030,342 | 1241,501 | 776,473 | 1495,370 |
| 10 | 2 | 268,890 | 6,210 | 0,089 | 308,528 | 256,141 | 290,532 | 274,137 |
| | 3 | 174,720 | -1,063 | -6,880 | 170,323 | 196,589 | 153,221 | 213,691 |

Tabel 6.23 Gaya aksial maksimum kolom struktur 15 portal 3 dinding geser

| Lantai | Kolom | N_{Gk} (kN) | $N_{E,kx}$ (kN) | $N_{E,ky}$ (kN) | $N_{u,kx}$ (kN) | | $N_{u,ky}$ (kN) | |
|--------|-------|------------------|--------------------|--------------------|-----------------|----------|-----------------|----------|
| | | | | | Atas | Bawah | Atas | Bawah |
| | | | | | | | | |
| 1 | 2 | 4844,210 | -43,710 | -0,210 | 4902,574 | 5270,267 | 5030,464 | 5142,377 |
| | 3 | 2997,450 | -17,690 | -312,120 | 2679,753 | 3614,892 | 1814,129 | 4480,516 |
| 3 | 2 | 3757,800 | -55,560 | -0,110 | 3712,199 | 4179,181 | 3875,222 | 4016,158 |
| | 3 | 2348,110 | -19,910 | -225,840 | 2097,335 | 2833,696 | 1491,901 | 3439,130 |
| 5 | 2 | 2729,340 | -45,800 | -0,020 | 2673,422 | 3058,192 | 2808,015 | 2923,599 |
| | 3 | 1716,400 | -13,680 | -142,710 | 1564,949 | 2039,491 | 1185,601 | 2418,839 |
| 7 | 2 | 1734,840 | -31,340 | 0,050 | 1690,017 | 1953,147 | 1782,304 | 1860,860 |
| | 3 | 1089,830 | -7,870 | -69,970 | 1023,105 | 1265,538 | 840,531 | 1448,112 |
| 10 | 2 | 268,720 | -10,640 | 0,080 | 237,569 | 326,743 | 269,086 | 295,226 |
| | 3 | 176,230 | -3,040 | -4,990 | 165,986 | 204,097 | 160,253 | 209,830 |

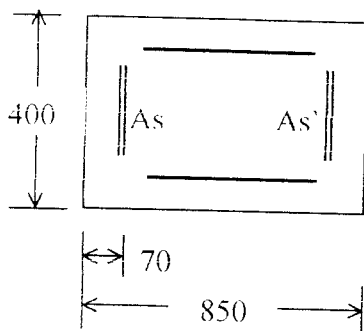
Tabel 6.24 Gaya aksial maksimum kolom struktur 16 portal 4 dinding geser

| Lantai | Kolom | $N_{G,K}$ (kN) | $N_{E,KX}$ (kN) | $N_{E,KY}$ (kN) | $N_{U,KX}$ (kN) | | $N_{U,KY}$ (kN) | |
|--------|-------|-------------------|--------------------|--------------------|-----------------|----------|-----------------|----------|
| | | | | | Atas | Bawah | Atas | Bawah |
| 1 | 2 | 4849,680 | -39,770 | -0,241 | 4924,826 | 5259,502 | 5041,042 | 5143,286 |
| | 3 | 2993,870 | -16,446 | -315,389 | 2677,100 | 3610,027 | 1798,208 | 4488,919 |
| 3 | 2 | 3763,970 | -52,650 | -0,128 | 3730,877 | 4173,460 | 3885,292 | 4019,045 |
| | 3 | 2345,030 | -18,840 | -232,195 | 2090,588 | 2833,975 | 1463,324 | 3461,239 |
| 5 | 2 | 2736,050 | -42,240 | -0,033 | 2695,404 | 3050,301 | 2819,494 | 2926,211 |
| | 3 | 1714,200 | -12,763 | -149,793 | 1557,566 | 2042,254 | 1154,698 | 2445,122 |
| 7 | 2 | 1741,680 | -27,980 | 0,059 | 1711,322 | 1946,206 | 1793,757 | 1863,771 |
| | 3 | 1088,770 | -7,033 | -74,759 | 1019,474 | 1266,943 | 820,359 | 1466,058 |
| 10 | 2 | 273,080 | -10,250 | 0,098 | 243,807 | 329,661 | 274,231 | 299,237 |
| | 3 | 176,670 | -2,912 | -5,232 | 166,681 | 204,326 | 159,860 | 211,117 |

Tabel 6.25 Gaya aksial maksimum kolom struktur 15 portal 5 dinding geser

| Lantai | Kolom | $N_{G,K}$ (kN) | $N_{E,KX}$ (kN) | $N_{E,KY}$ (kN) | $N_{U,KX}$ (kN) | | $N_{U,KY}$ (kN) | |
|--------|-------|-------------------|--------------------|--------------------|-----------------|----------|-----------------|----------|
| | | | | | Atas | Bawah | Atas | Bawah |
| 1 | 2 | 4676,690 | -9,315 | -0,216 | 4871,129 | 4949,920 | 4897,880 | 4923,169 |
| | 3 | 2966,100 | -11,148 | -287,975 | 2704,735 | 3524,075 | 1890,864 | 4337,946 |
| 3 | 2 | 3597,550 | -14,763 | -0,104 | 3715,292 | 3839,563 | 3758,389 | 3796,466 |
| | 3 | 2320,270 | -13,598 | -219,735 | 2102,306 | 2770,261 | 1496,263 | 3376,304 |
| 5 | 2 | 2590,170 | -10,969 | -0,008 | 2673,599 | 2765,758 | 2705,824 | 2733,533 |
| | 3 | 1696,070 | -8,144 | -147,697 | 1560,570 | 2001,177 | 1150,285 | 2411,462 |
| 7 | 2 | 1628,960 | -6,627 | 0,009 | 1682,585 | 1738,231 | 1702,094 | 1718,722 |
| | 3 | 1080,940 | -3,469 | -78,363 | 1021,680 | 1248,294 | 801,491 | 1468,483 |
| 10 | 2 | 249,590 | -2,600 | 0,126 | 251,308 | 272,831 | 259,323 | 264,816 |
| | 3 | 178,510 | -2,092 | -7,299 | 169,452 | 205,419 | 154,144 | 220,727 |

6.2.3. Grafik Interaksi Kolom



Mutu bahan dan dimensi kolom tengah adalah

$$b = 400 \text{ mm} \quad f_c = 30 \text{ Mpa}$$

$$h = 850 \text{ mm} \quad f_y = 400 \text{ Mpa}$$

$$d' = 70 \text{ mm}$$

$$d = 780 \text{ mm}$$

Luas tulangan total yang digunakan disebar ke 4 sisi kolom sesuai dengan persyaratan bangunan tahan gempa. Karena kolom menahan beban gempa siklis dari arah x dan y maka $A_s = A_s' = 0,25 A_{st}$. Dicoba luas tulangan minimum 1% dari luas bruto (A_g).

$$A_{st} = 1\% \cdot A_g = 1\% \cdot 400.850 = 3400 \text{ mm}^2.$$

1. Kondisi beban sentris

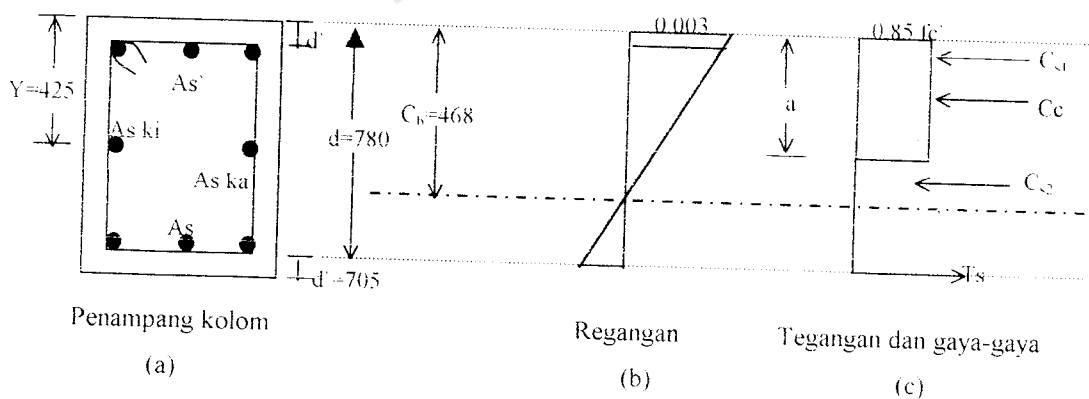
Gaya desak P berhimpit dengan sumbu memanjang kolom sehingga terjadi diseluruh penampang kolom yang mengakibatkan seluruh tulangan mengalami gaya desak. Karena itu luas tulangan yang digunakan adalah luas tulangan total (A_{st}).

$$\begin{aligned} P_o &= 0,85 \cdot f_c' \cdot (A_g - A_{st}) + f_y \cdot A_{st} \\ &= (0,85 \cdot 30 \cdot (340000 - 3400)) + 400 \cdot 3400 \cdot 10^{-3} = 9943,3 \text{ kN} \end{aligned}$$

$$\begin{aligned} P_n \text{ max} &= 0,8 \cdot 0,85 \cdot f_c' \cdot (A_g - A_{st}) + f_y \cdot A_{st} \\ &= 0,8 \cdot 9943,3 = 7954,64 \text{ kN} \end{aligned}$$

$$\phi P_n = 0,65 \cdot 7954,64 = 5170,516 \text{ kN}$$

2. Kondisi balance



Letak garis netral dalam kondisi seimbang adalah,

$$c_b = \frac{600 \cdot d}{600 + f_y} = \frac{600 \cdot 780}{600 + 400} = 468 \text{ mm}$$

$$a_b = \beta_1 \cdot c_b = 0,85 \cdot 468 = 397,8 \text{ mm}$$

Cek regangan yang terjadi,

Untuk baja mutu $f_y = 400 \text{ Mpa}$, regangan lelehnya adalah ,

$$\epsilon_s = \frac{f_y}{E_s} = \frac{400}{200000} = 0,002$$

$$\epsilon_{s1} = \frac{c_b - d'}{c_b} \cdot 0,003 = \frac{468 - 70}{468} \cdot 0,003 = 0,00255 > \epsilon_s = 0,002, \text{ baja desak leleh}$$

$$\epsilon_{s2} = \frac{c_b - y}{c_b} \cdot 0,003 = \frac{468 - 425}{468} \cdot 0,003 = 0,00028 < \epsilon_s = 0,002, \text{ baja desak belum}$$

leleh

$$\epsilon_{s3} = \frac{d - c_b}{c_b} \cdot 0,003 = \frac{780 - 468}{468} \cdot 0,003 = 0,002 = \epsilon_s = 0,002, \text{ baja tarik leleh}$$

Tegangan pada bagian baja desak yang belum leleh adalah,

$$f_{s2} = E_s \cdot \frac{c_b - y}{c_b} \cdot 0,003 = E_s \cdot \epsilon_{s2} = 200000 \cdot 0,00028 = 56 \text{ Mpa}$$

$$C_c = 0,85 \cdot f_c' \cdot a_b \cdot b \cdot 10^{-3} = 4057,56 \text{ kN}$$

Tulangan yang berada dekat garis netral mempunyai tegangan-tegangan yang lebih kecil dari tegangan luluh baja, sehingga dari sumbu netral C dapat dicari regangan baja yang terjadi pada penampang kolom tersebut. Berdasarkan gambar diatas maka luas tulangan $A_s = A_s'$.

$$A_s = A_s' = (0,25 + (0,25/2)) \cdot A_{st} = 0,375 \cdot 3400 = 1275 \text{ mm}^2$$

$$\text{Pada sisi } A_{s_{ki}} = A_{s_{kt}} = 0,25 \cdot A_{st} = 0,25 \cdot 3400 = 850 \text{ mm}^2$$

$$\text{Tegangan desak baja } C_{s1} = A_s' \cdot f_y = 1275 \cdot 400 \cdot (10^{-3}) = 510 \text{ kN}$$

$$C_{s2} = A_{s_{ki}} = A_{s_{ka}} \cdot f'_s s_2 = 850.56 \cdot (10^{-3}) = 47,6 \text{ kN}$$

$$T_s = A_s \cdot f_y = 1275.400 \cdot (10^{-3}) = 510 \text{ kN}$$

$$P_{nb} = C_c + C_{s1} + C_{s2} - T_s$$

$$= 4057,56 + 510 + 47,6 - 510 = 4105,16 \text{ kN}$$

$$M_{nb} = C_c \cdot (y - a_p/2) + C_{s1} \cdot (y - d') + C_{s2} \cdot 0 + T_s \cdot (d - y)$$

$$= 4057,56 \cdot (425 - 397,8/2) + 510 \cdot (425 - 70) + 47,6 \cdot (0) + 510 \cdot (780 - 425) \cdot (10^{-3})$$

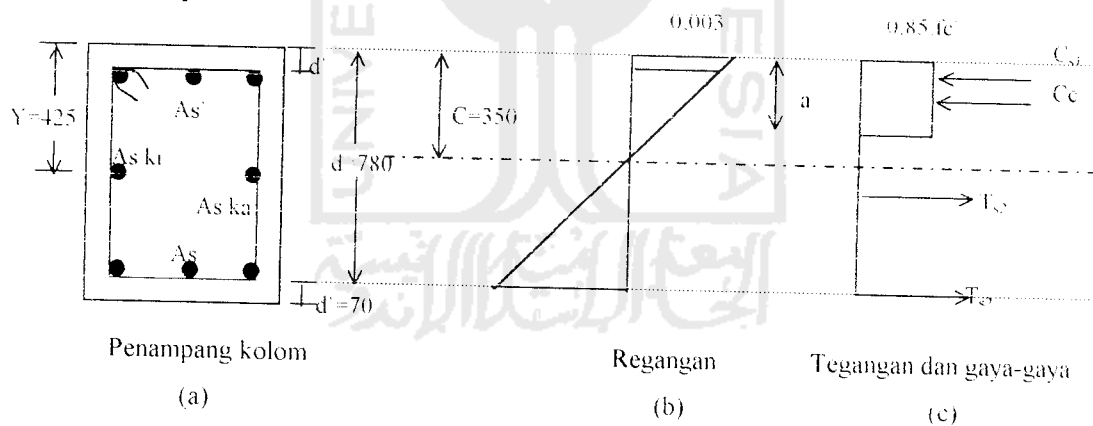
$$= 1279,514 \text{ kN-m}$$

$$e_b = \frac{M_{nb}}{P_{nb}} = \frac{1279,514}{4105,16} = 0,3117 \text{ m} = 311,7 \text{ mm}$$

$$\phi P_{nb} = 0,65 \cdot 4105,16 = 2668,354$$

$$\phi M_n = 0,65 \cdot 1279,514 = 831,6841 \text{ kN-m}$$

3. Kondisi patah tarik



Syarat keruntuhan tarik $e > e_b$ atau $P_n < P_{nb}$

Diambil $c = 350 \text{ mm} < c_b = 468 \text{ mm}$

$a = \beta_1 \cdot c = 0,85 \cdot 350 = 297,5 \text{ mm}$

Cek regangan yang terjadi,

$$\epsilon_s = \frac{c - d'}{c} \cdot 0,003 = \frac{350 - 70}{350} \cdot 0,003 = 0,0024 > \epsilon_y = 0,002$$

$$\epsilon_{s1} = \frac{d-c}{c} \cdot 0,003 = \frac{780-350}{350} \cdot 0,003 = 0,00368 > \epsilon_y = 0,002$$

$$\epsilon_{s2} = \frac{v-c}{c} \cdot 0,003 = \frac{425-350}{350} \cdot 0,003 = 0,0006 < \epsilon_y = 0,002$$

$$f_{s2} = \epsilon_{s2} \cdot E_s = 0,0006 \cdot 200000 = 120 \text{ Mpa}$$

$$C_c = 0,85 \cdot f_c' \cdot a \cdot b$$

$$= 0,85 \cdot 30 \cdot 297,5 \cdot 400 \cdot (10^{-3}) = 3034,5 \text{ kN}$$

$$C_{s1} = A_{s1} \cdot f_y = 1275 \cdot 400 \cdot (10^{-3}) = 510 \text{ kN}$$

$$T_{s2} = A_{s2} \cdot f_{s2} = 850 \cdot 120 \cdot (10^{-3}) = 102 \text{ kN}$$

$$T_{s1} = A_{s1} \cdot f_y = 1275 \cdot 400 \cdot (10^{-3}) = 510 \text{ kN}$$

$$P_n = C_c + C_{s1} - T_{s1} - T_{s2}$$

$$= 3034,5 + 510 - 102 - 510 = 2932,5 \text{ kN} < P_{nb} = 4105,16 \text{ kN}$$

$$M_n = C_c \cdot (y-a/2) + C_{s1} \cdot (y-d') + T_{s2} \cdot (0) + T_{s1} \cdot (y-d')$$

$$= \{3034,5 \cdot (425 - 297,5/2) + 510 \cdot (425 - 70) + 102 \cdot (0) + 510 \cdot (425 - 70)\} \cdot 10^{-3}$$

$$= 1200,381 \text{ kN-m}$$

$$e = \frac{M_n}{P_n} = \frac{1200,381}{2932,5} = 0,409 \text{ m} = 409 \text{ mm} > e_b = 311,7 \text{ mm}$$

Cek faktor reduksi yang digunakan dengan persamaan $(0,1 \cdot A_g \cdot f_c')$. Bila

$(0,1 \cdot A_g \cdot f_c') > P_n$ maka faktor reduksi (ϕ) yang digunakan $> 0,65$.

$$0,1 \cdot 340000 \cdot 30 \cdot (10^{-3}) = 1020 \text{ kN}$$

$\phi P_n = 0,65 \cdot 2932,5 = 1906,125 \text{ kN} > 0,1 \cdot A_g \cdot f_c'$ sehingga faktor ϕ tetap = 0,65.

$$\phi M_n = 0,65 \cdot 1200,381 = 780,248 \text{ kN-m.}$$

$$\text{Diambil } c = 300 \text{ mm} < c_b = 468 \text{ mm}$$

$$a = \beta_1 \cdot c = 0,85 \cdot 300 = 255 \text{ mm}$$

Cek regangan yang terjadi,

$$\varepsilon_{s'} = \frac{c-d'}{c} \cdot 0,003 = \frac{300-70}{300} \cdot 0,003 = 0,0023 > \varepsilon_y = 0,002$$

$$\varepsilon_{s1} = \frac{d-c}{c} \cdot 0,003 = \frac{780-300}{300} \cdot 0,003 = 0,0048 > \varepsilon_y = 0,002$$

$$\varepsilon_{s2} = \frac{y-c}{c} \cdot 0,003 = \frac{425-300}{300} \cdot 0,003 = 0,00125 < \varepsilon_y = 0,002, \text{ baja tarik belum}$$

luluh

$$f_{s2} = \varepsilon_{s2} \cdot E_s = 0,00125 \cdot 200000 = 250 \text{ Mpa}$$

$$C_c = 0,85 \cdot f_c' \cdot a \cdot b$$

$$= 0,85 \cdot 30 \cdot 255 \cdot 400 \cdot (10^{-3}) = 2601 \text{ kN}$$

$$C_{s1} = A_{s1} \cdot f_y = 1275 \cdot 400 \cdot (10^{-3}) = 510 \text{ kN}$$

$$T_{s2} = A_{sk2} \cdot f_{s2} = A_{sk2} \cdot f_{s2} = 850 \cdot 250 \cdot (10^{-3}) = 212,5 \text{ kN}$$

$$T_{s1} = A_{s1} \cdot f_y = 1275 \cdot 400 \cdot (10^{-3}) = 510 \text{ kN}$$

$$P_n = C_c + C_{s1} - T_{s1} - T_{s2}$$

$$= 2601 + 510 - 212,5 - 510 = 2388,5 \text{ kN} < P_{nb} = 4105,16 \text{ kN}$$

$$M_n = C_c \cdot (y-a/2) + C_{s1} \cdot (y-d') + T_{s2} \cdot (0) + T_{s1} \cdot (y-d')$$

$$= \{2601 \cdot (425 - 255/2) + 510 \cdot (425 - 70) + 212,5 \cdot (0) + 510 \cdot (425 - 70)\} \cdot 10^{-3}$$

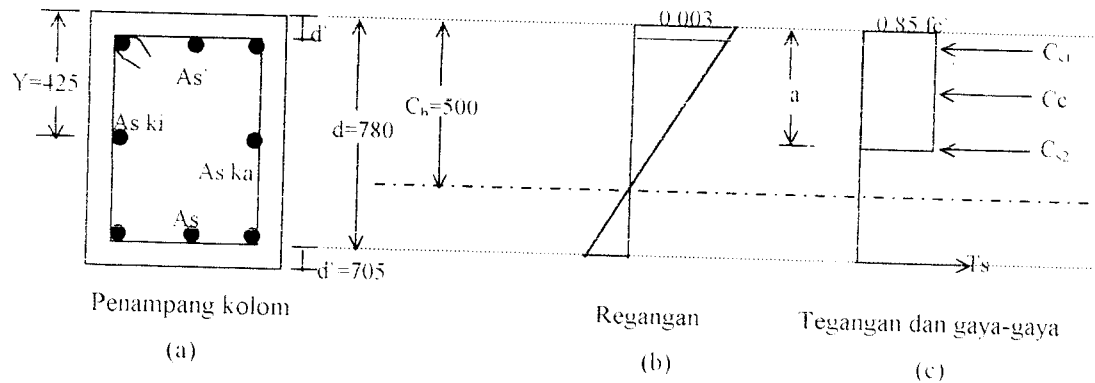
$$= 954,8475 \text{ kN-m}$$

$$e = \frac{M_n}{P_n} = \frac{954,8475}{2388,5} = 0,40 \text{ m} = 400 \text{ mm} > e_b = 311,7 \text{ mm}$$

$$\phi P_n = 0,65 \cdot 2388,5 = 1552,525 \text{ kN} > 0,1 \cdot A_g \cdot f_c' = 1020 \text{ kN}$$

$$\phi M_n = 0,65 \cdot 954,8475 = 620,6509 \text{ kN-m}$$

4. Kondisi patah tekan



Syarat keruntuhan tekan $e < e_b$ atau $P_n > P_{nb}$

$$\text{Diambil } c = 500 \text{ mm} > e_b = 468 \text{ mm}$$

$$a = \beta_1 \cdot c = 0,85 \cdot 500 = 425 \text{ mm}$$

Cek regangan yang terjadi,

$$\varepsilon_{s1} = \frac{c - d'}{c} \cdot 0,003 = \frac{500 - 70}{500} \cdot 0,003 = 0,00258 > \varepsilon_y = 0,002$$

$$\varepsilon_{s2} = \frac{c - y}{c} \cdot 0,003 = \frac{500 - 425}{500} \cdot 0,003 = 0,00045 > \varepsilon_y = 0,002$$

$$\varepsilon_s = \frac{d - c}{c} \cdot 0,003 = \frac{780 - 500}{500} \cdot 0,003 = 0,00168 < \varepsilon_y = 0,002$$

$$f_{s2} = \varepsilon_{s2} \cdot E_s = 0,00045 \cdot 200000 = 90 \text{ Mpa}$$

$$f_s = \varepsilon_s \cdot E_s = 0,00168 \cdot 200000 = 336 \text{ Mpa}$$

$$C_c = 0,85 \cdot f_c' \cdot a \cdot b$$

$$= 0,85 \cdot 30 \cdot 425 \cdot 400 \cdot (10^{-3}) = 4355 \text{ kN}$$

$$C_{s1} = A_{s'} \cdot f_y = 1275 \cdot 400 \cdot (10^{-3}) = 510 \text{ kN}$$

$$C_{s2} = 0,25 \cdot A_{st} \cdot f_{s2} = 850 \cdot 90 \cdot (10^{-3}) = 76,5 \text{ kN}$$

$$T_s = A_s \cdot f_s = 1275 \cdot 336 \cdot (10^{-3}) = 428,4 \text{ kN}$$

$$P_n = C_c + C_{s1} + C_{s2} - T_s$$

$$= 4335 + 510 + 76,5 - 428,4 = 4493,1 \text{ kN} > P_{nb} = 4105,16 \text{ kN}$$

$$M_n = C_c \cdot (y - a/2) + C_{s1} \cdot (y - d') + C_{s2} \cdot (0) + T_s \cdot (d - y)$$

$$= \{4335 \cdot (425 - 425/2) + 510 \cdot (425 - 70) + 76,5 \cdot (0) + 428,4 \cdot (780 - 425)\} \cdot 10^{-3}$$

$$= 1254,3195 \text{ kN-m}$$

$$e = \frac{M_n}{P_n} = \frac{1254,3195}{4493,1} = 0,279 \text{ m} = 279 \text{ mm} < e_b = 311,7 \text{ mm}$$

$$\phi P_n = 0,65 \cdot 4493,1 = 2920,515 \text{ kN}$$

$$\phi M_n = 0,65 \cdot 1254,3195 = 815,3077 \text{ kN-m}$$

$$\text{Diambil } e = 550 \text{ mm} > e_b = 468 \text{ mm}$$

$$a = \beta_1 \cdot c = 0,85 \cdot 550 = 467,5 \text{ mm}$$

Cek regangan yang terjadi,

$$\epsilon_{s1} = \frac{e - d'}{c} \cdot 0,003 = \frac{550 - 70}{550} \cdot 0,003 = 0,00262 > \epsilon_y = 0,002$$

$$\epsilon_{s2} = \frac{e - y}{c} \cdot 0,003 = \frac{550 - 425}{550} \cdot 0,003 = 0,00068 > \epsilon_y = 0,002$$

$$\epsilon_s = \frac{d - c}{c} \cdot 0,003 = \frac{780 - 550}{550} \cdot 0,003 = 0,00125 < \epsilon_y = 0,002$$

$$f_{s2} = \epsilon_{s2} \cdot E_s = 0,00068 \cdot 200000 = 136 \text{ Mpa}$$

$$f_s = \epsilon_s \cdot E_s = 0,00125 \cdot 200000 = 250 \text{ Mpa}$$

$$C_c = 0,85 \cdot f_c' \cdot a \cdot b$$

$$= 0,85 \cdot 30 \cdot 467,5 \cdot 400 \cdot (10^{-3}) = 4768,5 \text{ kN}$$

$$C_{s1} = A_s' \cdot f_y = 1275 \cdot 400 \cdot (10^{-3}) = 510 \text{ kN}$$

$$C_{s2} = 0,25 \cdot A_s \cdot f_{s2} = 850 \cdot 136 \cdot (10^{-3}) = 115,6 \text{ kN}$$

$$T_s = A_s \cdot f_s = 1275 \cdot 250 \cdot (10^{-3}) = 318,75 \text{ kN}$$

$$P_n = C_c + C_{s1} + C_{s2} - T_s$$

$$= 4768,5 + 510 + 115,6 - 318,75 = 5075,35 \text{ kN} > P_{nb} = 4105,16 \text{ kN}$$

$$M_n = C_{c1} \cdot (y - a/2) + C_{s1} \cdot (y - d') + C_{s2} \cdot (0) + T_s \cdot (d - y)$$

$$= \{4768,5 \cdot (425 - 467,5/2) + 510 \cdot (425 - 70) + 115,6 \cdot (0) + 318,75 \cdot (780 - 425)\} \cdot 10^{-3}$$

$$= 1206,1819 \text{ kN-m}$$

$$e = \frac{M_n}{P_n} = \frac{1206,1819}{5075,35} = 0,238 \text{ m} = 238 \text{ mm} < e_b = 311,7 \text{ mm}$$

$$\phi P_n = 0,65 \cdot 5075,35 = 3928,9775 \text{ kN}$$

$$\phi M_n = 0,65 \cdot 1206,1819 = 784,018 \text{ kN-m}$$

5. Kondisi momen murni

Pada kondisi momen murni gaya aksial $P = 0$ sehingga kontribusi tulangan desak

A_s' dapat diabaikan dalam perhitungan (Nawy, 1990).

$A_s = 1275 \text{ mm}^2$ dianggap tulangan tarik telah leleh sehingga,

$$a = \frac{A_s \cdot f_y}{0,85 \cdot f_c' \cdot b} = \frac{1275 \cdot 400}{0,85 \cdot 30 \cdot 400} = 56,67 \text{ mm}$$

$$c = \frac{a}{\beta_1} = \frac{56,67}{0,85} = 66,67 \text{ mm}$$

Cek regangan yang terjadi,

$$\varepsilon_{s1} = \frac{d - c}{c} \cdot 0,003 = \frac{780 - 66,7}{66,7} \cdot 0,003 = 0,032 > \varepsilon_y = 0,002$$

$$\varepsilon_{s2} = \frac{y - c}{c} \cdot 0,003 = \frac{425 - 66,7}{66,7} \cdot 0,003 = 0,0161 > \varepsilon_y = 0,002$$

$$M_{n0} = A_s \cdot f_y \cdot (d - a/2) + (0,25 \cdot A_{s1}) \cdot f_y \cdot (y - a/2)$$

$$= \{1275 \cdot 400 \cdot (780 - 56,67/2) + 850 \cdot 400 \cdot (425 - 56,67/2)\} \cdot (10^{-6})$$

$$= 518,2152 \text{ kN-m}$$

Perhitungan grafik interaksi kolom selanjutnya dilakukan dengan cara yang sama dengan luas tulangan yang digunakan 1%, 2%, 3%, 4%. Meskipun beberapa peraturan memberikan batas maksimum sebesar 8%, disarankan untuk tidak menggunakan tulangan lebih dari 4% agar tulangan tersebut tidak berdesakan dalam penampang beton terutama pada pertemuan balok-kolom (Nawy, 1990).

Tabel 6.26 Hasil perhitungan grafik interaksi kolom ukuran 400/850

| R % | P _o (kN) | P _n _{maks} (kN) | P _n _b (kN) | M _n _b (kNm) | P _n _{tangk} (kN) | M _n _{tangk} (kNm) | P _n _{tekan} (kN) | M _n _{tekan} (kNm) | M _o (kNm) |
|--------|------------------------|--|-------------------------------------|--------------------------------------|---|--|---|--|-------------------------|
| 1 | 9943,300 | 7954,640 | 4105,160 | 1279,514 | 2932,500 | 1200,381 | 4493,100 | 1254,320 | 518,215 |
| 2 | 11216,600 | 8973,280 | 4151,278 | 1641,614 | 2830,500 | 1562,481 | 4651,200 | 1587,452 | 999,600 |
| 3 | 12489,900 | 9991,920 | 4198,137 | 2003,714 | 2728,500 | 1924,581 | 4809,300 | 1920,584 | 1435,650 |
| 4 | 13763,200 | 11010,600 | 4244,996 | 2365,814 | 2626,500 | 2286,681 | 4967,400 | 2253,716 | 1729,200 |

Tabel 6.27 Hasil perhitungan grafik interaksi kolom ukuran 400/750

| R % | P _o (kN) | P _n _{maks} (kN) | P _n _b (kN) | M _n _b (kNm) | P _n _{tangk} (kN) | M _n _{tangk} (kNm) | P _n _{tekan} (kN) | M _n _{tekan} (kNm) | M _o (kNm) |
|--------|------------------------|--|-------------------------------------|--------------------------------------|---|--|---|--|-------------------------|
| 1 | 8773,500 | 7018,800 | 3573,760 | 987,632 | 2748,520 | 941,955 | 4081,500 | 959,376 | 401,956 |
| 2 | 9897,000 | 7917,600 | 3610,154 | 1262,132 | 2679,288 | 1216,455 | 4261,500 | 1201,851 | 770,824 |
| 3 | 11020,500 | 8816,400 | 3646,551 | 1536,632 | 2610,058 | 1490,955 | 4441,500 | 1444,326 | 1106,600 |
| 4 | 12144,000 | 9715,200 | 3682,948 | 1811,132 | 2540,827 | 1765,455 | 4621,500 | 1686,801 | 1409,290 |

Tabel 6.28 Hasil perhitungan grafik interaksi kolom ukuran 400/650

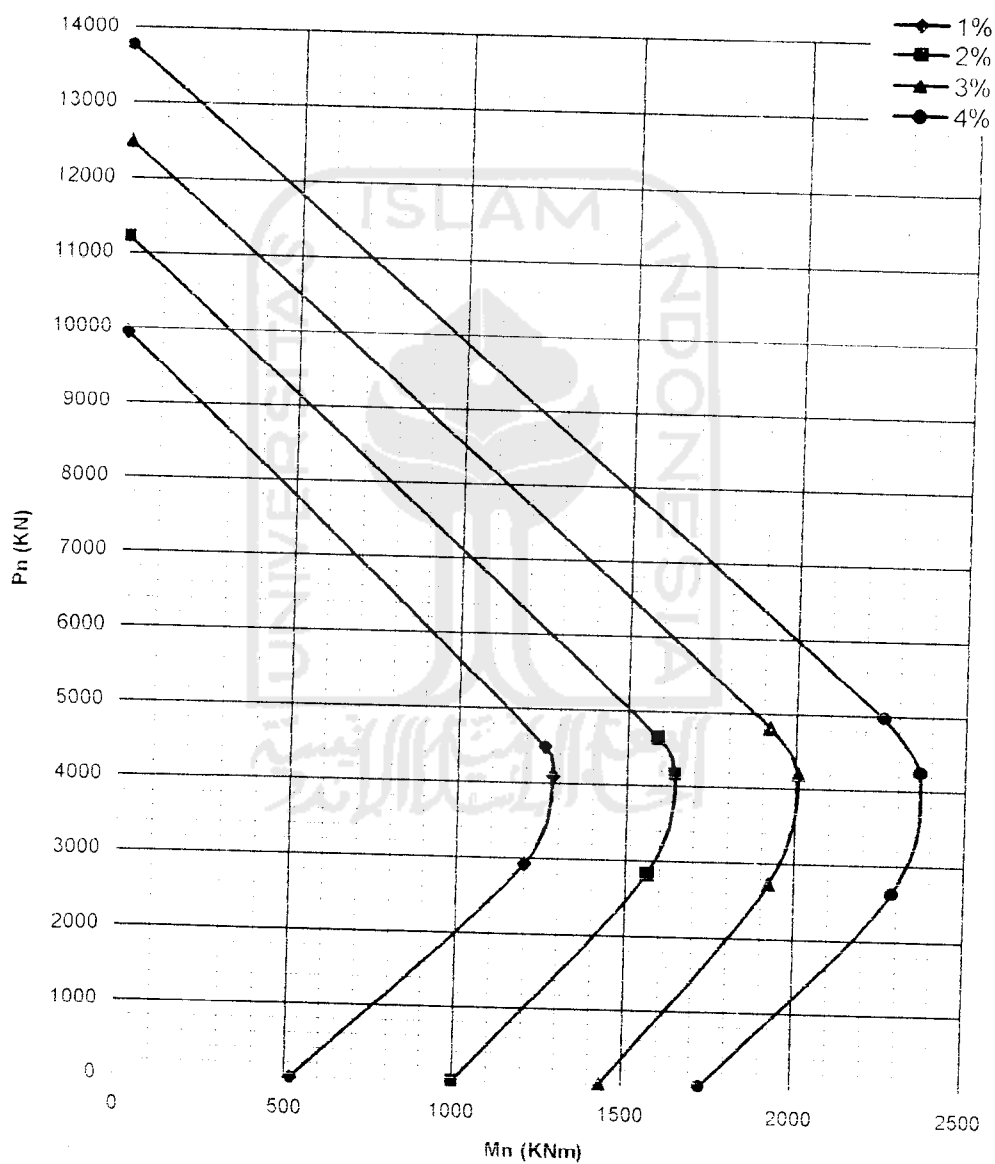
| R % | P _o (kN) | P _n _{maks} (kN) | P _n _b (kN) | M _n _b (kNm) | P _n _{tangk} (kN) | M _n _{tangk} (kNm) | P _n _{tekan} (kN) | M _n _{tekan} (kNm) | M _o (kNm) |
|--------|------------------------|--|-------------------------------------|--------------------------------------|---|--|---|--|-------------------------|
| 1 | 7603,700 | 6082,960 | 3042,940 | 733,239 | 2568,500 | 712,598 | 3667,875 | 704,119 | 298,274 |
| 2 | 8577,400 | 6861,920 | 3068,712 | 932,139 | 2536,000 | 911,498 | 3867,750 | 870,698 | 571,694 |
| 3 | 9551,100 | 7640,880 | 3094,488 | 1131,039 | 2503,500 | 1110,398 | 4067,625 | 1037,276 | 820,262 |
| 4 | 10524,800 | 8419,840 | 3120,263 | 1329,939 | 2471,000 | 1309,298 | 4267,500 | 1203,855 | 1043,980 |

Tabel 6.29 Hasil perhitungan grafik interaksi kolom ukuran 400/600

| R % | P _o (kN) | P _n _{maks} (kN) | P _n _b (kN) | M _n _b (kNm) | P _n _{tangk} (kN) | M _n _{tangk} (kNm) | P _n _{tekan} (kN) | M _n _{tekan} (kNm) | M _o (kNm) |
|--------|------------------------|--|-------------------------------------|--------------------------------------|---|--|---|--|-------------------------|
| 1 | 7018,800 | 5615,040 | 2777,440 | 620,101 | 2095,500 | 585,553 | 3168,214 | 605,642 | 252,212 |
| 2 | 7917,600 | 6334,080 | 2797,815 | 785,702 | 2023,500 | 751,153 | 3301,929 | 752,317 | 483,247 |
| 3 | 8816,400 | 7053,120 | 2818,192 | 951,301 | 1951,500 | 916,753 | 3435,643 | 898,991 | 693,106 |
| 4 | 9715,200 | 7772,160 | 2838,569 | 1116,901 | 1879,500 | 1082,353 | 3569,357 | 1045,665 | 881,788 |

Tabel 6.30 Hasil perhitungan grafik interaksi kolom ukuran 400/500

| R % | P_o (kN) | P_{nmax} (kN) | P_{nb} (kN) | M_{nb} (kNm) | P_{nmin} (kN) | M_{nmax} (kNm) | $P_{n tekan}$ (kN) | $M_{n tekan}$ (kNm) | M_o (kNm) |
|-----|------------|-----------------|---------------|----------------|-----------------|------------------|--------------------|---------------------|-------------|
| 1 | 5849,000 | 4679,200 | 2246,120 | 421,943 | 1659,000 | 394,110 | 2756,000 | 407,723 | 171,647 |
| 2 | 6598,000 | 5278,400 | 2255,460 | 529,943 | 1584,000 | 502,110 | 2911,000 | 496,823 | 328,588 |
| 3 | 7347,000 | 5877,600 | 2264,767 | 637,943 | 1509,000 | 610,110 | 3066,000 | 585,923 | 470,824 |
| 4 | 8096,000 | 6476,800 | 2274,069 | 745,943 | 1434,000 | 718,110 | 3221,000 | 675,023 | 598,353 |



Gambar 6.14 Grafik interaksi kolom 400/850

6.2.4 Perhitungan Penulangan Kolom

Contoh perhitungan diambil balok interior lantai 1 dengan ukuran kolom 400.850

$$A_{gr} = 1\%. A_{s_{total}} = 0,01.40.85 = 34 \text{ cm}^2$$

$$\frac{N_{uk-v}}{\phi \cdot A_{gr} \cdot 0,85 \cdot f_c'} = \frac{5096,049 \cdot 10^3}{0,65 \cdot 34 \cdot 0,85 \cdot 30} = 0,904$$

$$\frac{M_{uk-v}}{\phi \cdot A_{gr} \cdot 0,85 \cdot f_c' \cdot h} = \frac{624,461 \cdot 10^3}{0,65 \cdot 34 \cdot 0,85 \cdot 30 \cdot 85} = 0,130$$

dari grafik interaksi untuk kolom dengan tulangan pada empat sisi (Gideon, 1994) didapatkan nilai $r = 0,014 = 1,4\%$.

$$\beta = 1,2 \text{ untuk } f_c' = 30 \text{ Mpa}$$

$$\rho = r \cdot \beta = 1,4 \cdot 1,2 = 1,68\%$$

$$A_{s \text{ total}} = \rho \cdot A_{gr} = 1,68 \cdot 34 = 5712 \text{ mm}^2 \text{ , digunakan tulangan 16D22.}$$

Dengan cara yang sama dihitung penulangan untuk kolom yang lain dan hasilnya ditabelkan pada Tabel 6.31.

Tabel 6.31 Tulangan kolom, struktur 16 portal 2 dinding geser

| Lantai | Kolom | N_{uk} (kN) | M_{uk} (kNm) | (N_{uk}/ϕ) ($A_{gr} \cdot 0,85 \cdot f_c'$) | (M_{uk}/ϕ) ($A_{gr} \cdot 0,85 \cdot f_c' \cdot h$) | r pada Grafik (%) | $\rho = r \cdot \beta$ | $A_{s \text{ total}}$ (mm^2) | Tulangan Terpasang |
|--------|-------|------------------|-------------------|---|---|----------------------|------------------------|--|-----------------------|
| 1 | 2 | 5096,049 | 624,461 | 0,904 | 0,130 | 1,400 | 1,680 | 5712 | 16D22 |
| | 3 | 3178,150 | 396,396 | 0,639 | 0,106 | 1,000 | 1,200 | 3600 | 10D22 |
| 3 | 2 | 3946,249 | 870,788 | 0,700 | 0,182 | 1,600 | 1,920 | 6528 | 18D22 |
| | 3 | 2486,906 | 528,910 | 0,500 | 0,142 | 1,000 | 1,200 | 3600 | 10D22 |
| 5 | 2 | 2873,178 | 877,650 | 0,578 | 0,235 | 2,200 | 2,640 | 7920 | 20D22 |
| | 3 | 1827,556 | 564,072 | 0,424 | 0,201 | 1,250 | 1,500 | 3900 | 12D22 |
| 7 | 2 | 1832,988 | 778,088 | 0,425 | 0,278 | 2,700 | 3,240 | 8424 | 22D22 |
| | 3 | 1168,055 | 496,875 | 0,294 | 0,208 | 1,600 | 1,920 | 4608 | 14D22 |
| 10 | 2 | 307,222 | 633,320 | 0,077 | 0,265 | 3,000 | 3,600 | 8640 | 22D22 |
| | 3 | 170,323 | 433,213 | 0,051 | 0,261 | 2,950 | 3,540 | 7080 | 20D22 |

Tabel 6.32 Tulangan kolom struktur 15 portal 3 dinding geser

| Lantai | Kolom | N_{uk} (kN) | M_{uk} (kNm) | $(N_{uk}/\phi)'$ (Ag,0,85 f _c) | $(M_{uk}/\phi)'$ (Ag,0,85 f _c .h) | r pada Grafik (%) | $\rho = r.B$ | As total (mm ²) | Tulangan Terpasang |
|--------|-------|------------------|-------------------|---|---|----------------------|--------------|--------------------------------|-----------------------|
| 1 | 2 | 4902,574 | 625,657 | 0,870 | 0,131 | 1,200 | 1,440 | 4896 | 14D22 |
| | 3 | 2679,753 | 415,301 | 0,539 | 0,111 | 1,000 | 1,200 | 3600 | 10D22 |
| 3 | 2 | 3712,199 | 817,170 | 0,659 | 0,171 | 1,200 | 1,440 | 4896 | 14D22 |
| | 3 | 2097,335 | 464,471 | 0,422 | 0,125 | 1,000 | 1,200 | 3600 | 10D22 |
| 5 | 2 | 2673,422 | 749,361 | 0,538 | 0,201 | 1,400 | 1,680 | 5040 | 14D22 |
| | 3 | 1564,949 | 493,530 | 0,363 | 0,176 | 1,000 | 1,200 | 3120 | 10D22 |
| 7 | 2 | 1690,017 | 759,077 | 0,392 | 0,271 | 2,650 | 3,180 | 8268 | 22D22 |
| | 3 | 1023,105 | 498,095 | 0,257 | 0,209 | 1,500 | 1,800 | 4320 | 12D22 |
| 10 | 2 | 237,569 | 525,468 | 0,060 | 0,220 | 2,500 | 3,000 | 7200 | 20D22 |
| | 3 | 165,986 | 325,360 | 0,050 | 0,196 | 2,100 | 2,520 | 5040 | 14D22 |

Tabel 6.33 Tulangan kolom struktur 16 portal 4 dinding geser

| Lantai | Kolom | N_{uk} (kN) | M_{uk} (kNm) | $(N_{uk}/\phi)'$ (Ag,0,85 f _c) | $(M_{uk}/\phi)'$ (Ag,0,85 f _c .h) | r pada Grafik (%) | $\rho = r.B$ | As total (mm ²) | Tulangan Terpasang |
|--------|-------|------------------|-------------------|---|---|----------------------|--------------|--------------------------------|-----------------------|
| 1 | 2 | 4924,826 | 622,148 | 0,874 | 0,130 | 1,150 | 1,380 | 4692 | 14D22 |
| | 3 | 2677,100 | 408,445 | 0,538 | 0,110 | 1,000 | 1,200 | 3600 | 10D22 |
| 3 | 2 | 3730,877 | 792,823 | 0,662 | 0,166 | 1,150 | 1,380 | 4692 | 14D22 |
| | 3 | 2090,588 | 456,103 | 0,420 | 0,122 | 1,000 | 1,200 | 3600 | 10D22 |
| 5 | 2 | 2695,404 | 736,029 | 0,542 | 0,197 | 1,200 | 1,440 | 4320 | 12D22 |
| | 3 | 1557,566 | 485,602 | 0,361 | 0,173 | 1,000 | 1,200 | 3120 | 10D22 |
| 7 | 2 | 1711,322 | 752,314 | 0,397 | 0,269 | 2,500 | 3,000 | 7800 | 20D22 |
| | 3 | 1019,474 | 492,697 | 0,256 | 0,206 | 1,500 | 1,800 | 4320 | 12D22 |
| 10 | 2 | 243,807 | 525,468 | 0,061 | 0,220 | 2,500 | 3,000 | 7200 | 20D22 |
| | 3 | 166,681 | 325,360 | 0,050 | 0,196 | 2,100 | 2,520 | 5040 | 20D22 |

Tabel 6.34 Tulangan kolom struktur 15 portal 5 dinding geser

| Lantai | Kolom | N_{uk} (kN) | M_{uk} (kNm) | $(N_{uk}/\phi)'$ (Ag,0,85 f _c) | $(M_{uk}/\phi)'$ (Ag,0,85 f _c .h) | r pada Grafik (%) | $\rho = r.B$ | As total (mm ²) | Tulangan Terpasang |
|--------|-------|------------------|-------------------|---|---|----------------------|--------------|--------------------------------|-----------------------|
| 1 | 2 | 4871,129 | 566,905 | 0,864 | 0,118 | 1,000 | 1,200 | 4080 | 12D22 |
| | 3 | 2704,735 | 278,121 | 0,544 | 0,075 | 1,000 | 1,200 | 3600 | 10D22 |
| 3 | 2 | 3715,292 | 737,517 | 0,659 | 0,154 | 1,000 | 1,200 | 4080 | 12D22 |
| | 3 | 2102,306 | 442,143 | 0,423 | 0,119 | 1,000 | 1,200 | 3600 | 10D22 |
| 5 | 2 | 2673,599 | 743,106 | 0,538 | 0,199 | 1,200 | 1,440 | 4320 | 12D22 |
| | 3 | 1560,570 | 477,631 | 0,362 | 0,171 | 1,000 | 1,200 | 3120 | 10D22 |
| 7 | 2 | 1682,585 | 759,088 | 0,390 | 0,271 | 2,600 | 3,120 | 8112 | 22D22 |
| | 3 | 1021,680 | 484,383 | 0,257 | 0,203 | 1,500 | 1,800 | 4320 | 12D22 |
| 10 | 2 | 251,308 | 592,975 | 0,063 | 0,248 | 2,900 | 3,480 | 8352 | 22D22 |
| | 3 | 169,452 | 325,360 | 0,051 | 0,196 | 2,150 | 2,580 | 5160 | 14D22 |

6.2.5 Gaya Geser Rencana dan Gaya Geser Maksimum Kolom

1. Momen kapasitas kolom

Untuk mencari momen kapasitas kolom dilakukan interpolasi linier berdasarkan luas tulangan yang terpasang pada kolom. Setelah momen kapasitas kolom diperoleh maka momen nominal aktual kolom dikalikan dengan faktor penambah kekuatan,

$$M_{\text{kapasitas kolom}} = \phi \cdot M_{\text{nak kolom}}$$

Tulangan yang digunakan pada kolom interior lantai 1 adalah 16D22 dengan luas $A_s \text{ total} = 6082,123 \text{ mm}^2$.

$$\text{Rasio tulangan } \rho = A_s \text{ total} / A_g = 6082,123 / (400 \cdot 850) = 1,79 \%$$

$$N_{\text{uk}} \text{ yang bekerja} = 5096,049 / \phi = 5096,049 / 0,65 = 7840,075 \text{ kN}$$

Dari grafik interaksi kolom diperoleh nilai untuk rasio penulangan sebagai berikut,

$$\diamond \text{ Rasio } 1 \% = 88,21 \text{ kNm}$$

$$\diamond \text{ Rasio } 2 \% = 905,3 \text{ kNm}$$

Dengan interpolasi didapatkan momen untuk rasio 1,79 % sebesar 832,145 kNm.

$$M_{\text{nak kolom}} = 832,145 \text{ kNm}$$

$$M_{\text{kap kolom}} = 1,25 \cdot 832,145 = 1040,181 \text{ kNm}$$

2. Gaya geser rencana kolom

Untuk kolom lantai atas,

$$V_{\text{uk}} = \frac{M_{u, \text{katas}} + M_{u, \text{kbawah}}}{h_k}$$

Untuk lantai bawah,

$$V_{uk} = \frac{M_{uk, atas} + M_{kapasitas kolom}}{h_c}$$

Untuk kolom lantai 1 interior, $V_{uk} = \frac{624,461 + 1040,181}{4,6} = 361,879 \text{ kN}$

.3. Gaya geser maksimum kolom

Gaya geser maksimum adalah penjumlahan dari gaya geser akibat beban mati, beban hidup dan beban gempa yang dikalikan dengan faktor daktilitas yang direncanakan.

a. Gaya geser maksimum kolom lantai 1 interior arah x

$$V_{uk-x} = 1,05 \cdot (0,625 + 0,079 + 4 \cdot (123,289 + 0,3 \cdot 109,778)) = 656,874 \text{ kN}$$

b. Gaya geser maksimum kolom lantai 1 interior arah y

$$V_{uk-y} = 1,05 \cdot (0,625 + 0,079 + 4 \cdot (0,3 \cdot 123,289 + 109,778)) = 617,150 \text{ kN}$$

Gaya geser rencana kolom yang lain dihitung dengan cara yang sama dan ditabelkan dalam tabel 6.35.

Tabel 6.35 Gaya geser rencana dan gaya geser maksimum kolom struktur 16 portal 2 dinding geser

| Lantai | Kolom | $M_{uk, atas}$ (kNm) | $M_{uk, bwh}$ (kNm) | $V_{D,k}$ (kN) | $V_{L,k}$ (kN) | $V_{E,kx}$ (kN) | $V_{E,ky}$ (kN) | V_{uk} (kN) | $V_{ukx, maks}$ (kN) | $V_{uky, maks}$ (kN) |
|--------|-------|-------------------------|------------------------|-------------------|-------------------|--------------------|--------------------|------------------|-------------------------|-------------------------|
| 1 | 2 | 624,461 | 1040,181* | 0,625 | 0,079 | 123,289 | 109,778 | 361,879 | 656,874 | 617,150 |
| | 3 | 396,396 | 999,925* | 0,162 | 0,050 | 114,244 | 68,334 | 303,548 | 566,146 | 431,171 |
| 3 | 2 | 870,788 | 845,960 | 6,022 | 1,046 | 126,243 | 118,602 | 581,949 | 687,079 | 664,614 |
| | 3 | 528,910 | 524,486 | 0,308 | 0,030 | 111,453 | 61,444 | 357,084 | 545,876 | 398,851 |
| 5 | 2 | 877,650 | 790,215 | 8,896 | 1,519 | 106,506 | 108,395 | 565,378 | 594,838 | 600,392 |
| | 3 | 564,072 | 493,344 | 0,281 | 0,086 | 94,775 | 56,853 | 358,446 | 470,072 | 358,581 |
| 7 | 2 | 778,088 | 577,897 | 10,532 | 1,788 | 76,040 | 81,638 | 459,656 | 435,166 | 451,624 |
| | 3 | 496,873 | 382,022 | 0,273 | 0,123 | 69,449 | 46,785 | 297,931 | 351,052 | 284,420 |
| 10 | 2 | 1056,893* | 1056,893* | 12,771 | 2,308 | 18,761 | 19,969 | 716,538 | 119,792 | 123,344 |
| | 3 | 756,480* | 756,480* | 1,065 | 0,057 | 13,680 | 10,373 | 512,868 | 71,701 | 61,979 |

Ket * : $M_{kapasitas kolom} = \phi_o \cdot M_{nak kolom}$

Tabel 6.36 Gaya geser rencana dan gaya geser maksimum kolom struktur 15 portal 3 dinding geser

| Lantai | Kolom | M _{uk atas} (kNm) | M _{uk bwh} (kNm) | V _{DK} (kN) | V _{TK} (kN) | V _{TK1} (kN) | V _{TK2} (kN) | V _{uk} (kN) | V _{uks maks} (kN) | V _{uks maks} (kN) |
|--------|-------|-------------------------------|------------------------------|-------------------------|-------------------------|--------------------------|--------------------------|-------------------------|-------------------------------|-------------------------------|
| 1 | 2 | 625,657 | 1061,672* | 1,874 | 0,406 | 94,580 | 123,292 | 366,811 | 554,976 | 639,392 |
| | 3 | 415,301 | 1044,948* | 0,609 | 0,133 | 58,912 | 117,426 | 317,445 | 396,164 | 568,195 |
| 3 | 2 | 817,170 | 777,639 | 7,721 | 1,665 | 101,176 | 132,758 | 540,613 | 602,070 | 694,921 |
| | 3 | 464,471 | 456,596 | 2,469 | 0,563 | 52,487 | 115,622 | 312,226 | 369,310 | 554,927 |
| 5 | 2 | 749,361 | 674,920 | 11,892 | 2,572 | 92,171 | 111,589 | 482,807 | 542,908 | 599,998 |
| | 3 | 493,530 | 431,775 | 3,889 | 0,884 | 48,393 | 98,470 | 313,663 | 332,335 | 479,563 |
| 7 | 2 | 759,077 | 562,710 | 14,261 | 3,085 | 69,523 | 79,800 | 448,073 | 410,759 | 440,973 |
| | 3 | 498,095 | 381,930 | 4,929 | 1,119 | 39,850 | 72,197 | 298,314 | 264,687 | 359,789 |
| 10 | 2 | 966,854* | 966,854* | 11,296 | 2,491 | 15,871 | 21,472 | 655,494 | 108,188 | 124,654 |
| | 3 | 590,887* | 590,887* | 4,039 | 0,937 | 8,242 | 14,531 | 400,601 | 58,149 | 76,640 |

Tabel 6.37 Gaya geser rencana dan gaya geser maksimum kolom struktur 16 portal 4 dinding geser

| Lantai | Kolom | M _{uk atas} (kNm) | M _{uk bwh} (kNm) | V _{DK} (kN) | V _{TK} (kN) | V _{TK1} (kN) | V _{TK2} (kN) | V _{uk} (kN) | V _{uks maks} (kN) | V _{uks maks} (kN) |
|--------|-------|-------------------------------|------------------------------|-------------------------|-------------------------|--------------------------|--------------------------|-------------------------|-------------------------------|-------------------------------|
| 1 | 2 | 622,148 | 1038,284* | 1,725 | 0,375 | 90,447 | 125,288 | 360,963 | 539,946 | 642,378 |
| | 3 | 408,445 | 1034,094* | 20,253 | 4,503 | 56,377 | 120,267 | 313,595 | 414,313 | 602,150 |
| 3 | 2 | 792,823 | 787,562 | 6,790 | 1,474 | 98,500 | 136,697 | 535,724 | 594,616 | 706,916 |
| | 3 | 456,103 | 463,531 | 60,674 | 13,625 | 51,152 | 118,534 | 311,740 | 442,203 | 640,307 |
| 5 | 2 | 736,029 | 683,764 | 10,492 | 2,285 | 93,063 | 114,474 | 481,286 | 548,516 | 611,465 |
| | 3 | 485,602 | 440,086 | 58,189 | 13,173 | 48,878 | 100,937 | 313,793 | 407,399 | 560,451 |
| 7 | 2 | 752,314 | 571,396 | 12,614 | 2,744 | 72,816 | 81,658 | 448,715 | 424,844 | 450,837 |
| | 3 | 492,697 | 388,554 | 55,942 | 12,717 | 41,705 | 73,971 | 298,729 | 340,454 | 435,317 |
| 10 | 2 | 935,020* | 935,020* | 9,719 | 2,162 | 16,980 | 22,521 | 633,912 | 112,168 | 128,456 |
| | 3 | 561,934* | 561,934* | 50,540 | 10,729 | 8,756 | 14,472 | 380,972 | 119,342 | 136,149 |

Tabel 6.38 Gaya geser rencana dan gaya geser maksimum kolom struktur 15 portal 5 dinding geser

| Lantai | Kolom | M _{uk atas} (kNm) | M _{uk bwh} (kNm) | V _{DK} (kN) | V _{TK} (kN) | V _{TK1} (kN) | V _{TK2} (kN) | V _{uk} (kN) | V _{uks maks} (kN) | V _{uks maks} (kN) |
|--------|-------|-------------------------------|------------------------------|-------------------------|-------------------------|--------------------------|--------------------------|-------------------------|-------------------------------|-------------------------------|
| 1 | 2 | 566,905 | 1053,148* | 0,745 | 0,172 | 72,276 | 126,020 | 352,186 | 463,306 | 621,313 |
| | 3 | 278,121 | 1046,183* | 20,058 | 4,464 | 45,067 | 122,597 | 287,892 | 369,502 | 597,440 |
| 3 | 2 | 737,517 | 771,826 | 0,294 | 0,134 | 82,337 | 142,518 | 511,642 | 525,837 | 702,768 |
| | 3 | 442,143 | 478,592 | 59,479 | 13,383 | 42,767 | 121,575 | 312,113 | 409,309 | 641,005 |
| 5 | 2 | 743,106 | 713,636 | 0,597 | 0,242 | 81,649 | 119,054 | 493,811 | 493,814 | 603,787 |
| | 3 | 477,631 | 449,660 | 56,376 | 12,806 | 42,947 | 103,569 | 314,336 | 383,518 | 561,746 |
| 7 | 2 | 759,088 | 571,167 | 0,789 | 0,306 | 66,324 | 84,531 | 450,934 | 386,220 | 439,747 |
| | 3 | 484,383 | 421,871 | 54,053 | 12,345 | 38,139 | 75,934 | 307,205 | 325,578 | 436,696 |
| 10 | 2 | 1046,746* | 1046,746* | 3,781 | 0,619 | 17,431 | 25,804 | 709,659 | 110,344 | 134,961 |
| | 3 | 559,509* | 559,509* | 57,879 | 12,255 | 8,325 | 15,631 | 379,328 | 128,299 | 149,781 |

6.2.6 Tulangan Geser Kolom

a. Tulangan geser kolom interior lantai 1 bawah

Gunakan sengkang D12 dengan mutu baja 400 Mpa dengan luas sengkang,

$$A_{sv} = 2 (0,25 \cdot 7 \cdot 12^2) = 226,2 \text{ mm}^2$$

Pada lantai bawah $V_c = 0$ sehingga seluruh gaya geser ditahan oleh tulangan geser sehingga V_{tik} desain tidak direduksi dengan nilai V_c .

$$V_{tik} \text{ desain} = V_{tik} \cdot \phi = 361,879 \cdot 0,6 = 603,131 \text{ kN}$$

$$\text{Jarak sengkang perlu adalah } s = \frac{226,2 \cdot 400 \cdot 780}{603,131 \cdot 10^3} = 117,013 \approx 100 \text{ mm}$$

Gunakan jarak spasi sengkang 100 mm sehingga gaya geser yang mampu ditahan oleh sengkang adalah,

$$V_{tik} = \frac{226,2 \cdot 400 \cdot 780}{100} = 705,744 = V_{tik} \cdot \phi = 603,131 \text{ kN}$$

Berarti jarak sengkang telah memenuhi syarat.

b. Tulangan geser kolom lantai 1 atas

Pada kolom lantai 1 atas kontribusi V_c diperhitungkan dalam memberikan tahanan geser. Kemampuan beton dalam menahan geser V_c dihitung dengan persamaan,

$$V_c = (1 + N_u / 14 \cdot A_g) \cdot (\sqrt{f_c'} / 6) \cdot b \cdot d$$

N_u diambil dari nilai terkecil dari Tabel 6.18 dan Tabel 6.22 sehingga diperoleh nilai $N_u = 4937,325 \text{ kN}$.

$$V_c = (1 + (4937,325 / 14 \cdot 400 \cdot 850)) \cdot (\sqrt{30} / 6) \cdot 400 \cdot 780 \cdot 10^3 = 285,111 \text{ kN}$$

Gaya geser yang digunakan adalah gaya geser yang didapat dari pengurangan gaya geser rencana (V_{tik}) dengan gaya geser yang mampu disumbangkan oleh beton (V_c),

$$V_{u,k} = 603,131 + 285,111 = 318,020 \text{ kN}$$

$$\text{Jarak sengkang perlu adalah } s = \frac{226,240,780}{318,020 \cdot 10^3} = 221,918 \approx 220 \text{ mm}$$

Gaya geser yang mampu ditahan adalah,

$$V_k = \frac{226,240,780}{220} = 320,793 \text{ kN}$$

Sehingga gaya geser aktual yang mampu ditahan oleh sengkang dan beton adalah,

$$V_c = V_k - V_{u,k} \cdot \phi$$

$$285,115 = 320,793 - 605,904 \text{ kN} \quad V_{u,k} \cdot \phi = 603,131 \text{ kN}$$

Dengan cara yang sama, didapatkan sengkang dan jarak antar sengkang untuk kolom yang lain dan hasilnya dapat dilihat pada tabel berikut ini.

Tabel 6.39 Tulangan geser struktur 16 portal 2 dinding geser

| Portal | Kolom | V_u (kN) | $N_{u,k}$ (kN) | V_c (kN) | Tul. Geser (kN) | V_s (kN) | Cek $V_c + V_s - V_{u,k} / \phi$ |
|--------|-------|---------------|-------------------|---------------|--------------------|---------------|-------------------------------------|
| 1 | 2a | 361,879 | 4937,325 | 285,115 | D12-220 | 320,793 | 605,904 > 603,131 |
| | 2b | 361,879 | 4937,325 | 0,000 | D12-100 | 705,744 | 705,744 > 603,131 |
| 2 | 3a | 303,548 | 1568,379 | 248,483 | D12-235 | 261,814 | 541,377 > 505,914 |
| | 3b | 303,548 | 1568,379 | 0,000 | D12-100 | 615,264 | 585,966 > 505,914 |
| 3 | 2 | 581,949 | 3779,111 | 285,048 | D12-100 | 705,744 | 990,786 > 969,914 |
| | 3 | 357,084 | 11309,064 | 248,444 | D12-175 | 351,579 | 599,958 > 595,139 |
| 4 | 2 | 565,378 | 2712,220 | 248,466 | D12-85 | 723,840 | 972,301 > 942,297 |
| | 3 | 358,446 | 1065,556 | 211,888 | D12-135 | 388,729 | 600,577 > 597,410 |
| 5 | 2 | 459,656 | 1705,795 | 211,889 | D12-90 | 583,093 | 794,979 > 766,093 |
| | 3 | 297,931 | 776,473 | 193,592 | D12-155 | 369,383 | 502,957 > 495,551 |
| 6 | 2 | 716,538 | 256,141 | 193,543 | D12-40 | 1065,653 | 1259,197 > 1194,230 |
| | 3 | 812,868 | 153,221 | 157,923 | D12-50 | 707,389 | 864,411 > 854,780 |

Tabel 6.40 Tulangan geser struktur 15 portal 3 dinding geser

| Lantai | Kolom | V_{ud} (kN) | N_{uk} (kN) | V_c (kN) | Tul. Geser | V_s (kN) | Cek | |
|--------|-------|------------------|------------------|---------------|------------|---------------|-------------|---------------|
| | | | | | | | $V_c + V_s$ | V_{uk}/ϕ |
| 1 | 2a | 366,811 | 4902,574 | 285,109 | D12-215 | 328,253 | 613,362 | 611,351 |
| | 2b | 366,811 | 4902,574 | 0,000 | D12-100 | 705,744 | 705,744 | 611,351 |
| | 3a | 317,445 | 1814,129 | 248,408 | D12-215 | 286,169 | 534,577 | 529,076 |
| | 3b | 317,445 | 1814,129 | 0,000 | D12-100 | 615,264 | 615,264 | 529,076 |
| 3 | 2 | 540,613 | 3712,199 | 285,038 | D12-110 | 641,585 | 926,623 | 901,022 |
| | 3 | 312,226 | 1491,901 | 248,389 | D12-225 | 273,451 | 521,839 | 520,377 |
| 5 | 2 | 482,807 | 2673,422 | 248,459 | D12-110 | 559,331 | 807,790 | 804,679 |
| | 3 | 313,663 | 1185,601 | 211,855 | D12-165 | 318,051 | 529,906 | 522,771 |
| 7 | 2 | 448,073 | 1690,017 | 211,884 | D12-95 | 552,404 | 764,289 | 746,789 |
| | 3 | 298,314 | 840,531 | 193,577 | D12-155 | 309,383 | 502,960 | 497,189 |
| 10 | 2 | 658,494 | 263,243 | 193,544 | D12-80 | 959,088 | 1152,632 | 1092,490 |
| | 3 | 400,601 | 160,253 | 157,023 | D12-75 | 518,752 | 675,775 | 667,669 |

Tabel 6.41 Tulangan geser struktur 16 portal 4 dinding geser

| Lantai | Kolom | V_{ud} (kN) | N_{uk} (kN) | V_c (kN) | Tul. Geser | V_s (kN) | Cek | |
|--------|-------|------------------|------------------|---------------|------------|---------------|-------------|---------------|
| | | | | | | | $V_c + V_s$ | V_{uk}/ϕ |
| 1 | 2a | 360,963 | 4924,826 | 285,110 | D12-245 | 320,793 | 605,903 | 601,606 |
| | 2b | 360,963 | 4924,826 | 0,000 | D12-100 | 705,744 | 705,744 | 601,606 |
| | 3a | 313,595 | 1798,208 | 248,407 | D12-220 | 276,665 | 528,073 | 522,660 |
| | 3b | 313,595 | 1798,208 | 0,000 | D12-100 | 615,264 | 615,264 | 522,660 |
| 3 | 2 | 535,724 | 3730,877 | 285,039 | D12-115 | 613,690 | 898,729 | 892,873 |
| | 3 | 311,740 | 1463,324 | 248,387 | D12-225 | 273,451 | 521,838 | 519,567 |
| 5 | 2 | 481,286 | 2695,404 | 248,460 | D12-110 | 559,331 | 807,791 | 802,143 |
| | 3 | 313,793 | 1154,698 | 211,853 | D12-165 | 318,051 | 529,904 | 522,988 |
| 7 | 2 | 448,715 | 1711,322 | 211,886 | D12-95 | 552,404 | 764,290 | 747,859 |
| | 3 | 298,729 | 820,359 | 193,576 | D12-155 | 309,383 | 502,959 | 497,882 |
| 10 | 2 | 633,912 | 243,807 | 193,543 | D12-55 | 871,898 | 1259,196 | 1154,364 |
| | 3 | 380,972 | 166,591 | 157,023 | D12-80 | 486,330 | 864,412 | 839,918 |

Tabel 6.42 Tulangan geser struktur 15 portal 5 dinding geser

| Lantai | Kolom | V_{ud} (kN) | Nu,k (kN) | V_e (kN) | Tul. Geser (kN) | V_s (kN) | Cek |
|--------|-------|------------------|--------------|---------------|--------------------|---------------|--------------------------|
| | | | | | | | $V_e+V_s > V_{u,k}/\phi$ |
| 1 | 2a | 352,186 | 4871,129 | 285,107 | D12-230 | 306,845 | 591,952 > 586,976 |
| | 2b | 352,186 | 4871,129 | 0,000 | D12-100 | 705,744 | 705,744 > 586,976 |
| | 3a | 287,892 | 1890,864 | 248,413 | D12-265 | 232,175 | 480,588 > 479,820 |
| | 3b | 287,892 | 1890,864 | 0,000 | D12-100 | 615,264 | 615,264 > 479,820 |
| 3 | 2 | 511,642 | 3715,292 | 285,038 | D12-120 | 588,120 | 873,158 > 852,736 |
| | 3 | 312,113 | 1496,263 | 248,389 | D12-225 | 273,451 | 521,840 > 520,189 |
| 5 | 2 | 493,811 | 2673,599 | 248,459 | D12-105 | 585,966 | 834,425 > 823,018 |
| | 3 | 314,336 | 1150,285 | 211,853 | D12-165 | 318,051 | 529,904 > 523,893 |
| 7 | 2 | 450,934 | 1678,285 | 211,884 | D12-95 | 552,404 | 764,288 > 751,556 |
| | 3 | 307,205 | 801,491 | 193,575 | D12-150 | 319,096 | 513,271 > 512,008 |
| 10 | 2 | 709,659 | 223,242 | 193,541 | D12-45 | 1065,653 | 1259,195 > 1182,764 |
| | 3 | 379,328 | 154,144 | 157,022 | D12-80 | 486,330 | 643,352 > 632,213 |

6.3 Desain Dinding Geser

Sebagai contoh dihitung dinding geser pada struktur 16 portal dengan 2 dinding geser. Batas ketebalan dinding geser (b) diambil berdasarkan ketentuan seperti berikut:

$$b \geq b_c \quad b \geq 300 \text{ mm}$$

$$b \geq b_c \quad b \geq 310 \text{ mm}$$

$$b \geq \frac{h_w}{16} \quad b \geq \frac{5250}{16} = 328,12 \text{ mm}$$

b diambil 350 mm.

Batas tebal dinding geser kritis (b_c) dihitung dengan persamaan,

$$b_c = 0,0171 \lambda_w \sqrt{\mu} = 0,0171 \lambda_w \sqrt{11} = 0,0571 \lambda_w$$

λ_w = rasio daktilitas dengan anggapan perencanaan daktilitas penuh ($\mu_A=4$)

(dari gambar 3.4)

Dari gambar 3.5 untuk nilai $b_c l_w = 0,057$ dengan $\mu_A=4$ didapat nilai $h_w/l_w = 7,5$.

Lebar dinding geser $l_w = \frac{39}{7,5} = 5,2$ m diambil $l_w = 5500$ mm dan

b. $0,057 \cdot 5500 = 310$ mm.

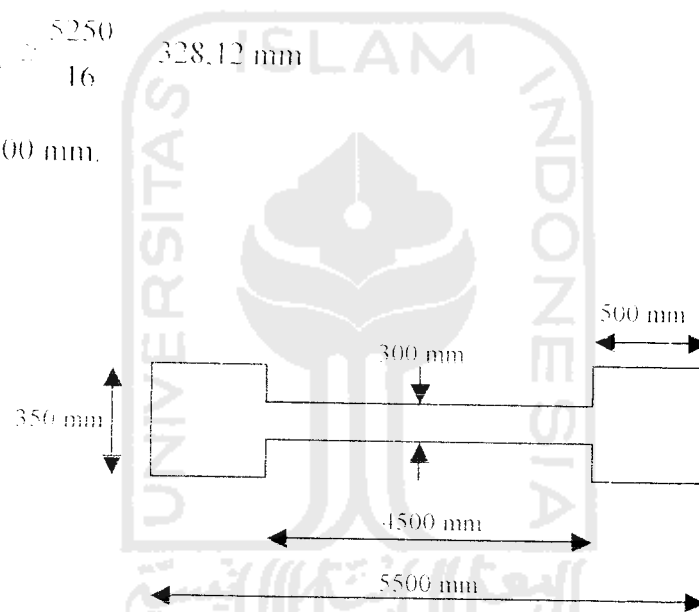
Janjang boundary element (l_e) dihitung dengan persamaan :

$$l_e \geq \frac{h_c \cdot l_w}{10 \cdot b} = l_e \geq \frac{310 \cdot 5500}{10 \cdot 350} = 487,143 \text{ mm}$$

$$l_e \geq \frac{h_c^2}{b} = l_e \geq \frac{310^2}{350} = 274,571 \text{ mm}$$

$$l_e \geq \frac{h_c}{16} = l_e \geq \frac{5250}{16} = 328,12 \text{ mm}$$

l_e diambil 500 mm.



Gambar 6.15 Dimensi dinding geser

Titik berat dinding geser $\frac{l_w}{2} = \frac{5500}{2} = 2750$ mm

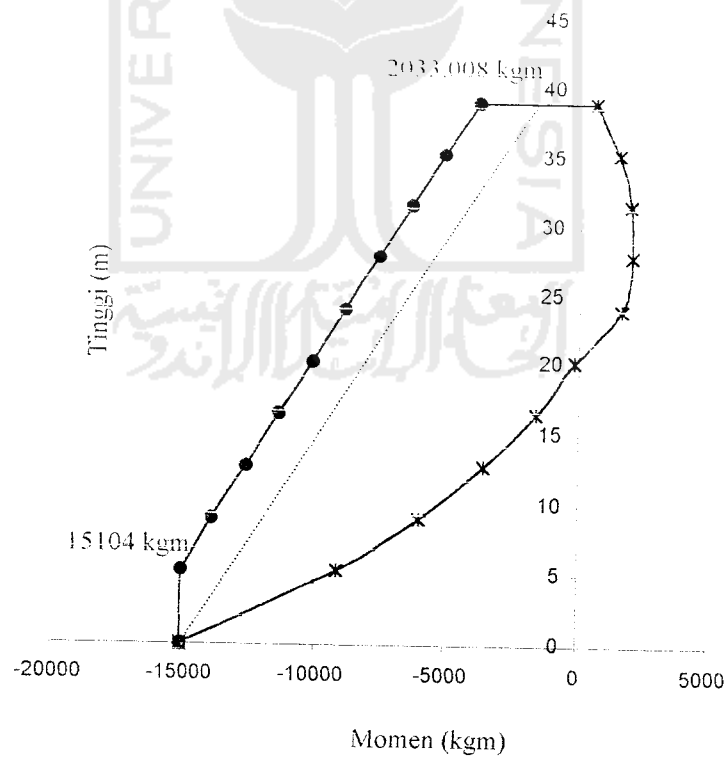
Dari hasil analisis dengan SAP90 didapat $P_u = 9710,895$ kN dan $M_u = 15104$ kNm.

$$P_n = \frac{P_u}{\phi} = \frac{9710,895}{0,65} = 14939,838 \text{ kN}$$

$$M_n = \frac{M_u}{\phi} = \frac{15104}{0,65} = 23236,923 \text{ kNm}$$

Tabel 6.43 Momen hasil interpolasi yang digunakan dalam perancangan

| Tinggi (m) | M dari SAP (kNm) | Momen Hasil interpolasi (kNm) |
|------------|------------------|-------------------------------|
| 0 | -15104,000 | -15104,000 |
| 5,25 | -9173,830 | -15104,000 |
| 9 | -5981,206 | -13930,962 |
| 12,75 | -3531,335 | -12674,136 |
| 16,5 | -1546,412 | -11417,310 |
| 20,25 | -144,340 | -10160,484 |
| 24 | 1605,515 | -8903,658 |
| 27,75 | 2033,008 | -7646,831 |
| 31,5 | 1921,491 | -6390,005 |
| 35,25 | 1485,889 | -5133,179 |
| 39 | 544,272 | -3876,353 |



Gambar 6.16 Bidang momen yang digunakan dalam perancangan dinding geser

3.3.1 Penulangan Lentur

a. Pada badan dinding geser (daerah II)

$$\rho_{\min} = 0,0025$$

$$\rho_{\min} = \frac{0,7}{f_y} = \frac{0,7}{400} = 0,0018$$

diambil yang terbesar yaitu $\rho_{\min} = 0,0025$

$$A_s = 0,0025 \cdot 300 \cdot 4500 = 3375 \text{ mm}^2$$

Diameter tulangan maksimum

$$D_{\max} = \frac{b_w}{10} = \frac{300}{10} = 30 \text{ mm}$$

Dicoba tulangan D12 dan dipakai 2 lapis tulangan.

$$\text{Jarak antar tulangan} = \frac{2.113}{0,0025 \cdot 300} = 301,33 \text{ mm}$$

Dipakai jarak antar tulangan 300 mm.

$$n = \frac{4500}{300} = 15$$

Dipakai tulangan 16D12

$$A_s \text{ aktual} = 2 \cdot 16 \cdot 0,25 \cdot \pi \cdot 12^2 = 3619 \text{ mm}^2 > 3375 \text{ mm}^2$$

Dianggap semua tulangan telah leleh, maka besar gaya aksial yang bekerja,

$$T_2 = A_s \text{ aktual} \cdot f_y = 3619 \cdot 400 = 1447,60 \text{ kN}$$

b. Pada daerah ujung (daerah I)

$$D_{\max} = \frac{b}{10} = \frac{500}{10} = 50 \text{ mm}$$

$$A_{s \min} = 0,001 \cdot b_w \cdot l_w = 0,001 \cdot 300 \cdot 5500 = 1650 \text{ mm}^2$$

Statis momen terhadap T1

$$14939,838.2,75 + 1447,60.2,75 + T3.(5,5 - 0,25) - 23236,923 = 0$$

$$T3 = 4157,815 \text{ kN}$$

$$A_{s3} = \frac{4157,815.10^3}{400} = 10394,539 \text{ mm}^2$$

$$D = 28 \text{ mm} < 50 \text{ mm}$$

$$A_{v \text{ ujung}} = 18.0,25.\pi.28^2 = 11083,589 \text{ mm}^2 > A_{s3}$$

6.3.2 Kapasitas lentur dinding geser

a. Desak daerah I

Dengan cara coba-coba garis netral dinding geser dari tulangan yang terpasang dapat ditentukan, sehingga gaya desak dikurangi gaya tarik akan kira-kira sama dengan P_n . Kemudian momen yang didapat berdasarkan tulangan tampang dapat ditentukan.

$$\text{Dicoba } e = 0,3.5500 = 1650 \text{ mm}$$

Dengan menganggap seluruh tulangan D12 luluh maka tulangan D12 memberikan

$$\text{sumbangan gaya sebesar } = \frac{2,0,25.\pi.12^2.400}{300} = 301,593 \text{ N/mm}$$

$$\text{Desak : } C_e = 0,85.30.0,85.1650.350 = 12517,313 \text{ kN}$$

$$C_{s1} = 18.0,25.\pi.28^2.400 = 4433,415 \text{ kN}$$

$$C \text{ total} = 16950,728 \text{ kN}$$

$$\text{Tarik : } T_{s1} = 18.0,25.\pi.28^2.400 = 4433,415 \text{ kN}$$

$$T_{s2} = (5500-500-1650).301,593 = 1010,327 \text{ kN}$$

$$T \text{ total} = 5443,742 \text{ kN}$$

$$C-T = 16950,728-5443,742 = 11506,986 \text{ kN} < 14939,838 \text{ kN}$$

$$A = \frac{(14939,838 - 11506,986).10^3}{0,85.30.300} = 448,739 \text{ mm}$$

Daesak harus ditambah sebesar 448,739 mm

$$e = 1650 + \frac{448,739}{0,85} = 2177,928 \text{ mm}$$

$$\text{Desak : } C_e = 0,85 \cdot 30 \cdot 0,85 \cdot 2177,928 \cdot 350 = 16522,306 \text{ kN}$$

$$C_{s1} = 18,0 \cdot 25 \cdot \pi \cdot 28^2 \cdot 400 = 4433,415 \text{ kN}$$

$$C_{\text{total}} = 20955,721 \text{ kN}$$

$$\text{Tarik : } T_{s1} = 18,0 \cdot 25 \cdot \pi \cdot 28^2 \cdot 400 = 4433,415 \text{ kN}$$

$$T_{s2} = (5500 - 500 - 2177,928) \cdot 301,593 = 851,117 \text{ kN}$$

$$T_{\text{total}} = 5284,532 \text{ kN}$$

$$C - T = 20955,721 - 5284,532 = 15671,189 \text{ kN} = 14939,838 \text{ kN}$$

$$\Delta = \frac{(15671,189 - 14939,838) \cdot 10^3}{0,85 \cdot 30 \cdot 300} = 95,601 \text{ mm}$$

Daesak harus dikurangi sebesar 95,601 mm

$$e = 2177,928 - \frac{95,601}{0,85} = 2065,456 \text{ mm}$$

$$\text{Desak : } C_e = 0,85 \cdot 30 \cdot 0,85 \cdot 2065,456 \cdot 350 = 15669,067 \text{ kN}$$

$$C_{s1} = 18,0 \cdot 25 \cdot \pi \cdot 28^2 \cdot 400 = 4433,415 \text{ kN}$$

$$C_{\text{total}} = 20102,482 \text{ kN}$$

$$\text{Tarik : } T_{s1} = 18,0 \cdot 25 \cdot \pi \cdot 28^2 \cdot 400 = 4433,415 \text{ kN}$$

$$T_{s2} = (5500 - 500 - 2065,456) \cdot 301,593 = 885,038 \text{ kN}$$

$$T_{\text{total}} = 5318,453 \text{ kN}$$

$$C - T = 20102,482 - 5318,453 = 14784,029 \text{ kN} = 14939,838 \text{ kN}$$

$$\Delta = \frac{(14939,838 - 14784,029) \cdot 10^3}{0,85 \cdot 30 \cdot 300} = 20,365 \text{ mm}$$

daerah desak harus ditambah sebesar 20,365 mm

$$e = 1650 + \frac{20,365}{0,85} = 2089,416 \text{ mm}$$

$$C_{desak} = C_c = 0,85 \cdot 30 \cdot 0,85 \cdot 2089,416 \cdot 350 = 15850,831 \text{ kN}$$

$$C_{s1} = 18 \cdot 0,25 \cdot 7 \cdot 28^2 \cdot 400 = 4433,415 \text{ kN}$$

$$C_{total} = 20284,246 \text{ kN}$$

$$T_{s1} = T_{s1} = 18 \cdot 0,25 \cdot 7 \cdot 28^2 \cdot 400 = 4433,415 \text{ kN}$$

$$T_{s2} = (5500 - 500 - 2089,416) \cdot 301,593 = 877,812 \text{ kN}$$

$$T_{total} = 5311,226 \text{ kN}$$

$$C - T = 20284,246 - 5311,226 = 14973,02 \text{ kN} \approx 14939,838 \text{ kN}$$

$$\Sigma M_{in} = 15830,831 \cdot (2,75 - 0,5 \cdot 0,85 \cdot 2,089) = 29517,021 \text{ kNm}$$

$$4433,415 \cdot (2,75 - 0,5 \cdot 0,5) = 11083,537 \text{ kNm}$$

$$4433,415 \cdot (5,5 - 2,75 - 0,5 \cdot 0,5) = 11083,537 \text{ kNm}$$

$$51684,095 \text{ kNm} > 23236,923 \text{ kNm}$$

b. Desak daerah III

Karena bentuk dinding geser dan tulangan yang digunakan pada dinding geser simetris maka perhitungan untuk desak pada daerah III sama dengan desak daerah I.

6.3.3 Perencanaan Geser

$$V_u = V_{wall} + \omega_v \cdot \phi_v \cdot V_f$$

$$\omega_v = 1,3 + \frac{10}{30} = 1,63$$

$$\omega = \frac{M_{kap,w}}{M_{ar}} = \frac{1,25 \cdot 51681,294}{15104} = 4,277$$

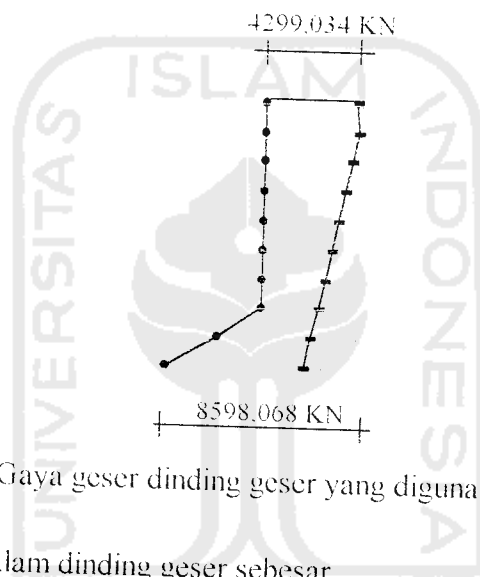
$$V_u = V_{wall} = 1,63 \cdot 4,277 \cdot 1233,315 = 8598,068 \text{ kN}$$

$$V_i = \frac{V_{wall}}{b_w \cdot d} = \frac{8598,068 \cdot 10^3}{300 \cdot 0,8 \cdot 5500} = 6,51 \text{ MPa}$$

Tetapi tidak lebih besar dari

$$V_i \text{ maks} = \left(\frac{0,22 \cdot 4,277}{4} + 0,03 \right) \cdot 30 = 7,957 \text{ MPa} > 0,16 \cdot f_c' = 4,8 \text{ MPa}$$

Maka digunakan $V_i = 4,8 \text{ MPa}$



Gambar 6.17 Gaya geser dinding geser yang digunakan dalam perencanaan

Kontribusi beton didalam dinding geser sebesar

$$V_c = 0,6 \cdot \sqrt{\frac{P_i}{A_g}} = 0,6 \cdot \sqrt{\frac{14939,84 \cdot 10^3}{170 \cdot 10^4}} = 1,779 \text{ MPa}$$

Digunakan sengkang 2D12, $A_v = 226,19 \text{ mm}^2$

$$V_s = V_i - V_c = 4,8 - 1,779 = 3,022 \text{ MPa}$$

$$\frac{A_v}{s} = \frac{V_s \cdot b_w}{f_y}$$

$$s = \frac{A_v \cdot f_y}{V_s \cdot b_w} = \frac{226,19 \cdot 400}{3,022 \cdot 300} = 99,797 \text{ mm}^2$$

digunakan sengkang D12-95 untuk tulangan geser horisontal.

Kontrol terhadap daktilitas yang tersedia

$$\epsilon_c = \frac{1,25 \cdot 51681,294}{15104} \cdot 1,1 \cdot \frac{5500}{8} = 2940,52 \text{ mm} > 2089 \text{ mm}$$

Jadi daerah desak beton tidak perlu dikekang, karena daktilitas yang tersedia terpenuhi untuk regangan 0,004. Bila digunakan regangan 0,003 maka daerah yang harus dikekang selebar α_c .

$$\alpha_c = \left(1 - \frac{0,7 \cdot 2940,52}{2089} \right) \cdot 0,015 = 0,5$$

Sehingga daerah yang harus dikekang selebar $0,5 \cdot 2089 = 1044,5 \text{ mm}$

$$sh \leq 6 \cdot db = 6 \cdot 28 = 168 \text{ mm}$$

$$sh \leq 150 \text{ mm}$$

$$sh \leq 0,5 \cdot b1 = 0,5 \cdot 500 = 250 \text{ mm}$$

dipakai sengkang D12-150 mm

Kontrol efek tekuk pada tulangan daerah II

$$p_c = \frac{\sum A_b}{b \cdot s_v} = \frac{2}{300 \cdot 300}$$

$$\frac{2 \cdot 113,09}{300 \cdot 300} = 0,00025 < \frac{2}{f_y} = 0,005$$

sehingga tulangan pada daerah II tidak perlu dikekang.

Dengan cara yang sama penulangan dinding geser untuk struktur-struktur yang lain dapat dihitung dan hasilnya dapat dilihat pada tabel berikut ini.

Tabel 6.44 Penulangan pada dinding geser, struktur 16 portal 2 dinding geser

| Tingkat | Tulangan lentur | Tulangan geser vertikal | Tulangan boundary element | Rasio P_n | Rasio M_n |
|---------|-----------------|-------------------------|---------------------------|-------------|-------------|
| 1 | 16D12 | D12-150 | 18D28 | 1,002 | 2,224 |
| 2 | 16D12 | D12-150 | 16D28 | 1,002 | 2,061 |
| 3 | 16D12 | D12-150 | 14D28 | 1,001 | 2,047 |
| 4 | 16D12 | D12-150 | 14D28 | 1,003 | 2,158 |
| 5 | 16D12 | D12-150 | 10D28 | 1,000 | 1,990 |
| 6 | 16D12 | D12-150 | 10D28 | 1,001 | 2,076 |
| 7 | 16D12 | D12-150 | 6D28 | 1,002 | 1,802 |
| 8 | 16D12 | D12-150 | 6D28 | 1,001 | 1,825 |
| 9 | 16D12 | D12-150 | 6D28 | 1,001 | 1,821 |
| 10 | 16D12 | D12-150 | 6D28 | 1,002 | 1,851 |

Tabel 6.45 Penulangan pada dinding geser, struktur 15 portal 3 dinding geser

| Tingkat | Tulangan lentur | Tulangan geser vertikal | Tulangan boundary element | Rasio P_n | Rasio M_n |
|---------|-----------------|-------------------------|---------------------------|-------------|-------------|
| 1 | 16D12 | D12-150 | 18D28 | 1,002 | 2,398 |
| 2 | 16D12 | D12-150 | 16D28 | 1,002 | 2,222 |
| 3 | 16D12 | D12-150 | 14D28 | 1,001 | 2,208 |
| 4 | 16D12 | D12-150 | 14D28 | 1,003 | 2,327 |
| 5 | 16D12 | D12-150 | 12D28 | 1,000 | 2,297 |
| 6 | 16D12 | D12-150 | 10D28 | 1,001 | 2,238 |
| 7 | 16D12 | D12-150 | 10D28 | 1,002 | 2,330 |
| 8 | 16D12 | D12-150 | 6D28 | 1,001 | 1,967 |
| 9 | 16D12 | D12-150 | 6D28 | 1,001 | 1,963 |
| 10 | 16D12 | D12-150 | 6D28 | 1,002 | 1,909 |

Tabel 6.46 Penulangan pada dinding geser, struktur 16 portal 4 dinding geser

| Tingkat | Tulangan lentur | Tulangan geser vertikal | Tulangan boundary element | Rasio P_n | Rasio M_n |
|---------|-----------------|-------------------------|---------------------------|-------------|-------------|
| 1 | 16D12 | D12-150 | 18D28 | 1,002 | 2,374 |
| 2 | 16D12 | D12-150 | 16D28 | 1,002 | 2,201 |
| 3 | 16D12 | D12-150 | 14D28 | 1,001 | 2,186 |
| 4 | 16D12 | D12-150 | 14D28 | 1,000 | 2,302 |
| 5 | 16D12 | D12-150 | 10D28 | 1,000 | 2,125 |
| 6 | 16D12 | D12-150 | 10D28 | 1,001 | 2,216 |
| 7 | 16D12 | D12-150 | 6D28 | 1,002 | 1,924 |
| 8 | 16D12 | D12-150 | 6D28 | 1,001 | 1,948 |
| 9 | 16D12 | D12-150 | 6D28 | 1,001 | 1,944 |
| 10 | 16D12 | D12-150 | 6D28 | 1,002 | 1,891 |

Tabel 6.47 Penulangan pada dinding geser, struktur 15 portal 5 dinding geser

| Fingkat | Tulangan lentur | Tulangan geser vertikal | Tulangan boundary element | Rasio P_n | Rasio M_n |
|---------|-----------------|-------------------------|---------------------------|-------------|-------------|
| 1 | 16D12 | D12-150 | 20D28 | 1,000 | 2,980 |
| 2 | 16D12 | D12-150 | 18D28 | 1,000 | 2,772 |
| 3 | 16D12 | D12-150 | 16D28 | 1,001 | 2,764 |
| 4 | 16D12 | D12-150 | 16D28 | 1,001 | 2,914 |
| 5 | 16D12 | D12-150 | 14D28 | 1,000 | 2,894 |
| 6 | 16D12 | D12-150 | 12D28 | 1,001 | 2,841 |
| 7 | 16D12 | D12-150 | 8D28 | 1,000 | 2,513 |
| 8 | 16D12 | D12-150 | 6D28 | 1,001 | 2,307 |
| 9 | 16D12 | D12-150 | 6D28 | 1,001 | 2,291 |
| 10 | 16D12 | D12-150 | 6D28 | 1,002 | 2,214 |

