

## BAB IV

### PERHITUNGAN KOLOM BETON BERTULANG

#### 4.1 Pembebanan

Dipakai tebal plat (SK SNI T-15 – 1991-03 pasal 3.1.4 ayat 3) :

$$h_{\min} = \frac{Lx(0,8 + \frac{f_y}{1500})}{36 + 9\beta} = \frac{4000(0,8 + \frac{300}{1500})}{36 + 9 \cdot \frac{6}{4}} = 86,1953 \text{ mm} < 120 \text{ mm}$$

h terpakai 120 mm

#### A. Atap

a). Beban hidup =  $100 \text{ kg/m}^2 = 1 \text{ KN/m}^2$

#### b). Beban mati

Plat atap =  $0,12 \cdot 2400 = 288 \text{ kg/m}^2$

Plafon+eternit =  $7+11 = 18 \text{ kg/m}^2$

Finishing =  $0,02 \cdot 2400 = 48 \text{ kg/m}^2$

Air hujan =  $0,05 \cdot 1000 = 50 \text{ kg/m}^2 +$

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$$404 \text{ kg/m}^2 = 4,04 \text{ KN/m}^2$$

#### B. Lantai I-V

a). Beban hidup untuk kantor =  $250 \text{ kg/m}^2 = 2,5 \text{ KN/m}^2$

Beban hidup untuk selasar =  $300 \text{ kg/m}^2 = 3 \text{ KN/m}^2$

b). Beban mati

$$\text{Plat} = 0,12 \cdot 2400 \cdot 1,1 = 288 \text{ kg/m}^2$$

$$\text{Plafon+eternit} = 7+11 = 18 \text{ kg/m}^2$$

$$\text{Ubin} = 2,24 = 48 \text{ kg/m}^2$$

$$\text{Spesi 1 cm} = 1,21 = 21 \text{ kg/m}^2$$

$$\text{Pasir 5 cm} = 0,05 \cdot 1600 = 80 \text{ kg/m}^2 +$$

$$455 \text{ kg/m}^2 = 4,55 \text{ KN/m}^2$$

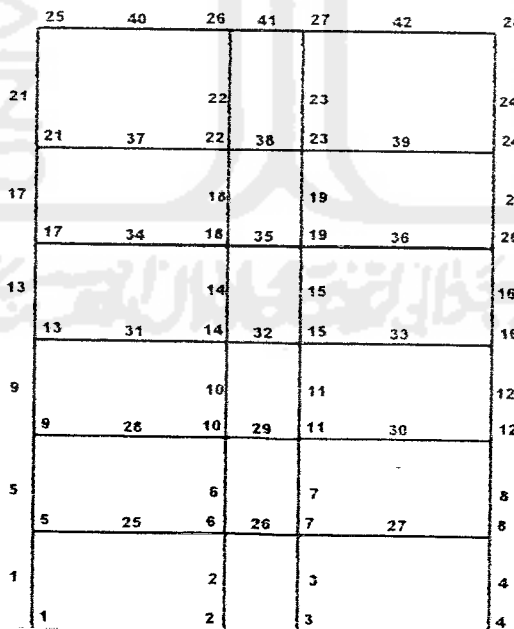
C. Lantai VI (ruang sidang)

a). Beban hidup =  $400 \text{ kg/m}^2 = 4 \text{ KN/m}^2$

b). Beban mati =  $455 \text{ kg/m}^2 = 4,55 \text{ KN/m}^2$

## 4.2 Mekanika Portal

### 4.2.1 Portal Melintang



Gambar 4.1  
Portal Melintang

Dalam perancangan denah gedung, terdapat balok anak yang terpasang sejajar dengan sumbu X atau arah membujur. Tetapi dalam distribusi beban arah melintang balok anak tersebut membebani balok induk sebagai beban titik sehingga beban yang terjadi pada balok induk sudah termasuk beban balok anak.

I. Portal As 2 = As 7 (lihat gambar 4.1)

a. Pembebanan Atap

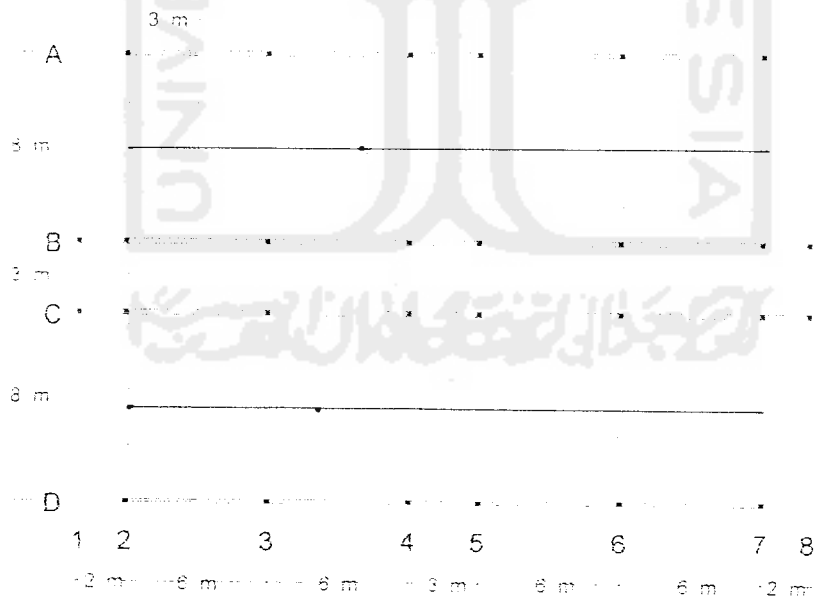
a.1 (elemen 40,42)

$$M_{D1} = 1/8 \cdot 3 \cdot 8^2 \cdot 4,04 = 96,96 \text{ KNm} \quad M_{D2} = 1/8 \cdot 3 \cdot 8^2 \cdot 1,0 = 24 \text{ KNm}$$

$$q_{eq} = \frac{96,96}{1 \cdot 8 \cdot 8^2} = 12,12 \text{ KN/m} \quad q_{eq} = \frac{24}{1 \cdot 8 \cdot 8^2} = 3 \text{ KN/m}$$

$$q_b = 5,568 \text{ KN/m} \quad q_{L1} = 3,0 \text{ KN/m}$$

$$q_{D1} = 12,12 + 5,568 = 29,808 \text{ KN/m}$$



Gambar 4.2

Distribusi beban bagian atap = bagian lantai  
Portal lintang As 2 = As 7

a.2 (elemen 41)

$$M_D = 1/8 \cdot 3 \cdot 3^2 \cdot 4,04 = 13,635 \text{ KNm} \quad M_L = 1/8 \cdot 3 \cdot 3^2 \cdot 1,0 = 3,375 \text{ KNm}$$

$$q_{eq} = \frac{13,635}{1 \cdot 8 \cdot 3^2} = 12,12 \text{ KN/m} \quad q_{eq} = \frac{3,375}{1 \cdot 8 \cdot 3^2} = 3 \text{ KN/m}$$

$$q_b = 3,648 \text{ KN/m} \quad q_l = 3,0 \text{ KN/m}$$

$$q_D = 12,12 + 3,648 = 15,768 \text{ KN/m}$$

b. Pembebanan Lantai

b.1 (elemen 25,27,28,30,31,33,34,36)

$$M_D = 1/8 \cdot 3 \cdot 8^2 \cdot 4,55 = 109,2 \text{ KNm} \quad M_L = 1/8 \cdot 3 \cdot 8^2 \cdot 2,5 = 60 \text{ KNm}$$

$$q_{eq} = \frac{109,2}{1 \cdot 8 \cdot 8^2} = 13,65 \text{ KN/m} \quad q_{eq} = \frac{60}{1 \cdot 8 \cdot 8^2} = 7,5 \text{ KN/m}$$

$$q_b = 5,568 \text{ KN/m} \quad q_l = 7,5 \text{ KN/m}$$

$$q_D = 13,65 + 5,568 = 19,218 \text{ KN/m}$$

b.2 (elemen 26,29,32,35,38)

$$M_D = 1/8 \cdot 3 \cdot 3^2 \cdot 4,55 = 15,3563 \text{ KNm} \quad M_L = 1/8 \cdot 3 \cdot 3^2 \cdot 3,0 = 10,125 \text{ KNm}$$

$$q_{eq} = \frac{15,3563}{1 \cdot 8 \cdot 3^2} = 13,650 \text{ KN/m} \quad q_{eq} = \frac{10,125}{1 \cdot 8 \cdot 3^2} = 9 \text{ KN/m}$$

$$q_b = 3,648 \text{ KN/m} \quad q_l = 9 \text{ KN/m}$$

$$q_D = 13,650 + 3,648 = 17,298 \text{ KN/m}$$

b.3 (elemen 37,39)

$$M_D = 1/8 \cdot 3 \cdot 8^2 \cdot 4,55 = 109,2 \text{ KNm} \quad M_L = 1/8 \cdot 3 \cdot 8^2 \cdot 3,0 = 96 \text{ KNm}$$

$$q_{eq} = \frac{109,2}{1 \cdot 8 \cdot 8^2} = 13,65 \text{ KN/m} \quad q_{eq} = \frac{96}{1 \cdot 8 \cdot 8^2} = 12 \text{ KN/m}$$

$$q_b = 5,568 \text{ KN/m} \quad q_l = 12 \text{ KN/m}$$

$$q_D = 13,65 + 5,568 = 32,868 \text{ KN/m}$$

## 2. Portal As 3 = As 6 (lihat gambar 4.2)

## a. Pembebanan Atap

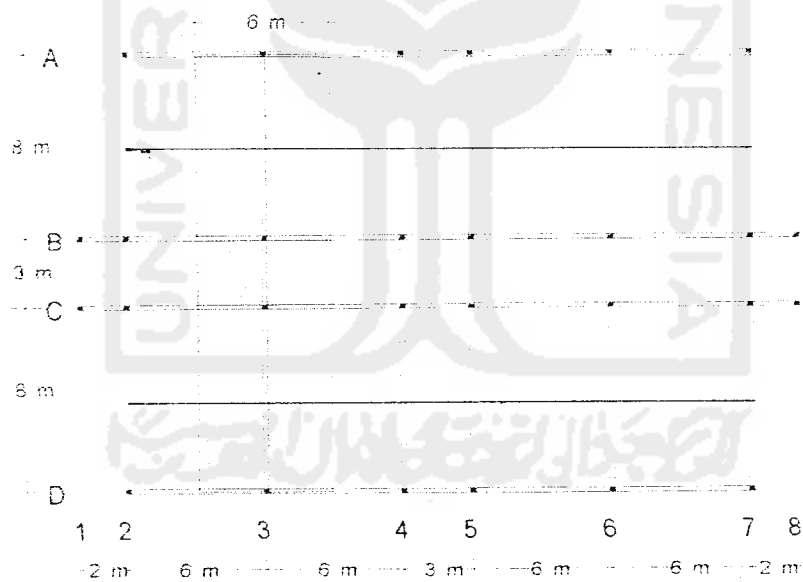
## a.1 (elemen 40,42)

$$M_D = 1/8 \cdot 6 \cdot 8^2 \cdot 4,04 = 193,92 \text{ KNm} \quad M_L = 1/8 \cdot 6 \cdot 8^2 \cdot 1,0 = 48 \text{ KNm}$$

$$q_{eq} = \frac{193,92}{1 \cdot 8 \cdot 8^2} = 24,24 \text{ KN/m} \quad q_{eq} = \frac{48}{1 \cdot 8 \cdot 8^2} = 6 \text{ KN/m}$$

$$q_b = 5,568 \text{ KN/m} \quad q_L = 6,0 \text{ KN/m}$$

$$q_D = 24,24 + 5,568 = 29,808 \text{ KN/m}$$



Gambar 4.3

Distribusi beban bagian atap = bagian lantai  
Portal lintang As 3 = As 6

a.2 (elemen 41)

$$M_{1D} = 1,8 \cdot 6,3^2 \cdot 4,04 = 27,27 \text{ KNm}$$

$$M_{1E} = 1,8 \cdot 6,3^2 \cdot 1,0 = 6,75 \text{ KNm}$$

$$q_{eq} = \frac{27,27}{1,8 \cdot 3^2} = 24,24 \text{ KN/m}$$

$$q_{eq} = \frac{6,75}{1,8 \cdot 3^2} = 6 \text{ KN/m}$$

$$q_b = 3,648 \text{ KN.m}$$

$$q_b = 6,0 \text{ KN.m}$$

$$q_D = 24,24 + 3,648 = 27,888 \text{ KN/m}$$

b. Pembebanan Lantai

b.1 (elemen 25,27,28,30,31,33,34,36)

$$M_{1D} = 1,8 \cdot 6,8^2 \cdot 4,55 = 218,4 \text{ KNm}$$

$$M_{1E} = 1,8 \cdot 6,8^2 \cdot 2,5 = 120 \text{ KNm}$$

$$q_{eq} = \frac{218,4}{1,8 \cdot 8^2} = 27,3 \text{ KN/m}$$

$$q_{eq} = \frac{120}{1,8 \cdot 8^2} = 15 \text{ KN/m}$$

$$q_b = 5,568 \text{ KN.m}$$

$$q_b = 15 \text{ KN.m}$$

$$q_D = 27,3 + 5,568 = 32,868 \text{ KN.m}$$

b.2 (elemen 26,29,32,35,38)

$$M_{1D} = 1,8 \cdot 6,3^2 \cdot 4,55 = 30,7125 \text{ KNm}$$

$$M_{1E} = 1,8 \cdot 6,3^2 \cdot 3,0 = 20,25 \text{ KNm}$$

$$q_{eq} = \frac{30,7125}{1,8 \cdot 3^2} = 27,3 \text{ KN/m}$$

$$q_{eq} = \frac{20,25}{1,8 \cdot 3^2} = 18 \text{ KN/m}$$

$$q_b = 3,648 \text{ KN.m}$$

$$q_b = 18,0 \text{ KN.m}$$

$$q_D = 27,3 + 3,648 = 30,943 \text{ KN.m}$$

b.3 (elemen 37,39)

$$M_{1D} = 1,8 \cdot 6,8^2 \cdot 4,55 = 218,4 \text{ KNm}$$

$$M_{1E} = 1,8 \cdot 6,8^2 \cdot 4,0 = 192 \text{ KNm}$$

$$q_{eq} = \frac{218,4}{1,8 \cdot 8^2} = 27,3 \text{ KN/m}$$

$$q_{eq} = \frac{192}{1,8 \cdot 8^2} = 24 \text{ KN/m}$$

$$q_b = 5,568 \text{ KN.m}$$

$$q_b = 24,0 \text{ KN.m}$$

$$q_D = 27,3 + 5,568 = 32,868 \text{ KN.m}$$

a.2 (elemen 41)

$$M_b = 1/8 \cdot 4,5 \cdot 3^2 \cdot 4,04 = 20,4525 \text{ KNm} \quad M_t = 1/8 \cdot 3 \cdot 4,5^2 \cdot 1 = 5,0625 \text{ KNm}$$

$$q_{eq} = \frac{20,4525}{1,8 \cdot 3} = 3,818 \text{ KN/m} \quad q_{eq} = \frac{5,0625}{1,8 \cdot 3} = 0,94 \text{ KN/m}$$

$$q_b = 3,648 \text{ KN/m} \quad q_t = 4,5 \text{ KN/m}$$

$$q_D = 18,18 + 3,648 = 22,448 \text{ KN/m}$$

b. Pembebanan Lantai

b.1 (elemen 25,27,28,30,31,33,34,36)

$$M_b = 1/8 \cdot 4,5 \cdot 8^2 \cdot 4,55 = 163,8 \text{ KNm} \quad M_t = 1/8 \cdot 4,5 \cdot 8^2 \cdot 2,5 = 90 \text{ KNm}$$

$$q_{eq} = \frac{163,8}{1,8 \cdot 8} = 11,5 \text{ KN/m} \quad q_{eq} = \frac{90}{1,8 \cdot 8} = 6,25 \text{ KN/m}$$

$$q_b = 5,568 \text{ KN/m} \quad q_t = 11,25 \text{ KN/m}$$

$$q_D = 20,475 + 5,568 = 26,043 \text{ KN/m}$$

b.2 (elemen 26,29,32,35,38)

$$M_b = 1/8 \cdot 4,5 \cdot 3^2 \cdot 4,55 = 23,0344 \text{ KNm} \quad M_t = 1/8 \cdot 4,5 \cdot 3^2 \cdot 3 = 15,1875 \text{ KNm}$$

$$q_{eq} = \frac{23,0344}{1,8 \cdot 3} = 4,22 \text{ KN/m} \quad q_{eq} = \frac{15,1875}{1,8 \cdot 3} = 2,85 \text{ KN/m}$$

$$q_b = 3,648 \text{ KN/m} \quad q_t = 13,5 \text{ KN/m}$$

$$q_D = 20,475 + 3,648 = 24,123 \text{ KN/m}$$

b.3 (elemen 37,39)

$$M_b = 1/8 \cdot 4,5 \cdot 8^2 \cdot 4,55 = 163,8 \text{ KNm} \quad M_t = 1/8 \cdot 4,5 \cdot 8^2 \cdot 4,0 = 144 \text{ KNm}$$

$$q_{eq} = \frac{163,8}{1,8 \cdot 8} = 11,5 \text{ KN/m} \quad q_{eq} = \frac{144}{1,8 \cdot 8} = 10 \text{ KN/m}$$

$$q_b = 5,568 \text{ KN/m} \quad q_t = 18,0 \text{ KN/m}$$

$$q_D = 20,475 + 5,568 = 26,043 \text{ KN/m}$$

a.2 (elemen 41)

$$M_b = 1/8 \cdot 4,5 \cdot 3^2 \cdot 4,04 = 20,4525 \text{ KNm} \quad M_t = 1/8 \cdot 3 \cdot 4,5^2 \cdot 1 = 5,0625 \text{ KNm}$$

$$q_{eq} = \frac{20,4525}{1/8 \cdot 3} = 18,18 \text{ KN/m} \quad q_{eq} = \frac{5,0625}{1/8 \cdot 3^2} = 4,5 \text{ KN/m}$$

$$q_b = 3,648 \text{ KN/m}$$

$$q_t = 4,5 \text{ KN/m}$$

$$q_p = 18,18 + 3,648 = 22,448 \text{ KN/m}$$

b. Pembebanan Lantai

b.1 (elemen 25,27,28,30,31,33,34,36)

$$M_b = 1/8 \cdot 4,5 \cdot 8^2 \cdot 4,55 = 163,8 \text{ KNm} \quad M_t = 1/8 \cdot 4,5 \cdot 8^2 \cdot 2,5 = 90 \text{ KNm}$$

$$q_{eq} = \frac{163,8}{1/8 \cdot 8^2} = 20,475 \text{ KN/m} \quad q_{eq} = \frac{90}{1/8 \cdot 8^2} = 11,25 \text{ KN/m}$$

$$q_b = 5,568 \text{ KN/m}$$

$$q_t = 11,25 \text{ KN/m}$$

$$q_p = 20,475 + 5,568 = 26,043 \text{ KN/m}$$

b.2 (elemen 26,29,32,35,38)

$$M_b = 1/8 \cdot 4,5 \cdot 3^2 \cdot 4,55 = 23,0344 \text{ KNm} \quad M_t = 1/8 \cdot 4,5 \cdot 3^2 \cdot 3 = 15,1875 \text{ KNm}$$

$$q_{eq} = \frac{23,0344}{1/8 \cdot 3^2} = 20,475 \text{ KN/m} \quad q_{eq} = \frac{15,1875}{1/8 \cdot 3^2} = 13,5 \text{ KN/m}$$

$$q_b = 3,648 \text{ KN/m}$$

$$q_t = 13,5 \text{ KN/m}$$

$$q_p = 20,475 + 3,648 = 24,123 \text{ KN/m}$$

b.3 (elemen 37,39)

$$M_b = 1/8 \cdot 4,5 \cdot 8^2 \cdot 4,55 = 163,8 \text{ KNm} \quad M_t = 1/8 \cdot 4,5 \cdot 8^2 \cdot 4,0 = 144 \text{ KNm}$$

$$q_{eq} = \frac{163,8}{1/8 \cdot 8^2} = 20,475 \text{ KN/m} \quad q_{eq} = \frac{144}{1/8 \cdot 8^2} = 18 \text{ KN/m}$$

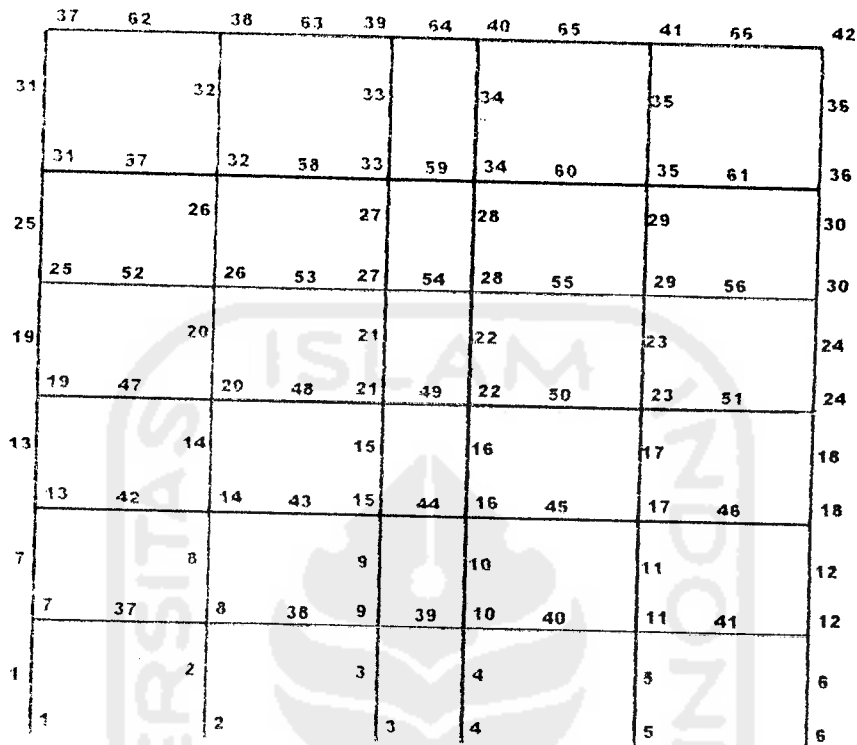
$$q_b = 5,568 \text{ KN/m}$$

$$q_t = 18,0 \text{ KN/m}$$

$$q_p = 20,475 + 5,568 = 26,043 \text{ KN/m}$$



## 4.2.2 Portal Membujur

Gambar 4.5  
Portal Membujur

1. Portal As A – As D (lihat gambar 4.4)

a. Pembebanan Atap

a.1 (elemen 62, 63, 65, 66)

$$M_D = 1/8 \cdot 4.6^2 \cdot 4.04 = 72.72 \text{ KNm}$$

$$M_U = 1/8 \cdot 4.6^2 \cdot 1.0 = 18 \text{ KNm}$$

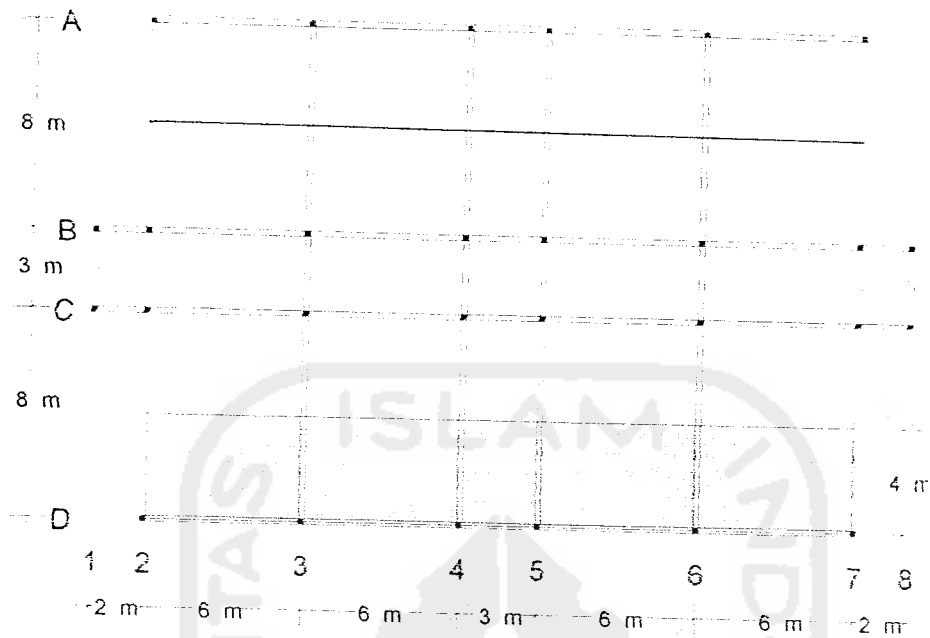
$$q_{eq} = \frac{72.72}{18.6^2} = 16.16 \text{ KN/m}$$

$$q_{eq} = \frac{18}{18.6^2} = 4 \text{ KN/m}$$

$$q_D = 5.568 \text{ KN.m}$$

$$q_U = 4 \text{ KN/m}$$

$$q_D = 16.16 + 5.568 = 21.76 \text{ KN/m}$$



Gambar 4.6

Distribusi beban bagian atap = bagian lantai  
Portal bujur As A = As D

a.2 (elemen 64)

$$M_D = 1/8 \cdot 4 \cdot 3^2 \cdot 4,04 = 18,18 \text{ KNm}$$

$$M_L = 1/8 \cdot 3 \cdot 4^2 \cdot 1 = 4,5 \text{ KNm}$$

$$q_{eq} = \frac{18,18}{1/8 \cdot 3^2} = 16,16 \text{ KN/m}$$

$$q_{eq} = \frac{4,5}{1/8 \cdot 3^2} = 4 \text{ KN/m}$$

$$q_b = 3,648 \text{ KN/m}$$

$$q_u = 4 \text{ KN/m}$$

$$q_D = 16,16 + 3,648 = 19,808 \text{ KN/m}$$

b. Pembebanan Lantai

b.1 (elemen 37,38,40,41,42,43,45,46,47,48)

$$M_D = 1/8 \cdot 4 \cdot 6^2 \cdot 4,55 = 81,9 \text{ KNm}$$

$$M_L = 1/8 \cdot 4 \cdot 6^2 \cdot 2,5 = 45 \text{ KNm}$$

$$q_{eq} = \frac{81,9}{1/8 \cdot 6^2} = 18,2 \text{ KN/m}$$

$$q_{eq} = \frac{45}{1/8 \cdot 6^2} = 10 \text{ KN/m}$$

## Bab. IV Perhitungan Kolom Beton Bertulang

$$q_b = 5,568 \text{ KN/m}$$

$$q_l = 10 \text{ KN/m}$$

$$q_D = 18,2 + 5,568 = 23,768 \text{ KN/m}$$

b.2 (elemen 39,44,49,54,59)

$$M_D = 1/8 \cdot 4,3^2 \cdot 4,55 = 20,475 \text{ KNm}$$

$$M_l = 1/8 \cdot 4,3^2 \cdot 3 = 13,5 \text{ KNm}$$

$$q_{eq} = \frac{220,475}{1 \cdot 8,3^2} = 18,2 \text{ KN/m}$$

$$q_{eq} = \frac{13,5}{1/8 \cdot 3^2} = 12 \text{ KN/m}$$

$$q_b = 3,3648 \text{ KN/m}$$

$$q_l = 12 \text{ KN/m}$$

$$q_D = 18,2 + 3,648 = 21,5648 \text{ KN/m}$$

b.3 (elemen 57,58,60,61)

$$M_D = 1/8 \cdot 4,6^2 \cdot 4,55 = 81,9 \text{ KNm}$$

$$M_l = 1/8 \cdot 4,6^2 \cdot 4,0 = 72 \text{ KNm}$$

$$q_{eq} = \frac{81,9}{1 \cdot 8,6^2} = 18,2 \text{ KN/m}$$

$$q_{eq} = \frac{72}{1/8 \cdot 6^2} = 16 \text{ KN/m}$$

$$q_b = 5,568 \text{ KN/m}$$

$$q_l = 16 \text{ KN/m}$$

$$q_D = 18,2 + 5,568 = 23,768 \text{ KN/m}$$

2. Portal As B = As C (lihat gambar 4.5)

a. Pembebanan Atap

a.1 (elemen 62, 63,65,66)

$$M_D = 1/8 \cdot 5,5 \cdot 6^2 \cdot 4,04 = 99,99 \text{ KNm}$$

$$M_l = 1/8 \cdot 5,5 \cdot 6^2 \cdot 1,0 = 24,75 \text{ KNm}$$

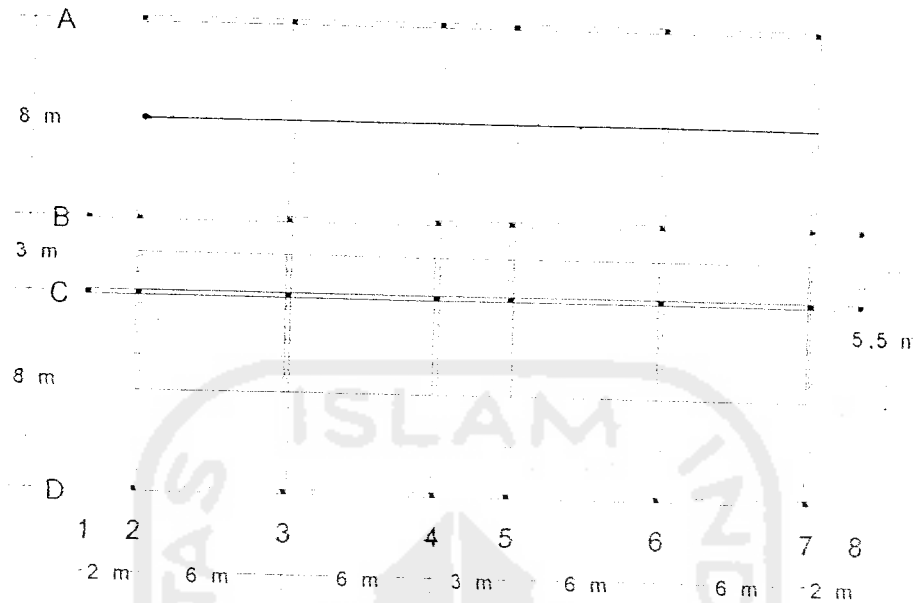
$$q_{eq} = \frac{99,99}{1 \cdot 8,6^2} = 22,22 \text{ KN/m}$$

$$q_{eq} = \frac{24,75}{1 \cdot 8,6^2} = 5,5 \text{ KN/m}$$

$$q_b = 5,568 \text{ KN/m}$$

$$q_l = 5,5 \text{ KN/m}$$

$$q_D = 22,22 + 5,568 = 27,788 \text{ KN/m}$$



Gambar 4.7

Distribusi beban bagian atap = bagian lantai  
Portal bujur As B = As C

a.2 (elemen 64)

$$M_{Dj} = 1/8.5.5.3^2 \cdot 4,04 = 24,9975 \text{ KNm} \quad M_{Dl} = 1/8.5.5.3^2 \cdot 1,0 = 6,1875 \text{ KNm}$$

$$q_{eqj} = \frac{24,9975}{18.3^2} = 22,22 \text{ KN/m} \quad q_{eql} = \frac{6,1875}{18.3^2} = 5,5 \text{ KN/m}$$

$$q_b = 3,648 \text{ KN/m} \quad q_{ll} = 5,5 \text{ KN/m}$$

$$q_D = 22,22 + 3,648 = 25,868 \text{ KN/m}$$

b. Pembebanan Lantai

b.1 (elemen 37,38,40,41,42,43,45,47,48,50,51,52,53,55,56)

$$M_{Dj} = 1/8.5.5.6^2 \cdot 4,55 = 112,6125 \text{ KNm} \quad M_{Dl} = 1/8.5.5.6^2 \cdot 2,5 = 61,875 \text{ KNm}$$

$$q_{eqj} = \frac{112,6125 \cdot 18,4}{18.6^2} = 25,025 \text{ KN/m} \quad q_{eql} = \frac{61,875}{18.6^2} = 13,75 \text{ KN/m}$$

$$q_b = 5,568 \text{ KN/m}$$

$$q_L = 13,75 \text{ KN/m}$$

$$q_D = 25,025 + 5,568 = 30,593 \text{ KN/m}$$

b.2 (elemen 39,44,49,54,59)

$$M_D = 1/8 \cdot 5,5 \cdot 3^2 \cdot 4,55 = 28,1531 \text{ KNm} \quad M_L = 1/8 \cdot 5,5 \cdot 3^2 \cdot 3,0 = 18,5625 \text{ KNm}$$

$$q_{eq} = \frac{28,1531}{1/8 \cdot 3^2} = 25,025 \text{ KN/m}$$

$$q_{eq} = \frac{18,5625}{1/8 \cdot 3^2} = 16 \text{ KN/m}$$

$$q_b = 3,648 \text{ KN/m}$$

$$q_L = 16,0 \text{ KN/m}$$

$$q_D = 25,025 + 3,648 = 28,673 \text{ KN/m}$$

b.3 (elemen 57,58,60,61)

$$M_D = 1/8 \cdot 4,5 \cdot 6^2 \cdot 4,55 = 112,6125 \text{ KNm} \quad M_L = 1/8 \cdot 4,5 \cdot 6^2 \cdot 4,0 = 99 \text{ KNm}$$

$$q_{eq} = \frac{112,6125 \cdot 18,4}{1/8 \cdot 6^2} = 25,025 \text{ KN/m}$$

$$q_{eq} = \frac{99}{1/8 \cdot 6^2} = 22 \text{ KN/m}$$

$$q_b = 5,568 \text{ KN/m}$$

$$q_L = 22 \text{ KN/m}$$

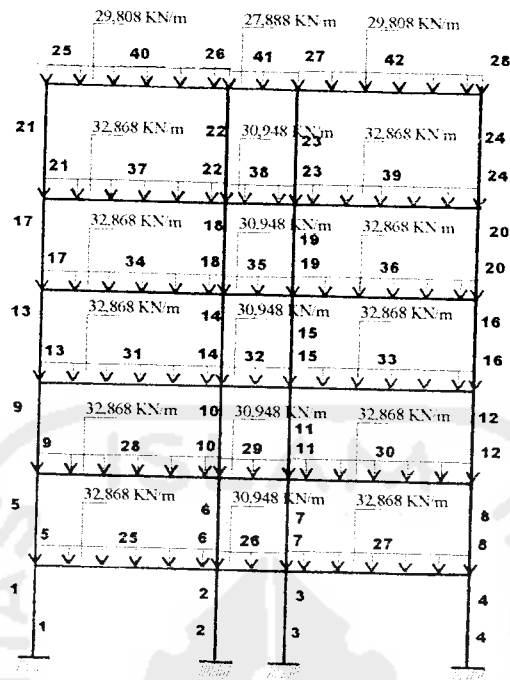
$$q_D = 25,025 + 5,568 = 30,593 \text{ KN/m}$$

#### 4.2.3 Penentuan Portal

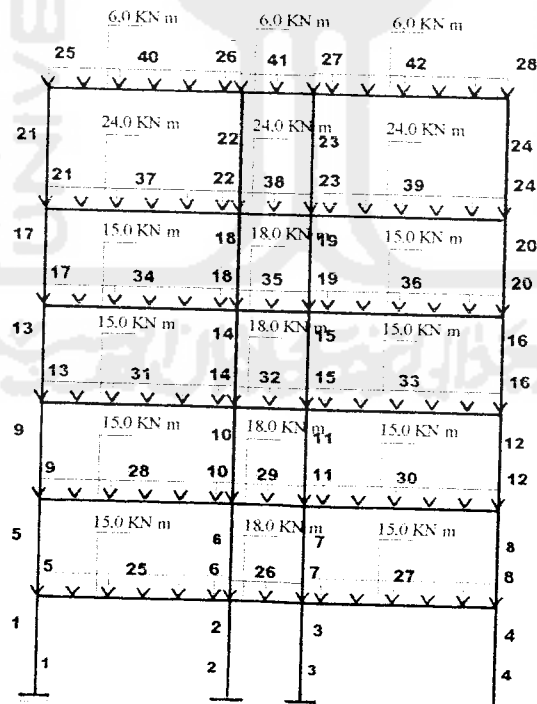
Berdasarkan pembebanan yang terjadi pada tiap-tiap portal baik portal melintang maupun portal membujur, selanjutnya dalam perancangan dipakai pembebanan yang terbesar pada portal arah melintang, yaitu portal melintang As 3 – As 6.

Perhitungan selanjutnya, arah Bujur hanya digunakan sebagai pengecekan stabilitas kolom pada arah Lintang dengan beban gravitasi. Sedangkan untuk perhitungan beban gempa sepenuhnya menggunakan portal Lintang As 3 – As 6.

## Bab. IV Perhitungan Kolom Beton Bertulang



Gambar 4.8a  
Portal Melintang As 3 = As 6 dengan Beban Merata Mati



Gambar 4.8b  
Portal Melintang As 3 = As 6 dengan Beban Merata Hidup

### 4.3 Contoh perhitungan dimensi dan penulangan kolom elemen 1 portal

#### Lintang As 3 = As 6 akibat beban gravitasi

Data-data contoh dibawah ini didapatkan dengan menggunakan program komputer aplikasi analisa struktur SAP90 (lihat lampiran 1).

Diketahui data-data dimensi kolom elemen 1 ( lihat gambar 4.9 ) :

$$\begin{array}{ll}
 P_u &= 1520760 \text{ N} & f_y &= 300 \text{ MPa} \\
 M_{2b} &= 1,46E+08 \text{ Nmm} & \beta_1 &= 0,85 \\
 M_{1b} &= 7,74E+07 \text{ Nmm} & d' &= 40 \text{ mm} \\
 M_{2s} &= 0 & \phi \text{ tul. pokok} &= 22 \text{ mm} \\
 f_c' &= 30 \text{ MPa} & \phi \text{ tul. sengk} &= 10 \text{ mm} \\
 d &= 800 - 40 - 10 - 0,5 \cdot 22 = 739 \text{ mm} & \rho \text{ dipakai} &= 1\% - 8\%
 \end{array}$$

#### 1. Eksentrisitas

$$e_{\min} = 15 + 0,03 \cdot 800 = 39 \text{ mm}$$

Jika  $e_{\min} < e$  maka dipakai  $e$ , dan jika  $e_{\min} > e$  maka dipakai  $e_{\min}$

#### 2. Kekakuan Kolom

$$E_c = 4700 \cdot \sqrt{f_c'} = 4700 \cdot \sqrt{30} = 25742,96 \text{ MPa}$$

$$\beta_d = 1,2MD \text{ (1,2MD+1,6ML)}$$

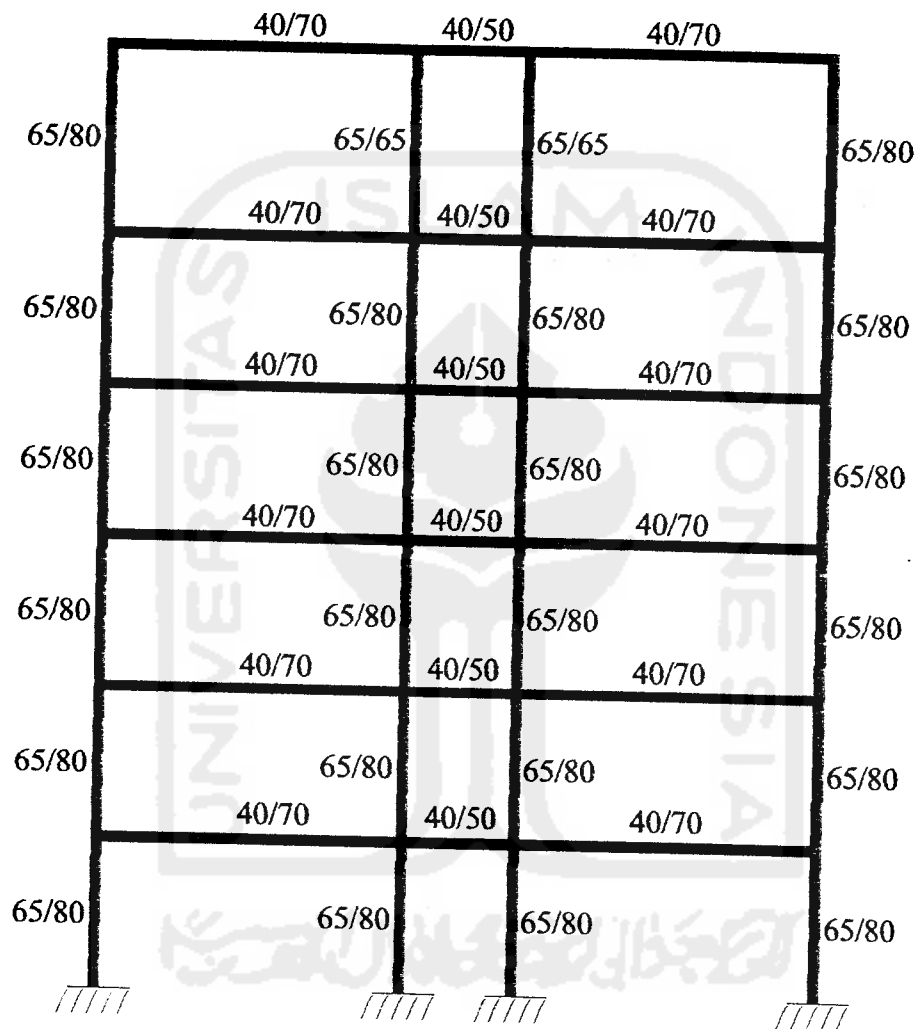
$$1,2 \cdot 7,54E+07 \cdot 1,46E+08 = 0,62143446 < 1$$

#### 3. Inersia Kolom

$$I_g = 1/12 \cdot b \cdot h^3 = 1/12 \cdot 650 \cdot 800^3 = 27733333333 \text{ mm}^4$$

$$I_{g_{\max}} = 1/12 \cdot b \cdot h^3 = 1/12 \cdot 650 \cdot 800^3 = 27733333333 \text{ mm}^4$$

$$I_{g_{\text{bawah}}} = 1/12 \cdot b \cdot h^3 = 0$$



Gambar 4.9

Dimensi Kolom dan Balok Pada  
Portal Lintang As 3 = As 6 untuk Beban Gravitasi



## 4. Inersia Balok

$$I_{cr,akam} = 0,5(1,12 \cdot b \cdot h^3) = 0,5(1,12 \cdot 400 \cdot 700^3) = 5,72E+9 \text{ mm}^4$$

$$I_{cr,akm} = 0,5(1,12 \cdot b \cdot h^3) = 0$$

$$I_{cr,bkam} = 0,5(1,12 \cdot b \cdot h^3) = 0$$

$$I_{cr,bkm} = 0,5(1,12 \cdot b \cdot h^3) = 0$$

## 5. Mencari EI Kolom

$$EI = (E_c \cdot I_g) \cdot (2,5(1 + \beta d)) \\ = (25742,96 \cdot 2,7733E+10) \cdot (2,5(1 + 0,62143446)) = 1,7613E+14 \text{ Nmm}^2$$

$$EI_{atas} = (E_c \cdot I_g) \cdot (2,5(1 + \beta d)) \\ = (25742,96 \cdot 2,7733E+10) \cdot (2,5(1 + 0,62143446)) = 1,7613E+14 \text{ Nmm}^2$$

$$EI_{bawah} = 0$$

## 6. Mencari EI Balok

$$EI_{b,ka} = (E_c \cdot I_{cr,ka}) = 254742,96 \cdot 5716666667 = 1,4716E+14 \text{ Nmm}^2$$

$$EI_{a,ki} = (E_c \cdot I_{cr,a,ki}) = 0$$

$$EI_{a,ka} = (E_c \cdot I_{cr,a,ka}) = 0$$

$$EI_{a,ki} = (E_c \cdot I_{cr,a,ki}) = 0$$

$$\psi A = (\sum EI_{ki}) / (\sum E_c \cdot I_{cr,atas,ka} \cdot L_{b,ka}) \\ = (2(1,7613E+14/4000)) / ((1,4716E+14)/8000) = 4,7872$$

$$\psi B = (\sum EI_{ki}) / (\sum E_c \cdot I_{cr,atas,ka} \cdot L_{b,ka}) = 0$$

$$\psi = (\psi A + \psi B) / 2 = (4,7872 + 0) / 2 = 2,3936 > 2$$

$$\text{jika } \psi > 2 \text{ maka } k = 0,9 \cdot (1 + \psi)^{0,5}$$

$$\psi < 2 \text{ maka } k = ((20 - \psi) / 20) \cdot (1 + \psi)^{0,5}$$

$$k \text{ dipakai} = 0,9 \cdot (1 + 2,3936)^{0,5} = 1,6580$$

## 7. Mencari angka kelangsingan

$$(k.L_k)/(0,3.h_k) = (1,6580.4000)/(0,3.800)$$

$$= 27,6325 > 22 \quad \text{kolom langsing}$$

$$P_c = (\pi^2.EI)/(k.L_k)^2 = (3.14^2.1.7613E+14)/(1.6580.4000)^2$$

$$= 39483536,88 \text{ N}$$

Perancangan untuk kolom 1 sangat dipengaruhi oleh kolom-kolom lain dalam satu tingkat yang sama, yaitu kolom 2 = kolom 3, sedangkan kolom 4 = kolom 1.

## 8. Inersia Kolom

$$I_{g \text{ bawah}} = 1/12.b.h.^3 = 1/12.650.800^3 = 27733333333 \text{ mm}^4$$

$$I_{g \text{ atas}} = 1/12.b.h.^3 = 1/12.650.800^3 = 27733333333 \text{ mm}^4$$

$$I_{g \text{ bawah}} = 1/12.b.h.^3 = 0$$

## 9. Inersia Balok

$$I_{cr \text{ kolom}} = 0,5(1/12.b.h.^3) = 0,5(1/12.400.500^3) = 2,08E+9 \text{ mm}^4$$

$$I_{cr \text{ kolom}} = 0,5(1/12.b.h.^3) = 0,5(1/12.400.700^3) = 5,72E+9 \text{ mm}^4$$

$$I_{cr \text{ kolom}} = 0,5(1/12.b.h.^3) = 0$$

$$I_{cr \text{ kolom}} = 0,5(1/12.b.h.^3) = 0$$

## 10. Mencari EI Kolom

$$EI = (E_c I_g) (2,5(1 + \beta d))$$

$$= (25742,96. 2,7733E+10)/(2,5(1 + 0,6314)) = 1,7505E+14 \text{ Nmm}^2$$

$$EI_{\text{atas}} = (E_c I_g) (2,5(1 + \beta d))$$

$$= (25742,96. 2,7733E+10)/(2,5(1 + 0,6314)) = 1,7505E+14 \text{ Nmm}^2$$

$$EI_{\text{bawah}} = 0$$

## 11. Mencari EI Balok

$$EI_{b,a,ka} = (E_c \cdot I_{cr,a,ka}) = 254742,96 \cdot 2,0833E+9 = 5,3631E+13 \text{ Nmm}^2$$

$$EI_{l,a,ki} = (E_c \cdot I_{cr,a,ki}) = 254742,96 \cdot 5,7167E+9 = 1,4716E+14 \text{ Nmm}^2$$

$$EI_{l,a,ka} = (E_c \cdot I_{cr,a,ka}) = 0$$

$$EI_{l,a,ki} = (E_c \cdot I_{cr,a,ki}) = 0$$

$$\begin{aligned} \psi A &= (\sum EI/L_k) / (\sum E_c \cdot I_{cr,atas} / L_{b,ka}) \\ &= (2(1,7505E+14/4000)) / ((5,3631E+13/3000) + (1,4716E+14/40000)) \\ &= 2,4130 \end{aligned}$$

$$\psi B = (\sum EI/L) / (\sum E_c \cdot I_{cr,atas} / L_{b,ka}) = 0$$

$$\psi' = (\psi A + \psi B) / 2$$

$$= (2,4130 + 0) / 2 = 1,2065 < 2$$

$$\text{jika } \psi' > 2 \text{ maka } k = 0,9 \cdot (1 + \psi')^{11,5}$$

$$\psi' < 2 \text{ maka } k = ((20 - \psi') / 20) \cdot (1 + \psi')^{11,5}$$

$$k \text{ dipakai} = ((20 - 1,2065) / 20) \cdot (1 + 1,2065)^{11,5} = 1,3958$$

## 12. Angka kelangsingan

$$(k \cdot L_k) / (0,3 \cdot h_k) = (1,3958 \cdot 4000) / (0,3 \cdot 800) = 23,2637 > 22 \text{ kolom langsing}$$

$$P_c = (\pi^2 \cdot EI) / (k \cdot L_k)^2 = (3,14^2 \cdot 1,7505E+14) / (1,3958 \cdot 4000)^2 = 55366270,8 \text{ N}$$

## 13. Pembesaran Momen

$$\Sigma P_c = 2(P_{c1} + P_{c2})$$

$$= 2(39483536,88 + 55366270,78)$$

$$= 1,8970E+8 \text{ N}$$

$$\Sigma P_u = 2(P_{u1} + P_{u2}) = 2(1520760 + 2054190)$$

$$= 7149900 \text{ N}$$

$$\delta_b = 1 / (1 - (P_u / 0,65 P_c)) = 1 / (1 - (1520760 / 0,65 \cdot 39483536,88))$$

$$= 1,0630 > 1$$

$$M_c = \delta_b \cdot M_{2b} = 1,0630 \cdot (1,46E+8)$$

$$= 1,55E+8 \text{ Nmm}$$

$$e = M_c / P_u = (1,55E+8) / 1520760$$

$$= 101,7442 \text{ mm}$$

#### 14. Penulangan

Diambil ratio penulangan total 2,4 %

$$\rho = \rho' = A_s / (b_k \cdot d) = 0,5 \cdot 0,024 = 0,012$$

$$\text{dipakai tulangan D22 : } A_s \text{ D22} = \pi \cdot 1/4 \cdot 22^2 = 379,94 \text{ mm}^2$$

Jumlah tulangan yang dipakai 16 buah

$$A_{\text{perlu}} = 379,94 \cdot 16 = 6079,04 \text{ mm}^2$$

$$\rho_{\text{perlu}} = A_s / (b_k \cdot d) = 6079,04 / (650 \cdot 739) = 0,0127$$

#### 15. Eksentrisitas Balanced = eb

$$C_k = (600 \cdot d) / (600 + f_y) = (600 \cdot 739) / (600 + 300) = 492,6667 \text{ mm}$$

$$ab = \beta_1 \cdot C_k = 0,85 \cdot 492,6667 = 418,7667 \text{ mm}$$

$$f_c = 600 \cdot ((C_k - d') / C_k) = 600 \cdot ((492,6667 - 40) / 492,6667)$$

$$= 551,2855 \text{ MPa} > f_y$$

jika  $f_s > f_y$ , maka dipakai  $f_y$  dan jika  $f_s < f_y$  maka dipakai  $f_s$ , maka

dipakai = 300 MPa

$$C_c = 0,85 \cdot f_c \cdot b_k \cdot ab = 0,85 \cdot 30 \cdot 650 \cdot 418,7667 = 6941057,5 \text{ N}$$

$$C_s = A_s \cdot f_s = 6079,04 \cdot 300 = 1823712 \text{ N}$$

$$T_s = A_s \cdot f_y = 6079,04 \cdot 300 = 1823712 \text{ N}$$

$$P_{nb} = C_c + C_s - T_s = 6941057,5 - 1823712 - 1823712 \\ = 6941057,5 \text{ N}$$

$$M_1 = 0,85 \cdot f'_c \cdot b_k \cdot a_b \cdot ((h_k/2) - (a_b/2)) \\ = 0,85 \cdot 30 \cdot 600 \cdot 418,7667 \cdot ((800/2) - (418,7667/2)) = 1,3231E+9 \text{ Nmm}$$

$$M_2 = A_s \cdot f_y \cdot ((h_k/2) - d') \\ = 6079,04 \cdot 300 \cdot ((800/2) - 40) = 6,5653E+8 \text{ Nmm}$$

$$M_3 = A_s \cdot f_y \cdot (d - (h_k/2)) \\ = 6079,04 \cdot 300 \cdot (739 - (800/2)) = 6,1824E+8 \text{ Nmm}$$

$$M_{nb} = M_1 + M_2 + M_3 \\ = (1,3231E+9) + (6,5653E+8) + (6,1824E+8) = 2,5979E+9 \text{ Nmm}$$

$$e_b = M_{nb}/P_{nb} = 2,5979E+9 / 6941057,5 \\ = 374,2738 \text{ mm} > e$$

termasuk keruntuhan kolom akibat desak

$$A = A_s \cdot f_y = 6079,04 \cdot 300 = 1823712$$

$$B = e/(d - d') = 101,7442/(739 - 40) = 0,1456$$

$$C = b_k \cdot h_k \cdot f'_c = 650 \cdot 800 \cdot 30 = 15600000$$

$$D = (3 \cdot h_k \cdot e)/d^2 = (3 \cdot 800 \cdot 101,7442)/739^2 = 0,4471$$

$$P_n = (A/(B+0,5)) + (C/(D+1,18)) \\ = (1823712/(0,1456+0,5)) + (15600000/(0,4471+1,18)) \\ = 9587442,925 \text{ N}$$

$$P_t = \phi \cdot P_u = 0,65 \cdot P_u = 0,65 \cdot 9587442,925 = 6231837,901 \text{ N}$$

$$P_t < P_u \quad (\text{OK})$$

#### 16. Cek Tegangan $\bar{f}_s$

$$a = \frac{P_t}{\phi \cdot (0,85 \cdot f'_c \cdot b_k)} = \frac{9587442,925}{(0,85 \cdot 30 \cdot 650)}$$

$$= 578,4279 \text{ mm}$$

$$c = a \cdot 0,85 = 578,4279 \cdot 0,85$$

$$= 680,5034 \text{ mm}$$

$$\bar{f}_s = 600 \left( \frac{c-d'}{c} \right) = 600 \left( \frac{680,5034-40}{680,5034} \right)$$

$$= 564,7320 \text{ MPa} > f_y \quad (\text{OK})$$

#### 17. Disain Tulangan Senggang

Jarak yang didapatkan yaitu :

$$16 \text{ kali diameter pokok} = 352 \text{ mm}$$

$$48 \text{ kali diameter sengkang} = 480 \text{ mm}$$

$$\text{dimensi terkecil kolom} = 650 \text{ mm}$$

$$\text{jarak terpakai} = 352 \text{ mm}$$

$$\text{jarak terpasang} = 350 \text{ mm}$$

Perhitungan kolom elemen 2,3,4,21,22,23 dan 24 selanjutnya dapat dilihat pada tabel perancangan kolom beton bertulang lampiran untuk beban gravitasi.

#### 4.4 Contoh perhitungan dimensi dan penulangan kolom elemen 1 portal

##### Lintang As 3 = As 6 akibat beban gempa daerah 4

Data-data contoh dibawah ini didapatkan dengan menggunakan program komputer aplikasi analisa struktur SAP90, dengan memperhitungkan gaya geser dasar pada daerah gempa 4, seperti dapat dilihat pada perhitungan berikut :

## A. Perhitungan gaya geser dasar gempa

## 1. Plat

$$\text{Beban plat atap } (q_a) = 5,04 \text{ KN/m}^2$$

$$\text{Beban plat lantai 6 } (q_{l,6}) = 8,55 \text{ KN/m}^2$$

$$\text{Beban plat lantai 2-5 (kantor) } (q_{l,25k}) = 7,05 \text{ KN/m}^2$$

$$\text{Beban plat lantai 2-5 (selasar) } (q_{l,25s}) = 7,55 \text{ KN/m}^2$$

$$\text{Lebar yang ditinjau } (L_f) = 6,00 \text{ m}$$

## 2. Balok

Balok Lintang Lt. I-VI

$$\text{Balok A-B=Balok C-D } (h_{b,AB}) = 0,70 \text{ m}$$

$$(b_{b,AB}) = 0,40 \text{ m}$$

$$(L_{b,AB}) = 8,00 \text{ m}$$

$$\text{Balok B-C } (h_{b,BC}) = 0,50 \text{ m}$$

$$(b_{b,BC}) = 0,40 \text{ m}$$

$$(L_{b,BC}) = 3,00 \text{ m}$$

Balok Bujur Lt. I-VI

$$\text{Balok L6-A=Balok L6-D } (h_{b,6A}) = 0,70 \text{ m}$$

$$(b_{b,6A}) = 0,40 \text{ m}$$

$$(L_{b,6A}) = 6,00 \text{ m}$$

$$\text{Balok L6-B=Balok L6-C } (h_{b,6B}) = 0,70 \text{ m}$$

$$(b_{b,6B}) = 0,40 \text{ m}$$

$$(L_{b,6B}) = 6,00 \text{ m}$$

## 3. Kolom

Kolom Lt. VI

Kolom L6-A-Kolom L6-D  $(h_{k,6A}) = 0,80 \text{ m}$  $(B_{k,6A}) = 0,65 \text{ m}$  $(L_{k,6A}) = 5,00 \text{ m}$ Kolom L6-B-Kolom L6-C  $(H_{k,6B}) = 0,65 \text{ m}$  $(B_{k,6B}) = 0,65 \text{ m}$  $(L_{k,6B}) = 5,00 \text{ m}$ 

Kolom Lt. II - Lt. V

Kolom L5-A-Kolom L5-D  $(h_{k,5A}) = 0,80 \text{ m}$  $(b_{k,5A}) = 0,65 \text{ m}$  $(L_{k,5A}) = 4,00 \text{ m}$ Kolom L5-B-Kolom L5-C  $(h_{k,5B}) = 0,80 \text{ m}$  $(b_{k,5B}) = 0,65 \text{ m}$  $(L_{k,5B}) = 4,00 \text{ m}$ 

## 4. Tinggi Gedung

Tinggi Total (H) = 25,00 m

## 5. Lebar Gedung Arah Lintang

Lebar Total (B) = 19,00 m

## 6. Rasio tinggi terhadap lebar gedung

 $H/B = 1,3 > 3$ 

## 7. Berat yang terjadi

Berat plat atap =  $(5,04)(6)(19) = 574,56 \text{ KN}$



## Bab. IV Perhitungan Kolom Beton Bertulang

$$\text{Berat plat lantai II-V} = 2(7,05.6.8)+(7,55.6.3) = 812,70 \text{ KN}$$

$$\text{Berat plat lantai VI} = 2(8,55.6.8)+(7,55.6.3) = 956,70 \text{ KN}$$

$$\begin{aligned} \text{Berat balok bujur} &= (2(0,70.0,40.6) + 2(0,70.0,40.6)).24 \\ &= 161,28 \text{ KN} \end{aligned}$$

$$\begin{aligned} \text{Berat balok lintang} &= (2(0,70.0,40.8) + (0,50.0,40.3)).24 \\ &= 121,92 \text{ KN} \end{aligned}$$

$$\begin{aligned} \text{Berat kolom atap} &= (2(0,80.0,65.2,5) + 2(0,65.0,65.2,5)).24 \\ &= 113,10 \text{ KN} \end{aligned}$$

$$\text{Berat kolom lantai II-V} = 4(0,80.0,65.4).24 = 199,68 \text{ KN}$$

$$\begin{aligned} \text{Berat kolom lantai VI} &= (4(0,80.0,65.2) + 2(0,80.0,65.2,5) + \\ &2(0,65.0,65.2,5)).24 \\ &= 212,94 \text{ KN} \end{aligned}$$

$$\begin{aligned} \text{Berat total lantai atap} &= 574,56 + 161,28 + 121,92 + 113,10 \\ &= 970,86 \text{ KN} \end{aligned}$$

$$\begin{aligned} \text{Berat total lantai Berat II (tipikal)} &= 812,70 + 161,28 + 121,92 + 199,68 \\ &= 1295,58 \text{ KN} \end{aligned}$$

$$\begin{aligned} \text{Berat total lantai VI} &= 856,70 + 161,28 + 121,92 + 212,94 \\ &= 1452,84 \text{ KN} \end{aligned}$$

8. Berat total Gedung (W)

$$W = W_a + (4.W_{1-5}) + W_6 = 7606,02 \text{ KN}$$

9. Waktu Getar (T)

$$T = 0,06(H)^{3/4} = 0,67082 \text{ detik}$$

10. Faktor Keutamaan Gedung (I) = 1,5

11. Faktor Jenis Struktur (K) = 1

12. Distribusi beban horizontal :

$$F_i = P \frac{w_i h_i}{\sum_{i=1}^n w_i h_i}$$

Gaya Geser Dasar Horizontal ( $V_d$ )

$$C_d = 0,0283$$

$$V_d = C_d K_1 W = 322,8755 \text{ KN}$$

Ut (l)	wi (KN)	hi (m)	wi hi (KN-m)	Fi (KN)
1	1295,6	4	5182,32	15,912701
2	1295,6	8	10364,64	31,825403
3	1295,6	12	15546,96	47,738104
4	1295,6	16	20729,28	63,650805
5	1452,8	20	29056,8	89,221079
6	970,86	25	24271,5	74,527457
		$\Sigma$	105151,5	

B. Diketahui data-data dimensi kolom elemen 1 ( lihat gambar 4.9 dan lampiran 8.a - 8.c ) :

$$P_{u1} = 1146500 \text{ N}$$

$$P_{u2} = 1032500 \text{ N}$$

$$P_{u3} = 1031700 \text{ N}$$

$$P_{u4} = 1145800 \text{ N}$$

$$M_{2b} = 0 \text{ Nmm}$$

$$f'_c = 300 \text{ MPa}$$

$$M_{1b} = 0 \text{ Nmm}$$

$$\beta_1 = 0,85$$

$$M_{2s} = 3,3350E+8 \text{ Nmm}$$

$$d' = 40 \text{ mm}$$

$$f'_c = 30 \text{ MPa}$$

$$\phi \text{ tul .pokok} = 22 \text{ mm}$$

$$d = 800 - 40 - 10 = 0,5,22$$

$$\phi \text{ tul .sengk} = 10 \text{ mm}$$

$$= 739 \text{ mm}$$

$$\rho \text{ dipakai } 1\% - 8\%$$

## 1. Eksentrisitas

$$e_{\min} = 15 + 0,03 \cdot 800 = 39 \text{ mm}$$

Jika  $e_{\min} < e$  maka dipakai  $e$ , dan jika  $e_{\min} > e$  maka dipakai  $e_{\min}$

## 2. Kekakuan Kolom

$$E_c = 4700 \cdot \sqrt{f'_c} = 4700 \cdot \sqrt{30}$$

$$= 25742,96 \text{ MPa}$$

$$\beta d = 1,2MD / (1,2MD + 1,6ML) = 1,2 \cdot (7,54E+07) / 1,46E+08$$

$$= 0,62143446 < 1$$

## 3. Inersia Kolom

$$I_g = 1/12 \cdot b \cdot h^3 = 1/12 \cdot 650 \cdot 800^3 = 27733333333 \text{ mm}^4$$

$$I_{g, \text{atas}} = 1/12 \cdot b \cdot h^3 = 1/12 \cdot 650 \cdot 800^3 = 27733333333 \text{ mm}^4$$

$$I_{g, \text{bawah}} = 1/12 \cdot b \cdot h^3 = 0$$

## 4. Inersia Balok

$$I_{cr, a, \text{kanan}} = 0,5(1/12 \cdot b \cdot h^3) = 0,5(1/12 \cdot 400 \cdot 700^3) = 5,72E+9 \text{ mm}^4$$

$$I_{cr, a, \text{kiri}} = 0,5(1/12 \cdot b \cdot h^3) = 0$$

$$I_{cr, b, \text{kanan}} = 0,5(1/12 \cdot b \cdot h^3) = 0$$

$$I_{cr, b, \text{kiri}} = 0,5(1/12 \cdot b \cdot h^3) = 0$$

## 5. Mencari EI Kolom

$$EI = (E_c \cdot I_g) / (2,5(1 + \beta d))$$

$$= (25742,96 \cdot 2,7733E+10) / (2,5(1 + 0,62143446)) = 1,7613E+14 \text{ Nmm}^2$$

$$EI_{k, \text{atas}} = (E_c \cdot I_g) / (2,5(1 + \beta d))$$

$$= (25742,96 \cdot 2,7733E+10) / (2,5(1 + 0,62143446)) = 1,7613E+14 \text{ Nmm}^2$$

$$EI_{k, \text{bawah}} = 0$$

## 6. Mencari EI Balok

$$EI_{b,ka} = (E_c \cdot I_{cr,ka}) = 254742,96 \cdot 5716666667 = 1,4716E+14 \text{ Nmm}^2$$

$$EI_{t,ka} = (E_c \cdot I_{cr,t,ka}) = 0$$

$$EI_{a,ka} = (E_c \cdot I_{cr,a,ka}) = 0$$

$$EI_{s,ka} = (E_c \cdot I_{cr,s,ka}) = 0$$

$$\begin{aligned} \psi A &= (\sum EI/L_k) / (\sum E_c \cdot I_{cr,atas,ka} / L_{b,ka}) \\ &= (2(1,7613E+14/4000)) / ((1,4716E+14)/8000) = 4,7872 \end{aligned}$$

$$\psi B = (\sum EI/L_k) / (\sum E_c \cdot I_{cr,atas} / L_{b,ka}) = 0$$

$$\begin{aligned} \psi &= (\psi A + \psi B) / 2 = (4,7872 + 0) / 2 \\ &= 2,3936 > 2 \end{aligned}$$

$$\text{jika } \psi > 2 \text{ maka } k = 0,9 \cdot (1 + \psi)^{0,5}$$

$$\text{jika } \psi < 2 \text{ maka } k = ((20 - \psi) / 20) \cdot (1 + \psi)^{0,5}$$

$$k \text{ dipakai} = 0,9 \cdot (1 + 2,3936)^{0,5} = 1,6580$$

## 7. Mencari angka kelangsingan

$$\begin{aligned} (k \cdot L_k) / (0,3 \cdot h_k) &= (1,6580 \cdot 4000) / (0,3 \cdot 800) \\ &= 27,6325 > 22 \quad \text{kolom langsing} \end{aligned}$$

$$\begin{aligned} P_{c1} &= (\pi^2 \cdot EI) / (k \cdot L_k)^2 = (3,14^2 \cdot 1,7613E+14) / (1,6580 \cdot 4000)^2 \\ &= 39483536,88 \text{ N} \end{aligned}$$

Perancangan untuk kolom 1 sangat dipengaruhi oleh kolom-kolom lain dalam satu tingkat yang sama, yaitu kolom 2, kolom 3, dan kolom 4, dengan cara yang sama seperti pada kolom 1, maka didapatkan harga-harga sebagai berikut :

$$P_{c2} = 55366270,8 \text{ N} \quad P_{c3} = 55366270,8 \text{ N} \quad P_{c4} = 39483536,9 \text{ N}$$

## 8. Pembesaran Momen

$$\begin{aligned}\Sigma P_c &= (P_{c1} + P_{c2} + P_{c3} + P_{c4}) \\ &= (39483536,9 + 55366270,8 + 55366270,8 + 39483536,9) \\ &= 189699615 \text{ N}\end{aligned}$$

$$\begin{aligned}\Sigma P_u &= (P_{u1} + P_{u2} + P_{u3} + P_{u4}) \\ &= (1146500 + 1032500 + 1031700 + 1145800) \\ &= 4356500 \text{ N}\end{aligned}$$

$$\begin{aligned}\delta_b &= 1/(1 - (P_u / 0,65 P_c)) = 1/(1 - (1146500 / 0,65 \cdot 39483536,9)) \\ &= 1,04676 > 1\end{aligned}$$

$$\begin{aligned}\delta_s &= 1/(1 - (\Sigma P_u / 0,65 \Sigma P_c)) = 1/(1 - (4356500 / 0,65 \cdot 189699615)) \\ &= 1,03663 > 1\end{aligned}$$

$$\begin{aligned}M_c &= \delta_b M_{2b} + \delta_s M_{2c} = 1,04676 \cdot (0) + 1,03663 \cdot 3,3350E+8 \\ &= 3,4571E+8 \text{ Nmm}\end{aligned}$$

$$e = M_c / P_u = (3,4571E+8) / 1146500 = 301,5390 \text{ mm}$$

## 9. Penulangan

Diambil ratio penulangan total 2,4 %

$$\rho = \rho' = A_s / (b_k \cdot d) = 0,5 \cdot 0,024 = 0,012$$

$$\text{dipakai tulangan D22 : } A_1 D22 = \pi \cdot 1/4 \cdot 22^2 = 379,94 \text{ mm}^2$$

Jumlah tulangan yang dipakai 16 buah

$$A_{\text{perlu}} = 379,94 \cdot 16 = 6079,04 \text{ mm}^2$$

$$\rho_{\text{perlu}} = A_s / (b_k \cdot d) = 6079,04 / (650 \cdot 739) = 0,0127$$

$$A = A_s \cdot f_y = 6079,04 \cdot 300 = 1823712$$

## 10. Eksentrisitas Balanced = eb

$$C_k = (600 \cdot d) / (600 + f_y) = (600 \cdot 739) / (600 + 300) = 492,6667 \text{ mm}$$

$$ab = \beta_1 \cdot C_k = 0,85 \cdot 492,6667 = 418,7667 \text{ mm}$$

$$f_s = 600 \cdot ((C_k - d') / C_k) = 600 \cdot ((492,6667 - 40) / 492,6667) \\ = 551,2855 \text{ MPa} > f_y$$

Jika  $f_s > f_y$ , maka dipakai  $f_y$  dan jika  $f_s < f_y$  maka dipakai  $f_s$ , maka dipakai = 300 MPa

$$C_c = 0,85 \cdot f_c \cdot b_k \cdot ab = 0,85 \cdot 30 \cdot 650 \cdot 418,7667 = 6941057,5 \text{ N}$$

$$C_s = A_s \cdot f_s = 6079,04 \cdot 300 = 1823712 \text{ N}$$

$$T_s = A_s \cdot f_y = 6079,04 \cdot 300 = 1823712 \text{ N}$$

$$P_{nb} = C_c - C_s - T_s = 6941057,5 + 1823712 - 1823712 = 6941057,5 \text{ N}$$

$$M_1 = 0,85 \cdot f_c \cdot b_k \cdot ab \cdot ((h_k/2) - (a_s/2)) \\ = 0,85 \cdot 30 \cdot 600 \cdot 418,7667 \cdot ((800/2) - (418,7667/2)) = 1,3231E+9 \text{ Nmm}$$

$$M_2 = A_s \cdot f_y \cdot ((h_k/2) - d') \\ = 6079,04 \cdot 300 \cdot ((800/2) - 40) = 6,5653E+8 \text{ Nmm}$$

$$M_3 = A_s \cdot f_y \cdot (d - (h_k/2)) \\ = 6079,04 \cdot 300 \cdot (739 - (800/2)) = 6,1824E+8 \text{ Nmm}$$

$$M_{nb} = M_1 + M_2 + M_3 \\ = (1,3231E+9) + (6,5653E+8) + (6,1824E+8) = 2,5979E+9 \text{ Nmm}$$

$$eb = M_{nb} / P_{nb} = 2,5979E+9 / 6941057,5 \\ = 374,2738 \text{ mm} > e$$

termasuk keruntuhan kolom akibat desak

$$B = e \cdot (d-d')$$

$$= 301,5390 / (739-40) = 0,4314$$

$$C = b_k \cdot h_k \cdot \Gamma_c = 650 \cdot 800 \cdot 30 = 15600000$$

$$D = (3 \cdot h_k \cdot e) \cdot d^2 = (3 \cdot 800 \cdot 301,5390) \cdot 739^2 = 1,3252$$

$$P_n = (A \cdot (B+0,5)) + (C \cdot (D+1,18))$$

$$= (1823712 \cdot (0,4314+0,5)) + (15600000 \cdot (1,3252+1,18))$$

$$= 6227165,671 \text{ N}$$

$$P_r = \phi \cdot P_n = 0,65 \cdot P_n$$

$$= 0,65 \cdot 6227165,671 = 4047657,686 \text{ N}$$

$$P_r > P_n \quad (\text{OK})$$

#### 11. Cek Tegangan $f_s$

$$a = P_n / (0,85 \cdot \Gamma_c \cdot b_k)$$

$$= 6227165,671 / (0,85 \cdot 30 \cdot 650) = 375,6963 \text{ mm}$$

$$c = a \cdot 0,85$$

$$= 375,6963 \cdot 0,85 = 441,9956 \text{ mm}$$

$$f_s = 600 \cdot ((c-d') \cdot c) = 600 \cdot ((441,9956-40) \cdot 441,9956)$$

$$= 545,7008 \text{ MPa} > f_s \quad (\text{OK})$$

#### 12. Disain Tulangan Sengkang

Jarak yang didapatkan yaitu : 16 kali diameter pokok = 352 mm,

48 kali diameter sengkang = 480 mm,

dimensi terkecil kolom = 650 mm

dipilih jarak yang paling minimum, maka jarak yang terpasang = 350 mm.

Atau dicari dengan memakai rumus sebagai berikut :

$$N_u = -1146,48 \text{ KN (lihat lampiran 8.a)}$$

$$A_g = b \times h = 650 \times 800 = 5,2E+5 \text{ mm}^2$$

$$V_u = 109,43 \text{ KN (lihat lampiran 8.b)}$$

$$V_c = 2 \left( 1 + \frac{N_u}{14 \cdot A_g} \right) \left( \sqrt{f'_c} \frac{1}{6} \right) b \cdot d$$

$$= 2 \left( 1 + \frac{-1146,48E+3}{14 \cdot 5,2E+5} \right) \left( \sqrt{30} \frac{1}{6} \right) 650 \cdot (800 - 40) = 7,5988E+5 \text{ N}$$

$$V_n = \frac{V_u}{\phi} = 109,43E+3 / 0,6 = 182,3833E+3 \text{ N}$$

$$\phi \cdot V_c = 0,6 \cdot 7,5988E+5$$

$$= 4,5593E+5 \text{ N} > V_u = 1,0943E+5 \text{ N}$$

maka tidak dibutuhkan tulangan sengkang untuk itu dipakai tulangan sengkang terpasang 350 mm.

Perancangan kolom elemen 2,3,4,21,22,23 dan 24 dapat dilihat pada lampiran 10.a dan 10.b pada daerah gempa 4. Ternyata dengan dimensi yang sama, perancangan kolom pada daerah gempa 1,2 dan 3 tidak memenuhi persyaratan rasio penulangan ( $\rho$ ) serta tegangan tekan baja ( $f_s$ ), sehingga harus diulangi lagi perancangannya dengan cara "trial and error" dimulai dari pendimensian kolom sampai memenuhi persyaratan yang ditetapkan baik pada daerah gempa 3, 2 maupun 1, seperti terlihat pada lampiran 13.a-13.b, lampiran 16.a-16.b dan lampiran 19.a-19.b.