

**INDRA CAHYA**

# **BETON BERTULANG**



**FAKULTAS TEKNIK  
UNIVERSITAS BRAWIJAYA  
MALANG  
JULI 1999**

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## SEKAPUR SIRIH

Tulisan ini merupakan perbaikan dari *Beton Bertulang* cetakan November 1995, perbaikannya berupa jarak tulangan (pelat) yang diambil genap.

Hal tersebut diambil dengan pertimbangan memudahkan penulisan jarak (angka) dalam satuan milimeter.

Dalam tulisan ini dilengkapi dengan gambar penulangan yang relatif benar dan mudah dicerna.

Tulisan ini hanya menyertakan perhitungan elastis (PBI 1971) dan kekuatan batas berdasarkan SKI SNI 1991. Mudah-mudahan tulisan ini bermanfaat bagi para pembaca, khususnya mahasiswa *teknik sipil* dan para *praktisi*.

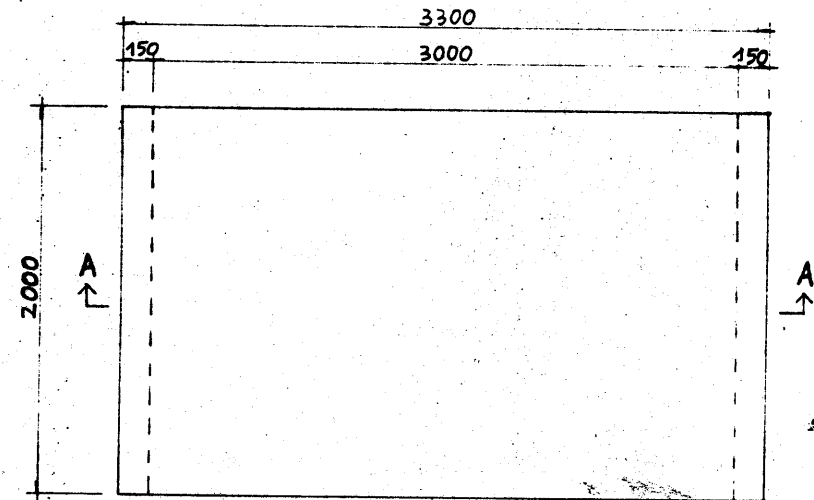
Akhir kata kepada teman-teman yang telah membantu dalam proses penyelesaian tulisan ini saya sampaikan terima kasih.

Malang, Juli 1999

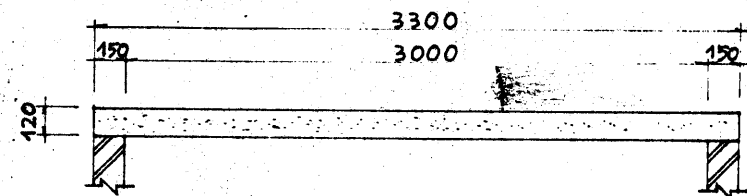
Indra Cahya.

1. Pelat atap mempunyai data sebagai berikut :
- tebal pelat = 12 cm ; tinggi air hujan = 5 cm
  - tebal spesi = 2 cm ; beton K 175
  - tegél dari keramik ; besi tulangan U 22
  - beban guna =  $100 \text{ kg/m}^2$

Pelat atap tersebut menumpu pada dinding batu merah, hitung penulangannya pada pembebanan tetap.



DENAH



POT. A-A

### 1.1. ELASTIS.

$$K 175 \rightarrow \bar{\sigma}_b' = 60 \text{ kg/cm}^2 ; n = 24$$

$$U 22 \rightarrow \bar{\sigma}_a = 1250 \text{ kg/cm}^2$$

$$\varphi_0 = \frac{\bar{\sigma}_a}{n \bar{\sigma}_b'} = \frac{1250}{24 \cdot 60} = 0,868$$

#### 1.1.1. Pembebanan.

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

$$\text{spesi} = 2 \cdot 21 = 42$$

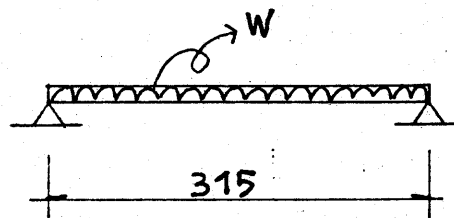
$$\text{keramik} = 1 \cdot 24 = 24$$

$$\text{air hujan} = 0,05 \cdot 1000 = 50$$

$$\text{beban guna} = 100$$

$$W = 505 \text{ kg/m}^2$$

#### 1.1.2. Statika.



$$M_{\text{Lap}} = \frac{1}{8} 505 \cdot 3,15^2 = 626 \text{ kgm (+)}$$

$$M_{\text{Tump}} = \frac{1}{24} 505 \cdot 3,15^2 = 209 \text{ kgm (-)}$$

#### 1.1.3. Penulangan.

##### a. Lapangan.

$$M = 626 \text{ kgm} ; b = 1 \text{ m}$$

$$d = 12 - 3 = 9 \text{ cm}$$

$$C_a = \frac{d}{\sqrt{\frac{n M}{b \bar{\sigma}_a}}} = \frac{9}{\sqrt{\frac{24 \cdot 626}{1 \cdot 1250}}} = 2,596$$

$$\text{tulangan tunggal} : \varphi = 0 \rightarrow \varphi = 1,268 > \varphi_0$$
$$nw = 0,174$$

$$\sigma_b' = \frac{\bar{\sigma}_a}{n \varphi} = \frac{1250}{24 \cdot 1,268} = 41 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$A_s = w b d = \frac{0,174}{24} 100 \cdot 9 = 6,53 \text{ cm}^2$$

$$A_{s \text{ min}} = 0,25 \% b h = 0,25 \% 100 \cdot 12 = 3 \text{ cm}^2$$

$$A_s^0 = 20 \% 6,53 = 1,31 \text{ cm}^2$$

##### b. Tumpuan.

$$M = 209 \text{ kgm} ; b = 1 \text{ m} ; d = 9 \text{ cm}$$

$$C_a = \frac{9}{\sqrt{\frac{24 \cdot 209}{1 \cdot 1250}}} = 4,493$$

$$\text{tulangan tunggal} : \varphi = 0 \rightarrow \varphi = 2,558 > \varphi_0$$

$$nw = 0,055$$

$$\sigma_b' = \frac{1250}{24 \cdot 2,558} = 20 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$A_s = \frac{0,055}{24} 100 \cdot 9 = 2,06 \text{ cm}^2$$

$$A_{s \text{ min}} = 3 \text{ cm}^2$$

$$A_s^0 = 20 \% 3 = 0,60 \text{ cm}^2$$

### 1.2. SK SNI 1991.

$$K 175 \rightarrow f_c' = 175 \text{ kg/cm}^2 = 17,5 \text{ MPa}$$

$$U 22 \rightarrow f_y = 2200 \text{ kg/cm}^2 = 220 \text{ MPa}$$

#### 1.2.1. Pembebanan.

##### a. Beban mati.

$$\text{pelat} = 288 \text{ kg/m}^2$$

$$\text{spesi} = 42$$

$$\text{keramik} = 24$$

$$w_1 = 354 \text{ kg/m}^2$$

##### b. Beban hidup.

$$\text{air hujan} = 50 \text{ kg/m}^2$$

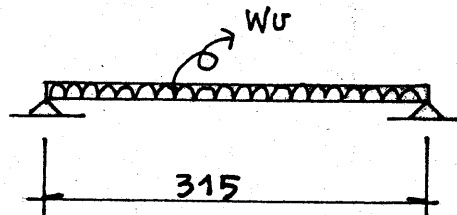
$$\text{beban guna} = 100$$

$$w_2 = 150 \text{ kg/m}^2$$

c. Beban berfaktor.

$$W_u = 1,2 \cdot 354 + 1,6 \cdot 150 = 665 \text{ kg/m}^2$$

1.2.2. Statika.



$$M_u \text{ Lap} = \frac{1}{8} 665 \cdot 3,15^2 = 625 \text{ kgm (+)}$$

$$M_u \text{ Tump} = \frac{1}{24} 665 \cdot 3,15^2 = 275 \text{ kgm (-)}$$

1.2.3. Penulangan.

$$\rho_{\min} = \frac{1,4}{f_y} = \frac{1,4}{220} = 0,006$$

$$\begin{aligned} \rho_{\max} &= 0,75 \frac{\beta f_c'}{f_y} 0,85 \frac{600}{600 + f_y} \\ &= 0,75 \frac{0,85 \cdot 17,5}{220} 0,85 \frac{600}{600 + 220} \\ &= 0,032 \end{aligned}$$

a. Lapangan.

$$\begin{aligned} M_u &= 825 \text{ kgm} = 8,25 \text{ kNm} ; b = 1000 \text{ mm} \\ d &= 90 \text{ mm} ; \phi = 0,8 \end{aligned}$$

$$R_n = \frac{M_u}{\phi b d^2} = \frac{8,25 \cdot 10^6}{0,8 \cdot 1000 \cdot 90^2} = 1,2731 \text{ MPa}$$

$$\begin{aligned} W &= 0,85 \left( 1 - \sqrt{1 - \frac{2,353 R_n}{f_c'}} \right) \\ &= 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 1,2731}{17,5}} \right) = 0,0762 \end{aligned}$$

$$\begin{aligned} \rho &= W \frac{f_c'}{f_y} = 0,0762 \frac{17,5}{220} = 0,0061 > 0,006 \\ &< 0,032 \end{aligned}$$

$$A_s = \rho b d = 0,0061 \cdot 1000 \cdot 90 = 5,49 \text{ cm}^2$$

$$A_s^o = 0,002 \cdot 100 \cdot 12 = 2,40 \text{ cm}^2$$

b. Tumpuan.

$$\begin{aligned} M_u &= 275 \text{ kgm} = 2,75 \text{ kNm} ; b = 1000 \text{ mm} \\ d &= 90 \text{ mm} ; \phi = 0,8 \end{aligned}$$

$$R_n = \frac{2,75 \cdot 10^6}{0,8 \cdot 1000 \cdot 90^2} = 0,4244 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 0,4244}{17,5}} \right) = 0,0246$$

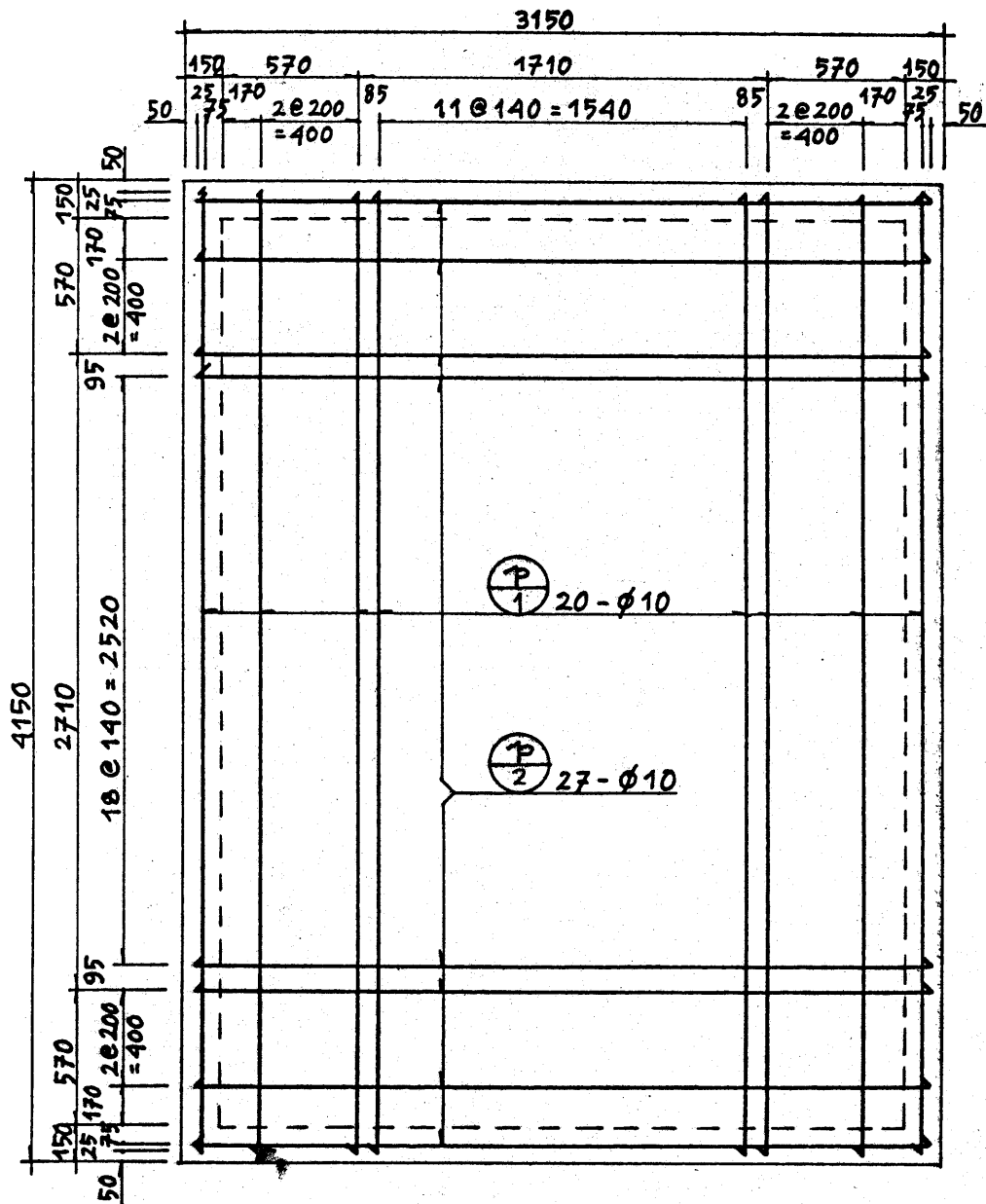
$$\begin{aligned} \rho &= 0,0246 \frac{17,5}{220} = 0,0019 < 0,006 \\ &< 0,032 \end{aligned}$$

$$A_s = 0,006 \cdot 100 \cdot 9 = 5,40 \text{ cm}^2$$

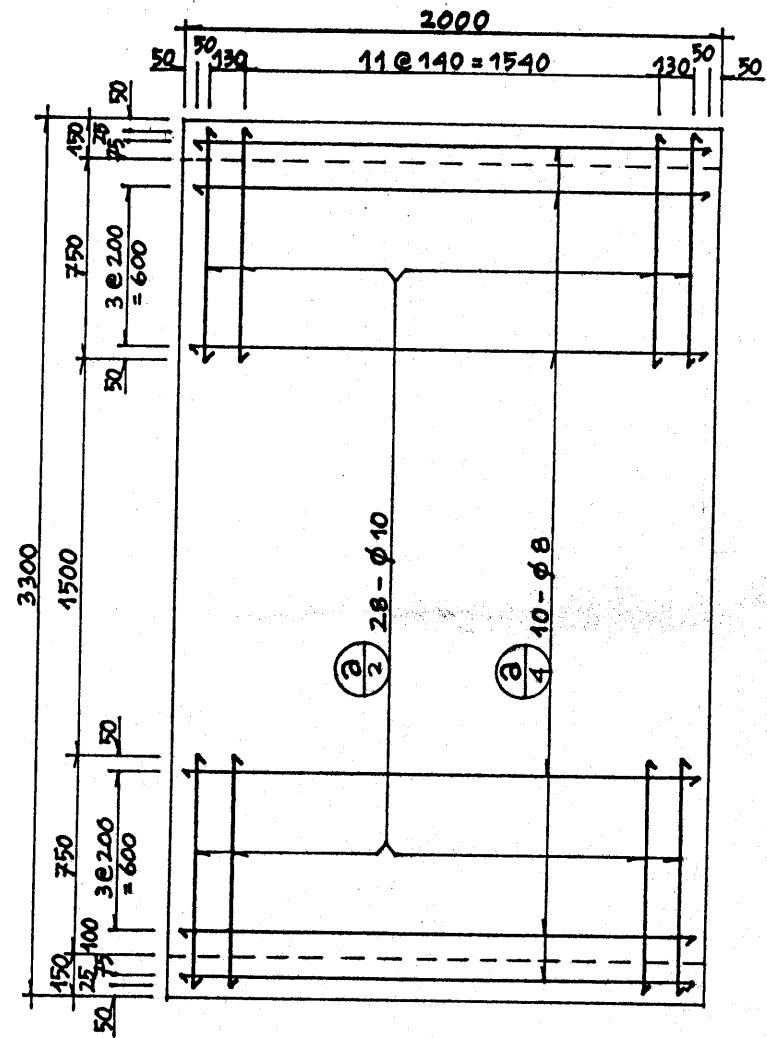
$$A_s^o = 0,002 \cdot 100 \cdot 12 = 2,4 \text{ cm}^2$$

Rekapitulasi :

	Elastis	SK SNI '91
	mm <sup>2</sup>	mm <sup>2</sup>
Lapangan :		
tulang bawah	653	549 → ϕ 10 - 140
tulang bagi	131	240 → ϕ 8 - 200
Tumpuan :		
tulang atas	206	540 → ϕ 10 - 140
tulang bagi	41	240 → ϕ 8 - 200



TULANG BAWAH

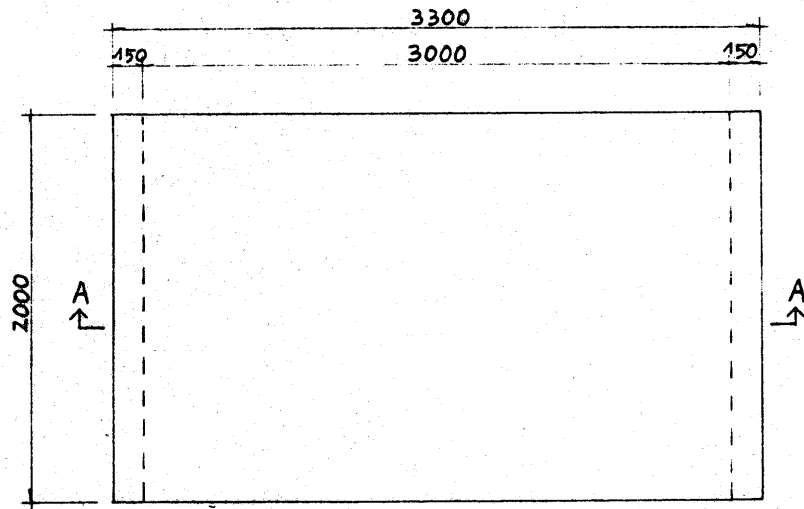


TULANG ATAS

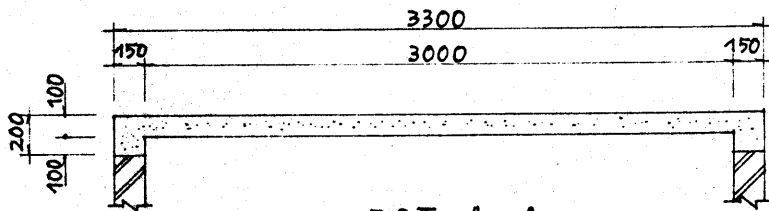




2. Soal No-1 pelat menumpu pada balok dan tebal pelat = 10 cm, data lainnya sama dengan soal No-1.



DENAH



POT. A-A

## 2.1. ELASTIS.

$$K 175 \rightarrow \bar{\sigma}_b' = 80 \text{ kg/cm}^2 ; n = 24$$

$$U 22 \rightarrow \bar{\sigma}_a = 1250 \text{ kg/cm}^2 ; \phi_0 = 0,868$$

### 2.1.1. Pembebanan.

$$\text{pelat} = 0,10 \cdot 2400 = 240 \text{ kg/m}^2$$

$$\text{spesi} = 2 \cdot 21 = 42$$

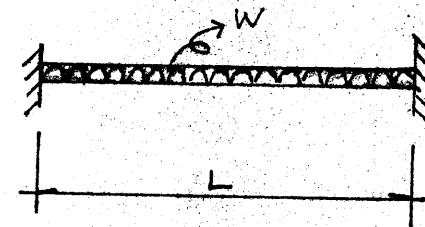
$$\text{keramik} = 1 \cdot 24 = 24$$

$$\text{air hujan} = 0,05 \cdot 1000 = 50$$

$$\text{beban guna} = 100$$

$$w = 460 \text{ kg/m}^2$$

### 2.1.2. Statika.



$$M_{\text{Lap}} = \frac{1}{11} 460 \cdot 3,15^2 = 415 \text{ kgm (+)}$$

$$M_{\text{Tump}} = \frac{1}{18} 460 \cdot 3,15^2 = 254 \text{ kgm (-)}$$

### 2.1.3. Penulangan.

#### a. Lapangan.

$$M = 415 \text{ kgm} ; b = 1 \text{ m}$$

$$d = 10 - 3 = 7 \text{ cm}$$

$$C_a = \frac{d}{\sqrt{\frac{n M}{b \bar{\sigma}_a}}} = \frac{7}{\sqrt{\frac{24 \cdot 415}{1 \cdot 1250}}} = 2,480$$

$$\text{tulangan tunggal} : \phi = 0 \rightarrow \phi = 1,188 > \phi_r$$

$$n_w = 0,192$$



$$\sigma_b' = \frac{\bar{\sigma}_a}{n \phi} = \frac{1250}{24 \cdot 1,188} = 44 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$A_s = w b d = \frac{0,192}{24} 100 \cdot 7 = 5,80 \text{ cm}^2$$

$$A_{s \text{ min}} = 0,25 \% 100 \cdot 10 = 2,50 \text{ cm}^2$$

$$A_s^\circ = 20 \% 5,80 = 1,12 \text{ cm}^2$$

#### b. Tumpuan.

$$M = 254 \text{ kgm} ; b = 1 \text{ m} ; d = 7 \text{ cm}$$

$$C_a = \frac{7}{\sqrt{\frac{24 \cdot 254}{1 \cdot 1250}}} = 3,170$$

$$\text{tulangan tunggal} : \delta = 0 \rightarrow \phi = 1,652 > \phi_0$$

$$n_w = 0,114$$

$$\sigma_b' = \frac{1250}{24 \cdot 1,652} = 32 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$A_s = \frac{0,114}{24} 100 \cdot 7 = 3,33 \text{ cm}^2$$

$$A_{s \text{ min}} = 2,50 \text{ cm}^2$$

$$A_s^\circ = 20 \% 3,33 = 0,67 \text{ cm}^2$$

### 2.2. SK SNI 1991.

$$K 175 \rightarrow f_c' = 175 \text{ kg/cm}^2 = 17,5 \text{ MPa}$$

$$U 22 \rightarrow f_y = 2200 \text{ kg/cm}^2 = 220 \text{ MPa}$$

#### 2.2.1. Pembebanan.

##### a. Beban mati.

$$\text{pelat} = 0,10 \cdot 2400 = 240 \text{ kg/m}^2$$

$$\text{spesi} = 2 \cdot 21 = 42$$

$$\text{keramik} = 1 \cdot 24 = 24$$

$$w_1 = 306 \text{ kg/m}^2$$

##### b. Beban hidup.

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

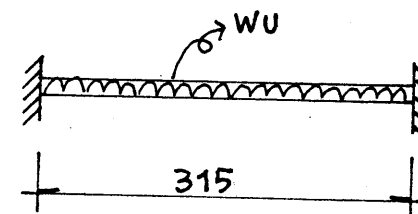
$$\text{beban guna} = 100$$

$$w_2 = 150 \text{ kg/m}^2$$

#### c. Beban berfaktor.

$$W_u = 1,2 \cdot 306 + 1,6 \cdot 150 = 607 \text{ kg/m}^2$$

#### 2.2.2. Statika.



$$M_u \text{ Lap} = \frac{1}{11} 607 \cdot 3,15^2 = 548 \text{ kgm (+)}$$

$$M_u \text{ Tump} = \frac{1}{18} 607 \cdot 3,15^2 = 335 \text{ kgm (-)}$$

#### 2.2.3. Penulangan.

$$\rho_{\text{min}} = \frac{1,4}{f_y} = \frac{1,4}{220} = 0,006$$

$$\rho_{\text{maks}} = 0,75 \frac{\beta f_c'}{f_y} \beta \frac{600}{600 + f_y}$$

$$= 0,75 \frac{0,85 \cdot 17,5}{220} 0,85 \frac{600}{600 + 220}$$

$$= 0,032$$

##### a. Lapangan.

$$M_u = 548 \text{ kgm} = 5,48 \text{ kNm} ; b = 1000 \text{ mm}$$

$$d = 100 - 30 = 70 \text{ mm} ; \phi = 0,8$$

$$R_n = \frac{M_u}{\phi b d^2} = \frac{5,48 \cdot 10^6}{0,8 \cdot 1000 \cdot 70^2} = 1,3979 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 R_n}{f_c'}} \right)$$

$$= 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 1,3979}{17,5}} \right) = 0,084$$

$$\rho = W \frac{f_c'}{f_y} = 0,084 \frac{17,5}{220} = 0,0067 > 0,006$$

$$< 0,032$$

$$A_s = \rho b d = 0,0067 \cdot 100 \cdot 7 = 4,69 \text{ cm}^2$$

$$A_s^o = 0,002 \cdot 1000 \cdot 100 = 200 \text{ cm}^2$$

b. Tumpuan.

$$M_u = 335 \text{ kgm} = 3,35 \text{ kNm} ; b = 1000 \text{ mm}$$

$$d = 70 \text{ mm} ; \rho = 0,8$$

$$R_n = \frac{3,35 \cdot 10^6}{0,8 \cdot 1000 \cdot 70^2} = 0,8546 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 0,8546}{17,5}} \right) = 0,0503$$

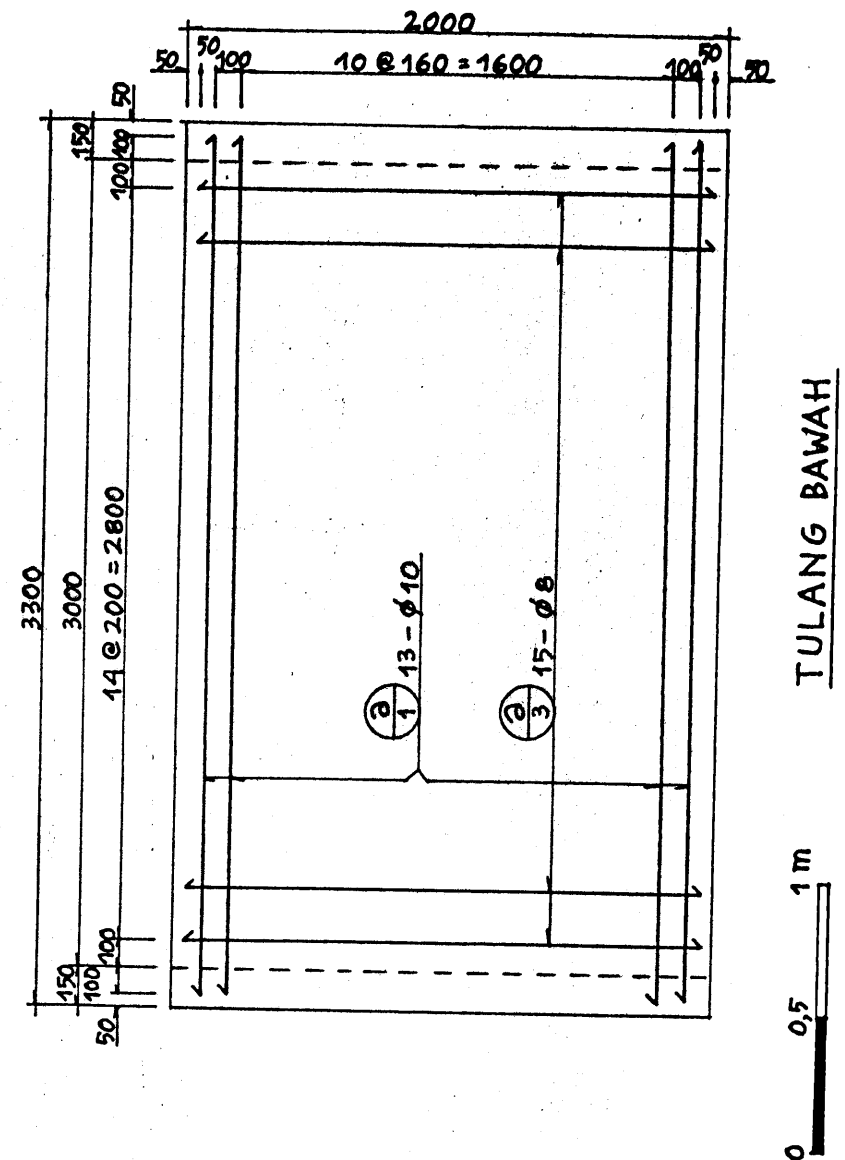
$$\rho = 0,0503 \frac{17,5}{220} = 0,004 < 0,006$$

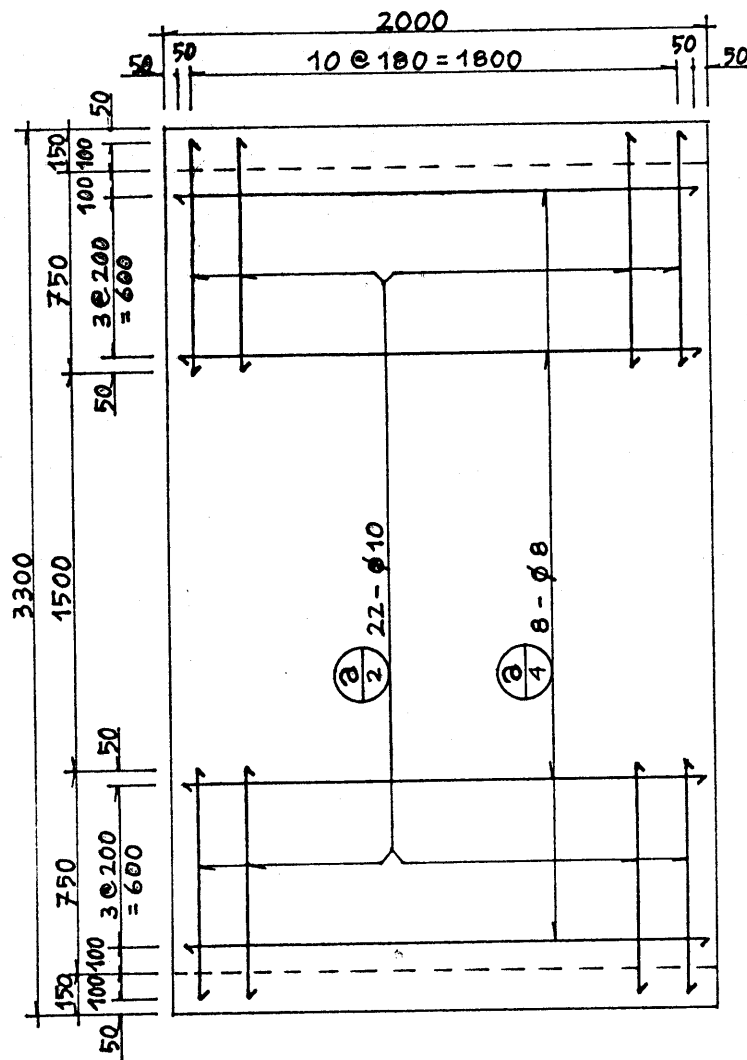
$$A_s = 0,006 \cdot 1000 \cdot 7 = 420 \text{ mm}^2$$

$$A_s^o = 0,002 \cdot 1000 \cdot 100 = 200 \text{ mm}^2$$

Rekapitulasi :

	Elastis	SK SNI '91
	mm <sup>2</sup>	mm <sup>2</sup>
Lapangan :		
tulang bawah	560	469 → $\phi 10 - 160$
tulang bagi	112	200 → $\phi 8 - 200$
Tumpuan :		
tulang atas	333	420 → $\phi 10 - 180$
tulang bagi	67	200 → $\phi 8 - 200$

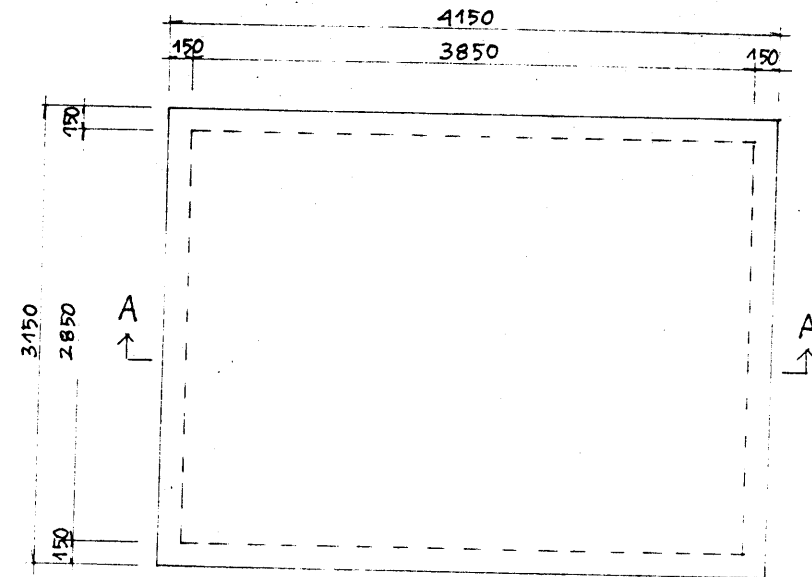




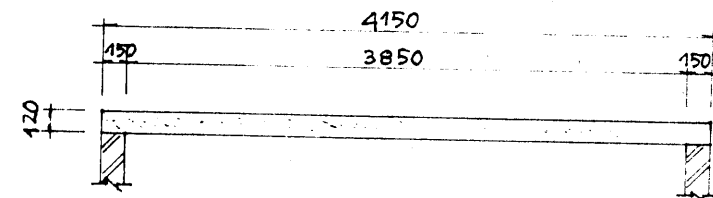
TULANG ATAS



3. Pelat lantai menumpu langsung pada dinding 1/2 batu, mempunyai data sebagai berikut :
- tebal pelat = 12 cm ; beban guna =  $250 \text{ kg/m}^2$
  - tebal spesi = 2 cm ; beton K 175
  - tegél teraso tebal = 2,5 cm
  - besi tulangan U 22
- Hitung penulangan pelat lantai tersebut.



DENAH



POT. A-A

### 3.1. ELASTIS.

$$K 175 \rightarrow \bar{\sigma}_b' = 60 \text{ kg/cm}^2 ; n = 24$$

$$U 22 \rightarrow \bar{\sigma}_a = 1250 \text{ kg/cm}^2$$

$$\varphi_0 = \frac{1250}{24 \cdot 60} = 0,868$$

#### 3.1.1. Pembebanan.

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

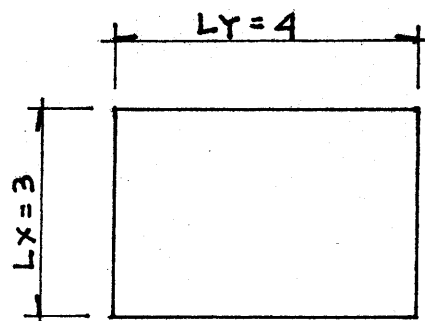
$$\text{spesi} = 2 \cdot 21 = 42$$

$$\text{tegél} = 2,5 \cdot 24 = 60$$

$$\text{beban guna} = 250$$

$$w = 640 \text{ kg/m}^2$$

#### 3.1.2. Statika.



$$Ly/Lx = 4/3 = 1,3$$

$$MLx = 0,001 w Lx^2 k$$

$$= 0,001 \cdot 840 \cdot 3^2 \cdot 66 = 380 \text{ kgm}$$

$$MLy = 0,001 w Ly^2 k$$

$$= 0,001 \cdot 840 \cdot 4^2 \cdot 44 = 253 \text{ kgm}$$

#### 3.1.3. Penulangan.

##### a. Lapangan x.

$$M = 380 \text{ kgm} ; b = 1 \text{ m}$$

$$d = 12 - 3 = 9 \text{ cm}$$

$$Ca = \frac{9}{\sqrt{\frac{24 \cdot 380}{1 \cdot 1250}}} = 3,332$$

$$\text{tulangan tunggal} : \delta = 0 \rightarrow \varphi = 1,770 > \varphi_0$$

$$nw = 0,102$$

$$\sigma_b' = \frac{1250}{24 \cdot 1,77} = 29 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$As = \frac{0,102}{24} 100 \cdot 9 = 3,83 \text{ cm}^2$$

$$As \text{ min} = 0,25 \% 100 \cdot 12 = 3 \text{ cm}^2$$

##### b. Lapangan y.

$$M = 253 \text{ kgm} ; b = 1 \text{ m} ; d = 9 \text{ cm}$$

$$Ca = \frac{9}{\sqrt{\frac{24 \cdot 253}{1 \cdot 1250}}} = 4,083$$

$$\text{tulangan tunggal} : \delta = 0 \rightarrow \varphi = 2,279 > \varphi_0$$

$$nw = 0,067$$

$$\sigma_b' = \frac{1250}{24 \cdot 2,279} = 2 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$As = \frac{0,067}{24} 100 \cdot 9 = 2,51 \text{ cm}^2$$

### 3.2. SK SNI 1991.

$$K 175 \rightarrow f_c' = 175 \text{ kg/cm}^2 = 17,5 \text{ MPa}$$

$$U 22 \rightarrow f_y = 2200 \text{ kg/cm}^2 = 220 \text{ MPa}$$

#### 3.2.1. Pembebanan.

##### a. Beban mati.

$$\text{pelat} = 288 \text{ kg/m}^2$$

$$\text{spesi} = 42$$

$$\text{tegél} = 60$$

$$w_1 = 390 \text{ kg/m}^2$$

##### b. Beban hidup.

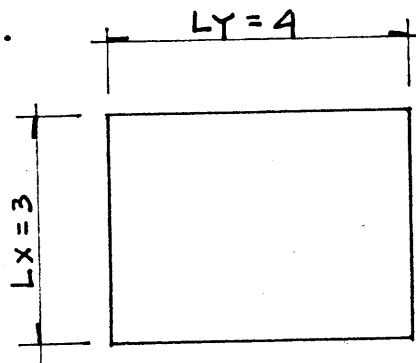
$$\text{beban guna} :$$

$$w_2 = 250 \text{ kg/m}^2$$

##### c. Beban berfaktor.

$$W_u = 1,2 \cdot 390 + 1,6 \cdot 250 = 870 \text{ kg/m}^2$$

## 3.2.2. Statika.



$$Ly/Lx = 4/3 = 1,3$$

$$\begin{aligned} MuLx &= 0,001 Wu Lx^2 k \\ &= 0,001 \cdot 870 \cdot 3^2 \cdot 66 = 517 \text{ kgm} \end{aligned}$$

$$\begin{aligned} MuLy &= 0,001 Wu Lx^2 k \\ &= 0,001 \cdot 870 \cdot 3^2 \cdot 44 = 345 \text{ kgm} \end{aligned}$$

## 3.2.3. Penulangan.

$$\rho_{\min} = \frac{1,4}{220} = 0,006$$

$$\begin{aligned} \rho_{\max} &= 0,75 \frac{0,85 \cdot 17,5}{220} \leq 0,85 \frac{600}{600 + 220} \\ &= 0,032 \end{aligned}$$

## a. Lapangan x.

$$\begin{aligned} Mu &= 517 \text{ kgm} = 5,17 \text{ kNm} ; b = 1000 \text{ mm} \\ d &= 120 - 30 = 90 \text{ mm} ; \phi = 0,8 \end{aligned}$$

$$Rn = \frac{5,17 \cdot 10^6}{0,8 \cdot 1000 \cdot 90^2} = 0,7978 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 0,7978}{17,5}} \right) = 0,0469$$

$$\rho = 0,0469 \frac{17,5}{220} = 0,0037 < 0,006$$

$$As = 0,006 \cdot 1000 \cdot 90 = 540 \text{ mm}^2$$

## b. Lapangan y.

$$\begin{aligned} Mu &= 345 \text{ kgm} = 3,45 \text{ kNm} ; b = 1000 \text{ mm} \\ d &= 90 \text{ mm} ; \phi = 0,8 \end{aligned}$$

$$Rn = \frac{3,45 \cdot 10^6}{0,8 \cdot 1000 \cdot 90^2} = 0,5342 \text{ MPa}$$

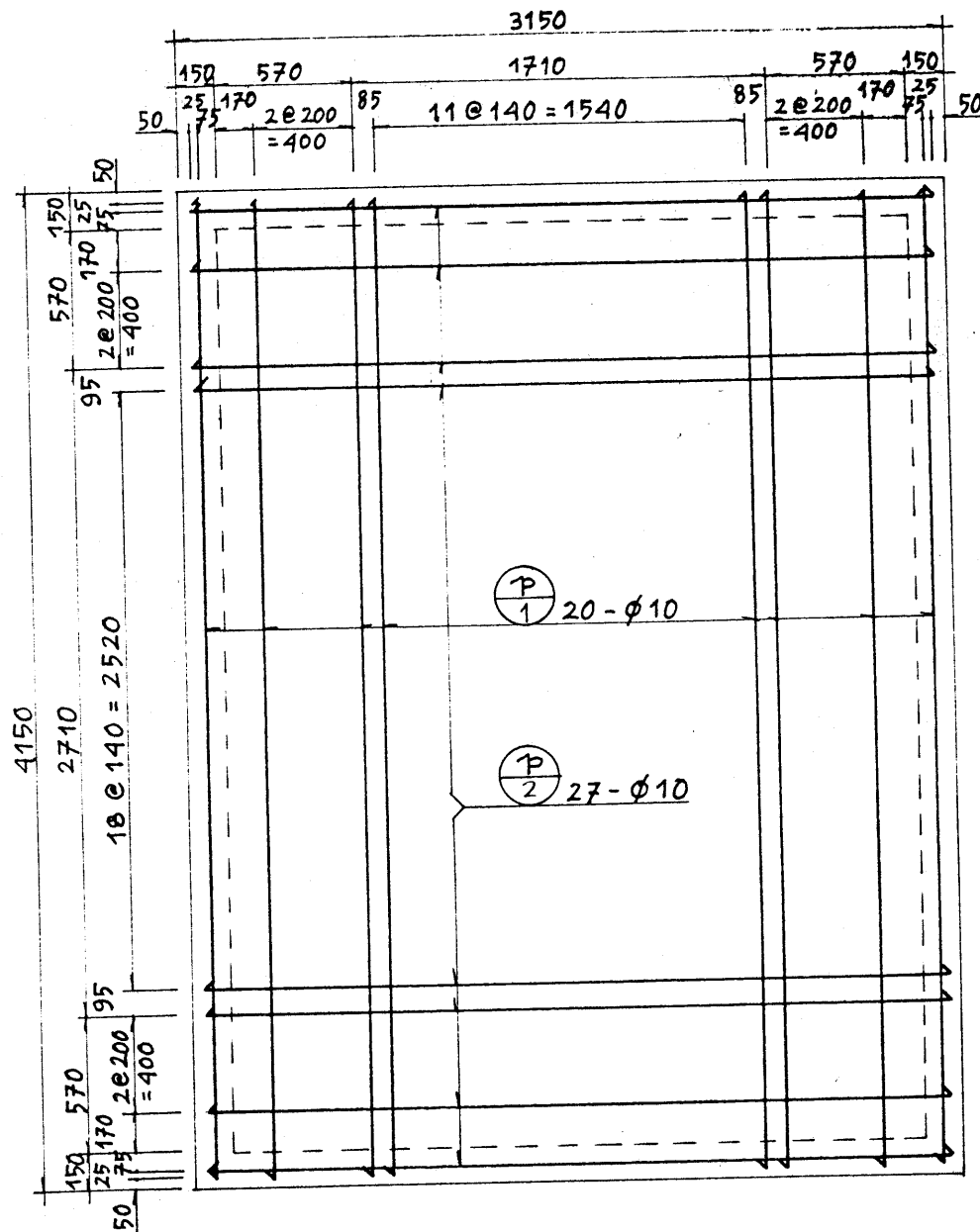
$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 0,5342}{17,5}} \right) = 0,0310$$

$$\rho = 0,0310 \frac{17,5}{220} = 0,0025 < 0,006 < 0,032$$

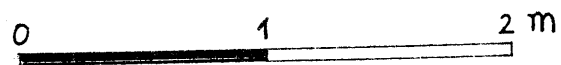
$$As = 0,006 \cdot 1000 \cdot 90 = 5,40 \text{ cm}^2$$

Rekapitulasi :

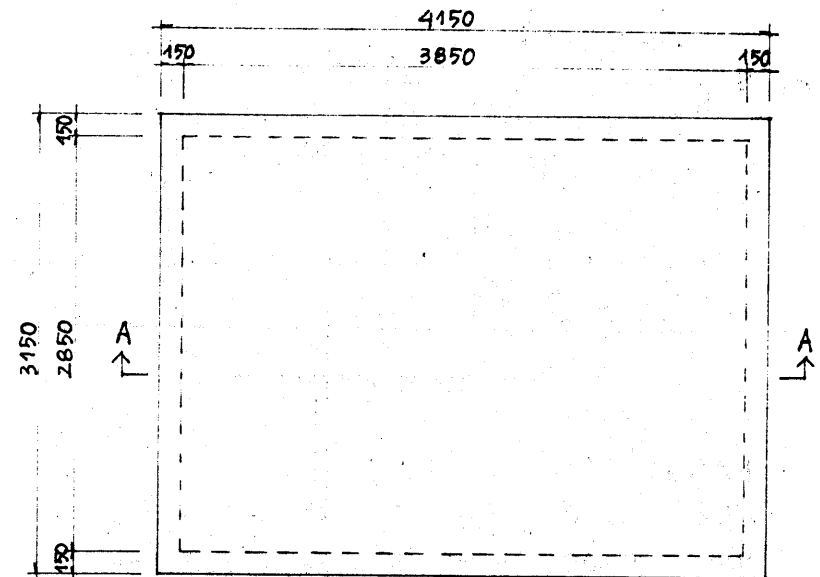
	Elastis	SK SNI '91
	mm <sup>2</sup>	mm <sup>2</sup>
Lapangan :		
tulang bawah	383	540 → $\phi$ 10 - 140
Tumpuan :		
tulang atas	251	540 → $\phi$ 10 - 140



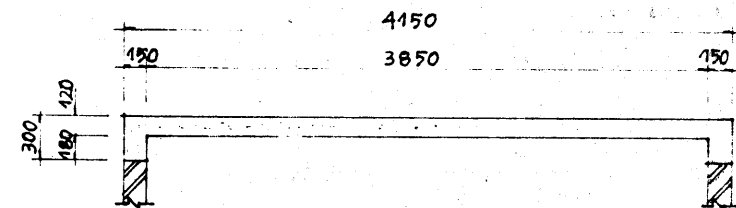
TULANG BAWAH



4. Soal No-3 pelat tersebut menumpu pada balok, data lainnya sama seperti No-3.



DENAH



POT. A-A

#### 4.1. ELASTIS.

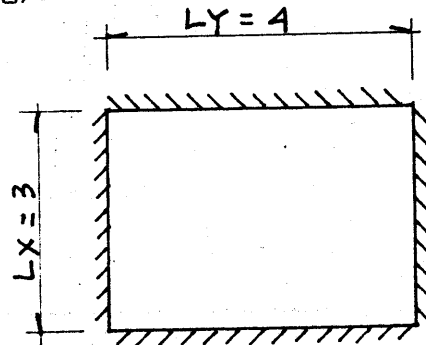
$$K 175 \rightarrow \bar{\sigma}_b' = 60 \text{ kg/cm}^2 ; n = 24$$

$$U 22 \rightarrow \bar{\sigma}_a = 1250 \text{ kg/cm}^2 ; \varphi_0 = 0,868$$

##### 4.1.1. Pembebanan.

$$W = 640 \text{ kg/m}^2$$

##### 4.1.2. Statika.



$$L_y/L_x = 4/3 = 1,3$$

$$M_{Lx} = 0,001 \cdot 640 \cdot 3^2 \cdot 31 = 179 \text{ kgm (+)}$$

$$M_{Tx} = 0,001 \cdot 640 \cdot 3^2 \cdot 69 = 397 \text{ kgm (-)}$$

$$M_{Ly} = 0,001 \cdot 640 \cdot 3^2 \cdot 19 = 109 \text{ kgm (+)}$$

$$M_{Ty} = 0,001 \cdot 640 \cdot 3^2 \cdot 57 = 328 \text{ kgm (-)}$$

##### 4.1.3. Penulangan.

###### a. Lapangan x.

$$M = 179 \text{ kgm} ; b = 1 \text{ m}$$

$$d = 12 - 3 = 9 \text{ cm}$$

$$C_a = \frac{9}{\sqrt{\frac{24 \cdot 179}{1 \cdot 1250}}} = 4,855$$

$$\text{tulangan tunggal} : \delta = 0 \rightarrow \varphi = 2,817 > \varphi_0$$

$$nw = 0,047$$

$$\sigma_b' = \frac{1250}{24 \cdot 2,817} = 18 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$A_s = \frac{0,047}{24} 100 \cdot 9 = 1,76 \text{ cm}^2$$

$$A_{s \text{ min}} = 0,25 \% 100 \cdot 12 = 3 \text{ cm}^2$$

###### b. Tumpuan x.

$$M = 397 \text{ kgm} ; b = 1 \text{ m} ; d = 9 \text{ cm}$$

$$C_a = \frac{9}{\sqrt{\frac{24 \cdot 397}{1 \cdot 1250}}} = 3,260$$

$$\text{tulangan tunggal} : \delta = 0 \rightarrow \varphi = 1,717 > \varphi_0$$

$$nw = 0,107$$

$$\sigma_b' = \frac{1250}{24 \cdot 1,717} = 30 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$A_s = \frac{0,107}{24} 100 \cdot 9 = 4,01 \text{ cm}^2$$

$$A_{s \text{ min}} = 3 \text{ cm}^2$$

$$A_s^o = 20 \% 4,01 = 0,80 \text{ cm}^2$$

###### c. Lapangan y.

$$M = 109 \text{ kgm} ; b = 1 \text{ m} ; d = 9 \text{ cm}$$

$$C_a = \frac{9}{\sqrt{\frac{24 \cdot 109}{1 \cdot 1250}}} = 6,221$$

$$\text{tulangan tunggal} : \delta = 0 \rightarrow \varphi = 3,762 > \varphi_0$$

$$nw = 0,028$$

$$\sigma_b' = \frac{1250}{24 \cdot 3,762} = 14 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$A_s = \frac{0,028}{24} 100 \cdot 9 = 1,05 \text{ cm}^2$$

$$A_{s \text{ min}} = 3 \text{ cm}^2$$

###### d. Tumpuan y.

$$M = 328 \text{ kgm} ; b = 1 \text{ m} ; d = 9 \text{ cm}$$

$$C_a = \frac{9}{\sqrt{\frac{24 \cdot 328}{1 \cdot 1250}}} = 3,586$$

$$\text{tulangan tunggal} : \delta = 0 \rightarrow \varphi = 1,941 > \varphi_0$$

$$nw = 0,088$$



$$\sigma_b' = \frac{1250}{24 \cdot 1,941} = 27 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$A_s = \frac{0,088}{24} 100 \cdot 9 = 3,30 \text{ cm}^2$$

$$A_{s \min} = 3 \text{ cm}^2$$

$$A_s^o = 20 \% 3,30 = 0,66 \text{ cm}^2$$

#### 4.2. SK SNI 1991.

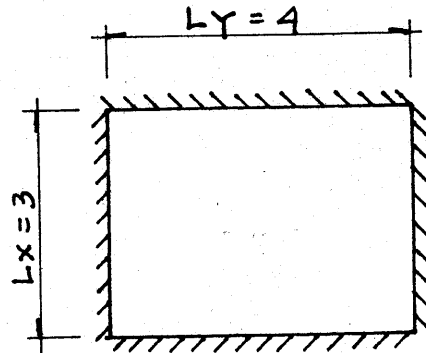
$$K 175 \rightarrow f_c' = 175 \text{ kg/cm}^2 = 17,5 \text{ MPa}$$

$$U 22 \rightarrow f_y = 1250 \text{ kg/cm}^2 = 220 \text{ MPa}$$

#### 4.2.1. Pembebanan.

$$W_u = 870 \text{ kg/m}^2$$

#### 4.2.2. Statika.



$$L_y/L_x = 4/3 = 1,3$$

$$M_{uLx} = 0,001 \cdot 870 \cdot 3^2 \cdot 31 = 243 \text{ kgm (+)}$$

$$M_{uTx} = 0,001 \cdot 870 \cdot 3^2 \cdot 69 = 540 \text{ kgm (-)}$$

$$M_{uLy} = 0,001 \cdot 870 \cdot 3^2 \cdot 19 = 149 \text{ kgm (+)}$$

$$M_{uTy} = 0,001 \cdot 870 \cdot 3^2 \cdot 57 = 446 \text{ kgm (-)}$$

#### 4.2.3. Penulangan.

$$\rho_{\min} = 0,006 \quad ; \quad \rho_{\max} = 0,032$$

##### a. Lapangan x.

$$M_u = 243 \text{ kgm} = 2,43 \text{ kNm} \quad ; \quad b = 1000 \text{ mm}$$

$$d = 90 \text{ mm} \quad ; \quad \phi = 0,8$$

$$R_n = \frac{2,43 \cdot 10^6}{0,8 \cdot 1000 \cdot 90^2} = 0,375 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 0,375}{17,5}} \right) = 0,0217$$

$$\rho = 0,0217 \frac{17,5}{220} = 0,0017 < 0,006$$

$$A_s = 0,006 \cdot 1000 \cdot 90 = 540 \text{ mm}^2$$

##### b. Tumpuan x.

$$M_u = 540 \text{ kgm} = 5,40 \text{ kNm} \quad ; \quad b = 1000 \text{ mm}$$

$$d = 90 \text{ mm} \quad ; \quad \phi = 0,8$$

$$R_n = \frac{5,40 \cdot 10^6}{0,8 \cdot 1000 \cdot 90^2} = 0,833 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 0,833}{17,5}} \right) = 0,049$$

$$\rho = 0,0490 \frac{17,5}{220} = 0,0039 < 0,006$$

$$A_s = 0,006 \cdot 1000 \cdot 90 = 540 \text{ mm}^2$$

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

##### c. Lapangan y.

$$M_u = 149 \text{ kgm} = 1,49 \text{ kNm} \quad ; \quad b = 1000 \text{ mm}$$

$$d = 90 \text{ mm} \quad ; \quad \phi = 0,8$$

$$R_n = \frac{1,49 \cdot 10^6}{0,8 \cdot 1000 \cdot 90^2} = 0,2299 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 0,2299}{17,5}} \right) = 0,0132$$

$$\rho = 0,0132 \frac{17,5}{220} = 0,0012 < 0,006$$

$$A_s = 0,006 \cdot 1000 \cdot 90 = 540 \text{ mm}^2$$

d. Tumpuan y.

$$Mu = 446 \text{ kgm} = 4,46 \text{ kNm} ; b = 1000 \text{ mm}$$

$$d = 90 \text{ mm} ; \rho = 0,8$$

$$Rn = \frac{4,46 \cdot 10^6}{0,8 \cdot 1000 \cdot 90^2} = 0,6883 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 0,6883}{17,5}} \right) = 0,0403$$

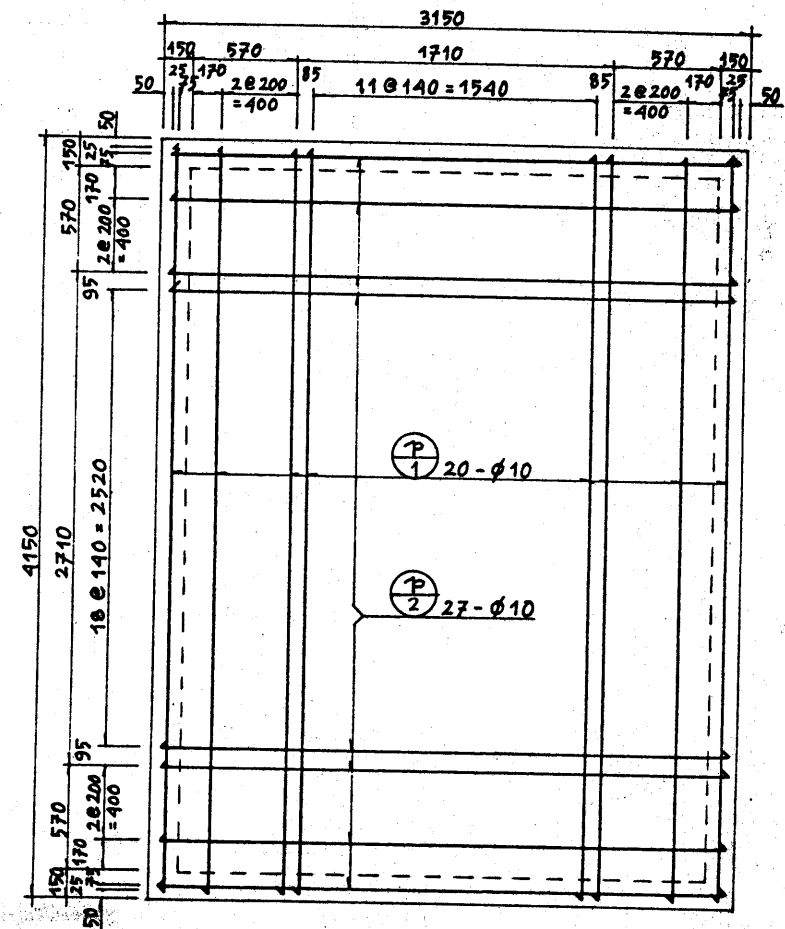
$$\rho = 0,0403 \frac{17,5}{220} = 0,0032 < 0,006$$

$$As = 0,006 \cdot 1000 \cdot 90 = 540 \text{ mm}^2$$

$$As^o = 0,002 \cdot 1000 \cdot 120 = 240 \text{ mm}^2$$

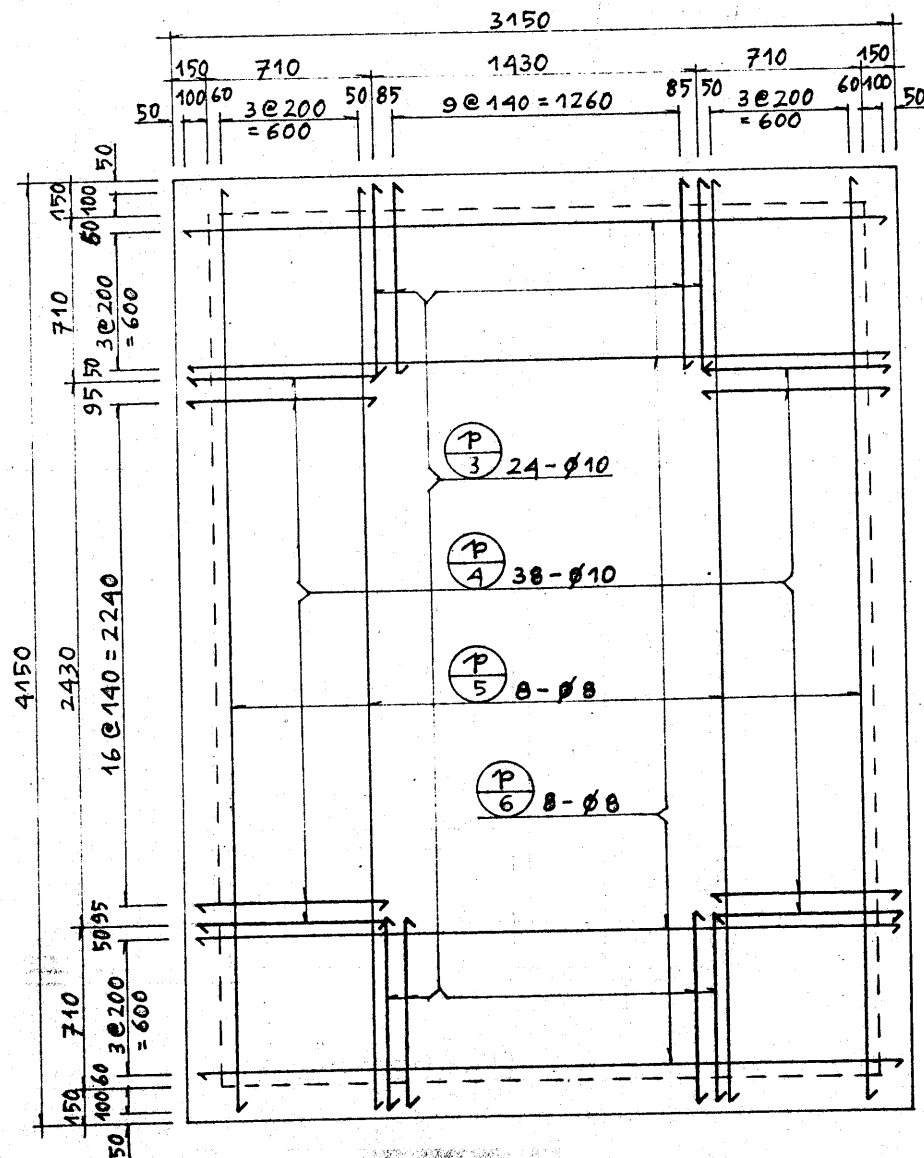
Rekapitulasi :

	Elastis	SK SNI '91
	mm <sup>2</sup>	mm <sup>2</sup>
Lapangan x :		
tulang bawah	176	540 → $\phi$ 10 - 140
Tumpuan x :		
tulang atas	401	540 → $\phi$ 10 - 140
tulang bagi	80	240 → $\phi$ 8 - 200
Lapangan y :		
tulang bawah	105	540 → $\phi$ 10 - 140
Tumpuan y :		
tulang atas	330	540 → $\phi$ 10 - 140
tulang bagi	66	240 → $\phi$ 8 - 200

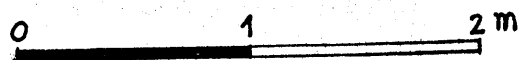


TULANG BAWAH

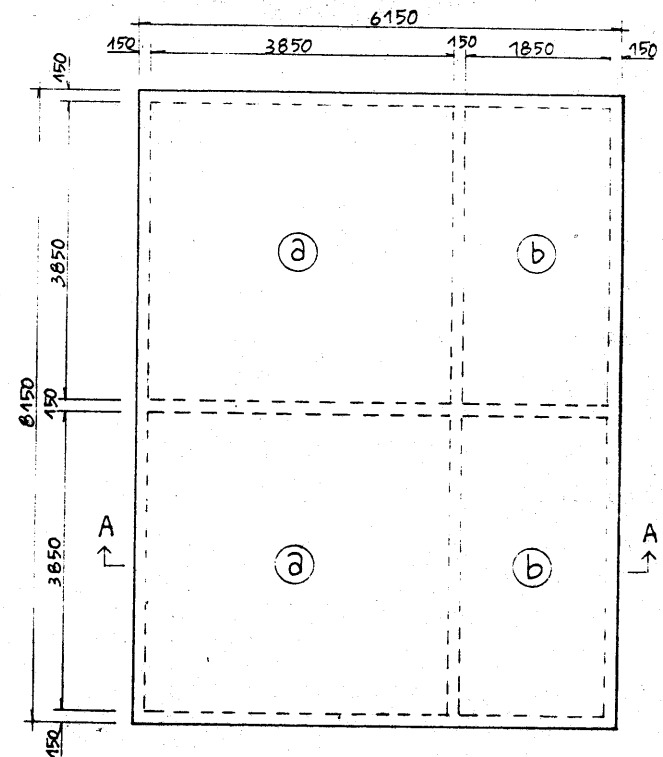
0 1 2 m



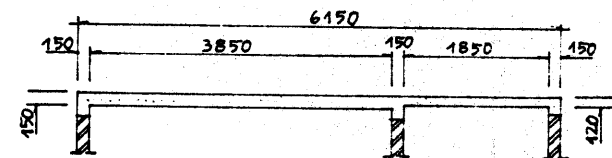
TULANG ATAS



5. Pelat lantai menumpu pada balok seperti gambar terlampir, hitung penulangannya pada pembebanan tetap, bila ditentukan :
- tebal pelat a = 15 cm ; beban guna =  $300 \text{ kg/m}^2$   
 tebal pelat b = 12 cm ; beton K 225  
 tebal spesi = 2 cm ; besi tulangan U 24  
 tegel dari keramik



DENAH



POT. A - A

### 5.1. ELASTIS.

$$K 225 \rightarrow \bar{\sigma}_b' = 75 \text{ kg/cm}^2 ; n = 21$$

$$U 24 \rightarrow \bar{\sigma}_a = 1400 \text{ kg/cm}^2$$

$$\phi_0 = \frac{1400}{21 \cdot 75} = 0,889$$

#### 5.1.1. Pembebanan.

##### a. Pelat a.

$$\text{pelat} = 0,15 \cdot 2400 = 360 \text{ kg/m}^2$$

$$\text{spesi} = 2 \cdot 21 = 42$$

$$\text{keramik} = 1 \cdot 24 = 24$$

$$\text{beban guna} = 300$$

$$W_1 = 730 \text{ kg/m}^2$$

##### b. Pelat b.

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

$$\text{spesi} = 2 \cdot 21 = 42$$

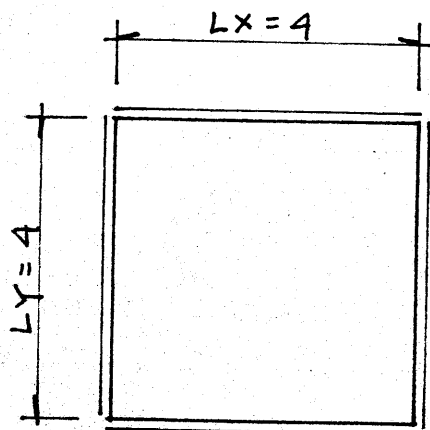
$$\text{keramik} = 1 \cdot 24 = 24$$

$$\text{beban guna} = 300$$

$$W_2 = 655 \text{ kg/m}^2$$

#### 5.1.2. Statika.

##### a. Pelat a.



$$Ly/Lx = 4/4 = 1$$

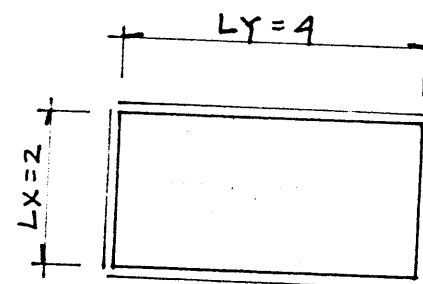
$$MLx = 0,001 \cdot 730 \cdot 4^2 \cdot 36 = 420 \text{ kgm (+)}$$

$$MTx = 420 \text{ kgm (-)}$$

$$MLy = 0,001 \cdot 730 \cdot 4^2 \cdot 36 = 420 \text{ kgm (+)}$$

$$MTy = 420 \text{ kgm (-)}$$

##### b. Pelat b.



$$Ly/Lx = 4/2 = 2$$

$$MLx = 0,001 \cdot 655 \cdot 2^2 \cdot 62 = 162 \text{ kgm (+)}$$

$$MTx = 162 \text{ kgm (-)}$$

$$MLy = 0,001 \cdot 655 \cdot 2^2 \cdot 35 = 92 \text{ kgm (+)}$$

$$MTy = 92 \text{ kgm (-)}$$

#### 5.1.3. Penulangan.

##### a. Pelat a.

##### a.1. Lapangan x.

$$M = 420 \text{ kgm} ; b = 1 \text{ m}$$

$$d = 15 - 3 = 12 \text{ cm}$$

$$Ca = \frac{12}{\sqrt{\frac{21 \cdot 420}{1 \cdot 1400}}} = 4,781$$

$$\text{tulangan tunggal} : \delta = 0 \rightarrow \phi = 2,759 > \phi_0$$

$$nw = 0,048$$

$$\sigma_b' = \frac{1400}{21 \cdot 2,759} = 24 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$As = \frac{0,048}{21} 100. 12 = 2,74 \text{ cm}^2$$

$$As_{\min} = 0,25 \% 100. 15 = 3,75 \text{ cm}^2$$

#### a.2. Tumpuan x.

sama dengan lapangan x →

$$As = 2,74 \text{ cm}^2$$

$$As_{\min} = 3,75 \text{ cm}^2$$

$$As^{\circ} = 20 \% 3,75 = 0,75 \text{ cm}^2$$

#### a.3. Lapangan y.

sama dengan lapangan x →

$$As = 2,74 \text{ cm}^2$$

$$As_{\min} = 3,75 \text{ cm}^2$$

#### a.4. Tumpuan y.

sama dengan lapangan y →

$$As = 2,74 \text{ cm}^2$$

$$As_{\min} = 3,75 \text{ cm}^2$$

$$As^{\circ} = 0,75 \text{ cm}^2$$

#### b. Pelat b.

##### b.1. Lapangan x.

$$M = 162 \text{ kgm} ; b = 1 \text{ m}$$

$$d = 12 - 3 = 9 \text{ cm}$$

$$Ca = \frac{9}{\sqrt{\frac{21 \cdot 162}{1 \cdot 1400}}} = 5,774$$

$$\text{tulangan tunggal} : \delta = 0 \rightarrow \varphi = 3,464 > \varphi_0$$

$$nw = 0,033$$

$$\sigma_b' = \frac{1400}{21 \cdot 3,464} = 19 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$As = \frac{0,033}{21} 100. 9 = 1,41 \text{ cm}^2$$

$$As_{\min} = 0,25 \% 100. 12 = 3 \text{ cm}^2$$

#### b.2. Tumpuan x.

sama dengan lapangan x →

$$As = 1,41 \text{ cm}^2$$

$$As_{\min} = 3 \text{ cm}^2$$

$$As^{\circ} = 20 \% 3 = 0,6 \text{ cm}^2$$

#### b.3. Lapangan y.

$$M = 92 \text{ kgm} ; b = 1 \text{ m} ; d = 9 \text{ cm}$$

$$Ca = \frac{9}{\sqrt{\frac{21 \cdot 92}{1 \cdot 1400}}} = 7,661$$

$$\text{tulangan tunggal} : \delta = 0 \rightarrow \varphi = 4,780 > \varphi_0$$

$$nw = 0,018$$

$$\sigma_b' = \frac{1400}{21 \cdot 4,780} = 14 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$As = \frac{0,018}{21} 100. 9 = 0,77 \text{ cm}^2$$

$$As_{\min} = 3 \text{ cm}^2$$

#### b.4. Tumpuan y.

sama dengan lapangan y →

$$As = 0,77 \text{ cm}^2$$

$$As_{\min} = 3 \text{ cm}^2$$

$$As^{\circ} = 0,6 \text{ cm}^2$$

#### N.2. SK SNI 1991.

$$K 225 \rightarrow f_c' = 225 \text{ kg/cm}^2 = 22,5 \text{ MPa}$$

$$U 24 \rightarrow f_y = 2400 \text{ kg/cm}^2 = 240 \text{ MPa}$$

$$\rho_{\min} = \frac{1,4}{240} = 0,0058$$

$$\rho_{\max} = 0,75 \frac{0,85 \cdot 22,5}{240} 0,85 \frac{600}{600 + 240} = 0,0363$$

## 5.2.1. Pembebanan.

## a. Pelat a.

## a.1. Beban mati.

$$\text{pelat} = 360 \text{ kg/m}^2$$

$$\text{spesi} = 42$$

$$\text{keramik} = 24$$

$$w_1 = 426 \text{ kg/m}^2$$

## a.2. Beban hidup.

$$\text{beban guna : } w_2 = 300 \text{ kg/m}^2$$

## a.3. Beban berfaktor.

$$W_{u1} = 1,2 \cdot 426 + 1,6 \cdot 300 = 995 \text{ kg/m}^2$$

## b. Pelat b.

## b.1. Beban mati.

$$\text{pelat} = 288 \text{ kg/m}^2$$

$$\text{spesi} = 42$$

$$\text{keramik} = 24$$

$$w_1 = 354 \text{ kg/m}^2$$

## b.2. Beban hidup.

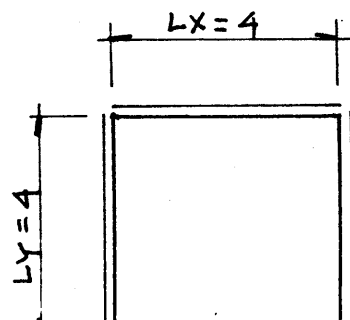
$$\text{beban hidup : } w_2 = 300 \text{ kg/m}^2$$

## b.3. Beban berfaktor.

$$W_{u2} = 1,2 \cdot 354 + 1,6 \cdot 300 = 905 \text{ kg/m}^2$$

## 5.2.2. Statika.

## a. Pelat a.



$$Ly/Lx = 4/4 = 1$$

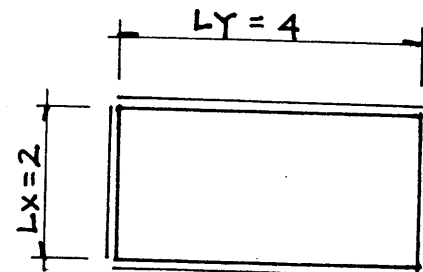
$$MuLx = 0,001 \cdot 995 \cdot 4^2 \cdot 36 = 573 \text{ kgm (+)}$$

$$MuTx = 573 \text{ kgm (-)}$$

$$MuLy = 0,001 \cdot 995 \cdot 4^2 \cdot 36 = 573 \text{ kgm (+)}$$

$$MuTy = 573 \text{ kgm (-)}$$

## b. Pelat b.



$$Ly/Lx = 4/2 = 2$$

$$MuLx = 0,001 \cdot 905 \cdot 2^2 \cdot 62 = 224 \text{ kgm (+)}$$

$$MuTx = 224 \text{ kgm (-)}$$

$$MuLy = 0,001 \cdot 905 \cdot 2^2 \cdot 35 = 127 \text{ kgm (+)}$$

$$MuTy = 127 \text{ kgm (-)}$$

## 5.3. Penulangan.

## a. Pelat a.

## a.1. Lapangan x.

$$Mu = 573 \text{ kgm} = 5,73 \text{ kNm} ; b = 1000 \text{ mm}$$

$$d = 150 - 30 = 120 \text{ mm} ; \phi = 0,8$$

$$R_n = \frac{5,73 \cdot 10^6}{0,8 \cdot 1000 \cdot 120^2} = 0,4974 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 0,4974}{22,5}} \right) = 0,0224$$

$$\rho = 0,0224 \frac{22,5}{240} = 0,0021 < 0,0058$$

$$As = 0,0058 \cdot 1000 \cdot 120 = 696 \text{ mm}^2$$

3.3.  
Mu  
d = s  
Rn =

a.2. Tumpuan x.

Sama dengan lapangan x →

$$As = 696 \text{ mm}^2$$

$$As^o = 0,002 \cdot 1000 \cdot 150 = 300 \text{ cm}^2$$

a.3. Lapangan y.

sama dengan lapangan x →

$$As = 696 \text{ mm}^2$$

a.4. Tumpuan y.

sama dengan lapangan y →

$$As = 696 \text{ mm}^2$$

$$As^o = 300 \text{ mm}^2$$

b. Pelat b.

b.1. Lapangan x.

$$Mu = 224 \text{ kgm} = 2,24 \text{ kNm} ; b = 1000 \text{ mm}$$

$$d = 120 - 30 = 90 \text{ mm} ; \phi = 0,8$$

$$Rn = \frac{2,24 \cdot 10^6}{0,8 \cdot 1000 \cdot 120^2} = 0,3457 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 0,3457}{22,5}} \right) = 0,0155$$

$$\rho = 0,0155 \frac{22,5}{240} = 0,0015 < 0,0058$$

$$As = 0,0058 \cdot 1000 \cdot 90 = 522 \text{ mm}^2$$

2. Tumpuan x.

sama dengan lapangan x →

$$= 522 \text{ mm}^2$$

$$0,002 \cdot 1000 \cdot 120 = 240 \text{ mm}^2$$

y.

$$Mm = 1,27 \text{ kNm} ; b = 1000 \text{ mm}$$

$$; \phi = 0,8$$

$$\frac{1,27 \cdot 10^6}{120^2} = 0,1960 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 0,1960}{22,5}} \right) = 0,0088$$

$$\rho = 0,0088 \frac{22,5}{240} = 0,0008 < 0,0058$$

$$As = 0,0058 \cdot 1000 \cdot 90 = 522 \text{ mm}^2$$

b.4. Tumpuan y.

sama dengan lapangan y →

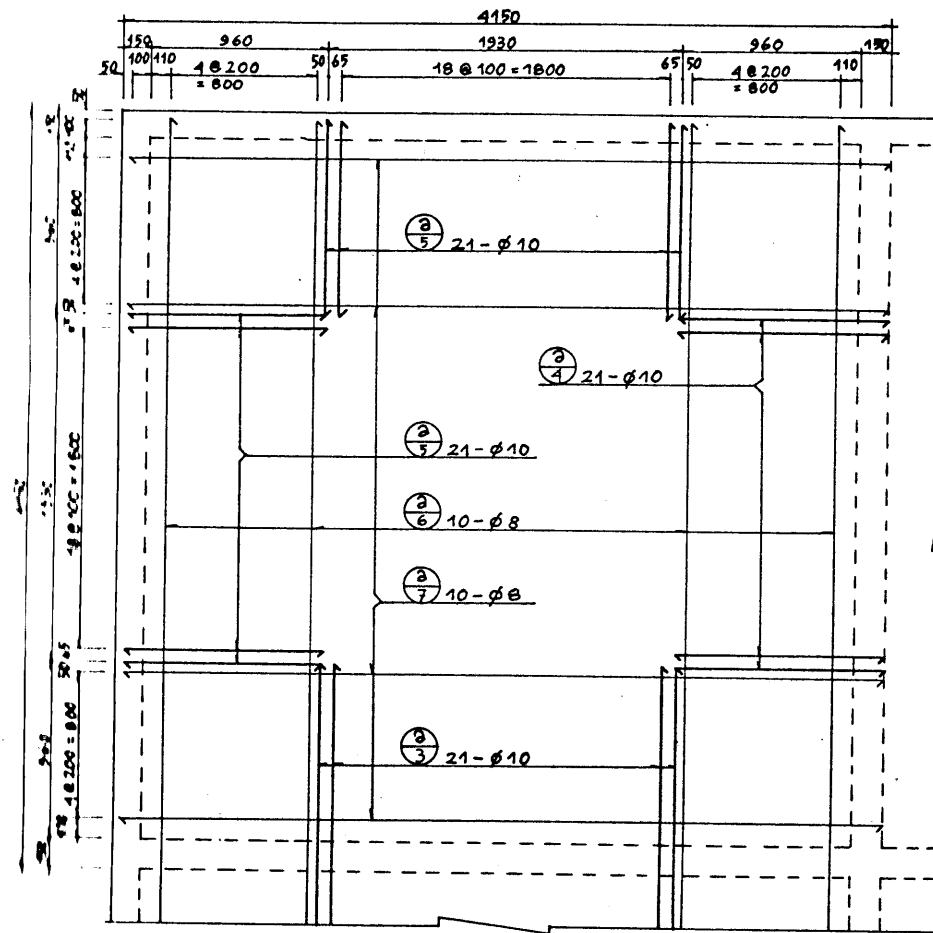
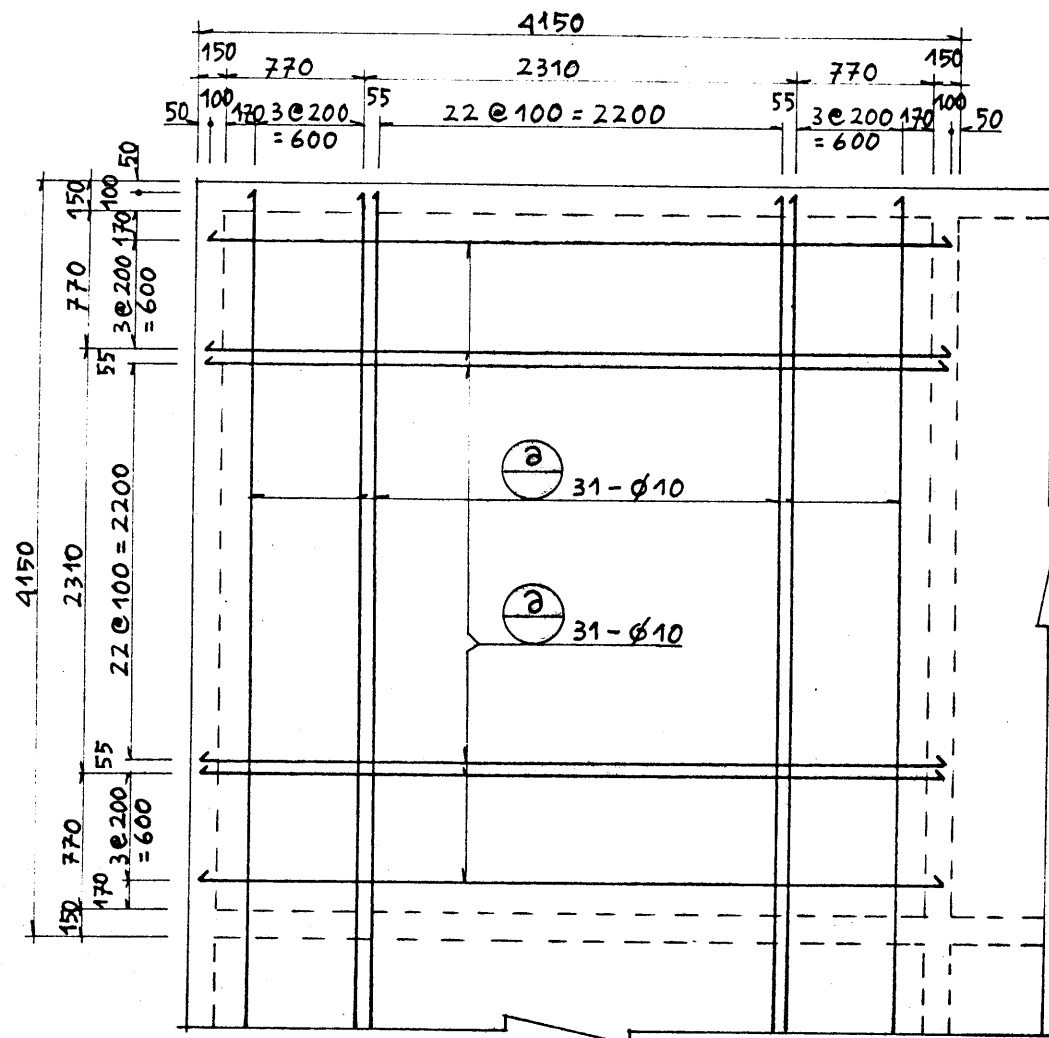
$$As = 522 \text{ mm}^2$$

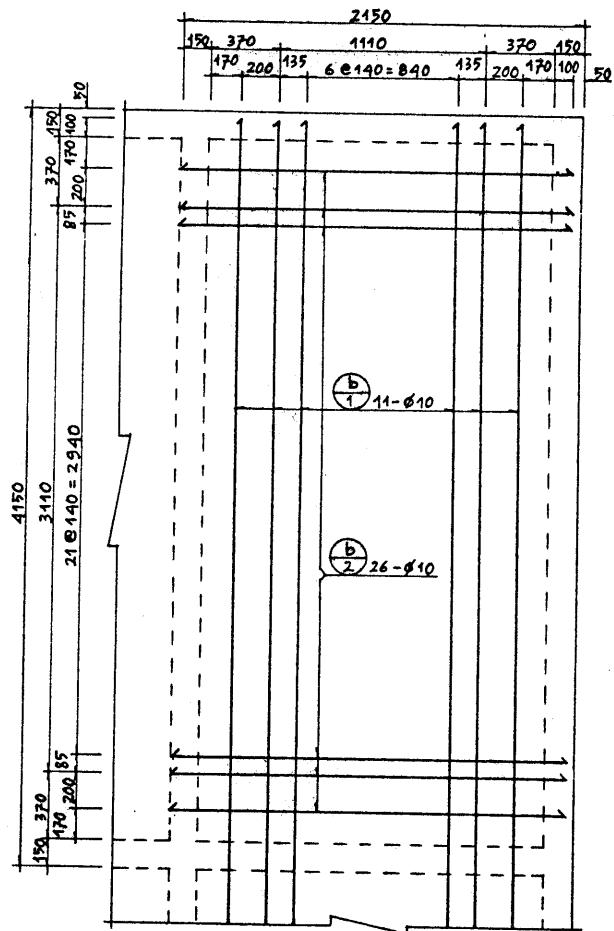
$$As^o = 0,002 \cdot 1000 \cdot 120 = 240 \text{ mm}^2$$

Rekapitulasi :

	Elastis	SK SNI '91
	Pelat a	
	mm <sup>2</sup>	mm <sup>2</sup>
Lapangan x & y :		
tulang bawah	274	696 → ϕ 10 - 100
Tumpuan x & y :		
tulang atas	274	696 → ϕ 10 - 100
tulang bagi	75	300 → ϕ 8 - 160
	Pelat b	
Lapangan x :		
tulang bawah	141	522 → ϕ 10 - 140
Tumpuan x :		
tulang atas	141	522 → ϕ 10 - 140
tulang bagi	60	240 → ϕ 8 - 200
Lapangan y :		
tulang bawah	77	522 → ϕ 10 - 140
Tumpuan y :		
tulang atas	77	522 → ϕ 10 - 140
tulang bagi	60	240 → ϕ 8 - 200

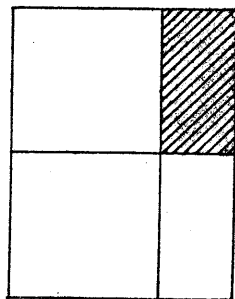




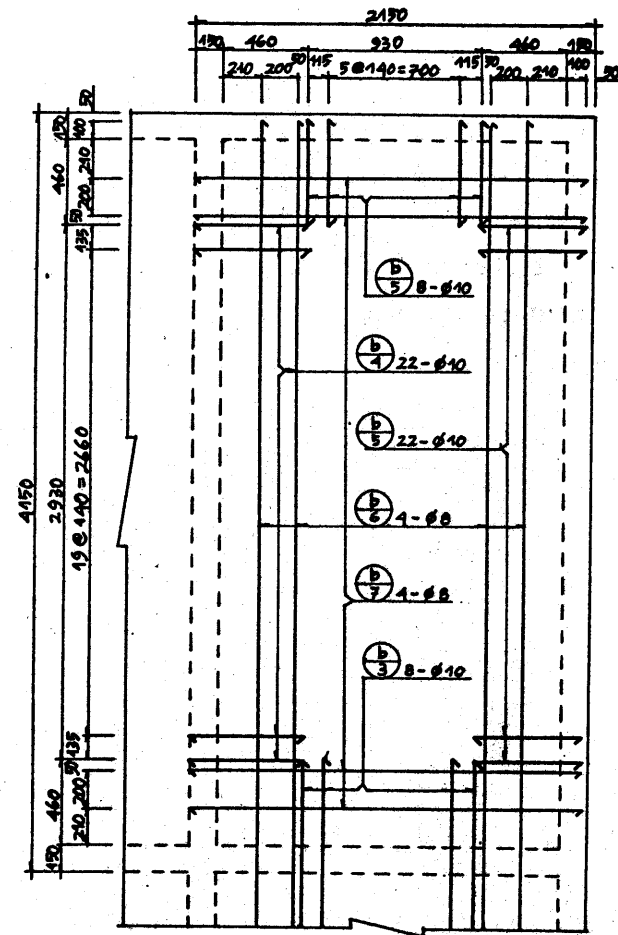


TULANG BAWAH

0 1 2 m

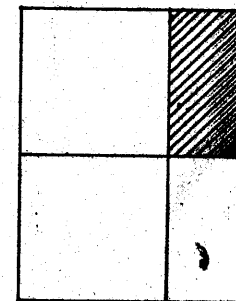


DENAH



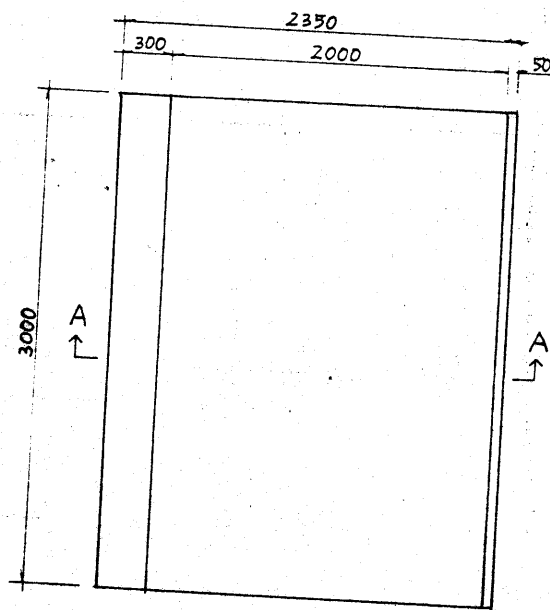
TULANG ATAS

0 1 2 m

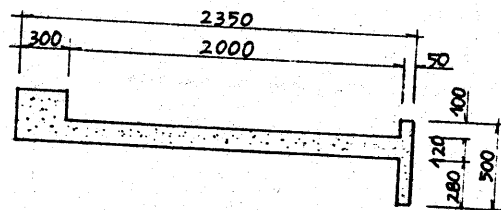


DENAH

6. Pelat kantilever seperti gambar mempunyai data sebagai berikut :
- tinggi air hujan = 5 cm
- beban guna =  $100 \text{ kg/m}^2$
- beton K 175
- besi tulangan U 24
- Hitung penulangannya pada pembebanan tetap.



DENAH



POT. A-A

### 0.1. ELASTIS.

$$K 175 \rightarrow \bar{\sigma}_b' = 60 \text{ kg/cm}^2 ; n = 24$$

$$U 24 \rightarrow \bar{\sigma}_a = 1400 \text{ kg/cm}^2$$

$$\rho_0 = \frac{1400}{24 \cdot 60} = 0,972$$

#### 0.1.1. Pembebanan.

##### a. Beban terbagi rata.

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

$$\text{air hujan} = 0,05 \cdot 1000 = 50$$

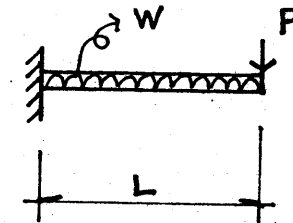
$$\text{beban guna} = 100$$

$$w = 440 \text{ kg/m}^2$$

##### b. Beban terpusat.

$$\text{plasia} : P = 0,05 \cdot 0,5 \cdot 2400 \cdot 1 = 60 \text{ kg}$$

#### 0.1.2. Statika.



$$M = 1/2 \cdot 440 \cdot 2^2 + 60 \cdot 2 = 1000 \text{ kgm} (-)$$

#### 0.1.3. Penulangan.

$$M = 1000 \text{ kgm} ; b = 1 \text{ m}$$

$$d = 12 - 3 = 9 \text{ cm}$$

$$C_a = \frac{9}{\sqrt{\frac{24 \cdot 1000}{1 \cdot 1400}}} = 2,174$$

$$\text{tulangan tunggal} : \delta = 0 \rightarrow \rho = 0,988 > \rho_0$$

$$n_w = 0,255$$

$$24. 0,988 = 88 \text{ kg/cm}^2 < \sigma_b$$

$$A_s = \frac{0,255}{24} 100. 9 = 9,56 \text{ cm}^2$$

$$A_s \text{ min} = 0,25 \% 100. 12 = 3 \text{ cm}^2$$

$$A_s^o = 20 \% 3 = 0,6 \text{ cm}^2$$

### 6.2. SK SNI 1991.

$$K 175 \rightarrow f_c' = 175 \text{ kg/cm}^2 = 17,5 \text{ MPa}$$

$$U 24 \rightarrow f_y = 2400 \text{ kg/cm}^2 = 240 \text{ MPa}$$

$$\rho \text{ min} = \frac{1,4}{240} = 0,0058$$

$$\rho \text{ maks} = 0,75 \frac{0,85. 17,5}{240} 0,85 \frac{600}{600 + 240} = 0,028$$

### 6.2.1. Pembebanan.

#### a. Beban terbagi rata.

##### a.1. Beban mati.

$$\text{pelat} : w_1 = 288 \text{ kg/m}^2$$

##### a.2. Beban hidup.

$$\text{air hujan} = 0,05. 1000 = 50 \text{ kg/m}^2$$

$$\text{beban guna} = 100$$

$$w_2 = 150 \text{ kg/m}^2$$

##### a.3. Beban berfaktor.

$$W_u = 1,2. 288 + 1,6. 150 = 590 \text{ kg/m}^2$$

##### b. Beban terpusat.

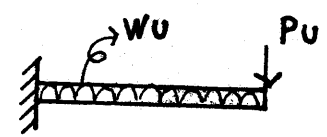
##### b.1. Beban mati.

$$\text{plasia} : P = 60 \text{ kg}$$

##### b.2. Beban berfaktor.

$$P_u = 1,2. 60 = 72 \text{ kg}$$

### 6.2.2. Statika.



$$M_u = 1/2. 590. 2^2 + 72. 2 = 1324 \text{ kgm} (-)$$

### 6.2.3. Penulangan.

$$M_u = 1324 \text{ kgm} = 13,24 \text{ kNm} ; b = 1000 \text{ mm}$$

$$d = 120 - 30 = 90 \text{ mm} ; \phi = 0,8$$

$$R_n = \frac{13,24. 10^6}{0,8. 1000. 90^2} = 2,0432 \text{ MPa}$$

$$W = 0,85 (1 - \sqrt{1 - \frac{2,353. 2,0432}{17,5}}) = 0,1261$$

$$\rho = 0,1261 \frac{17,5}{240} = 0,0092 > 0,0058 < 0,028$$

$$A_s = 0,0092. 1000. 90 = 828 \text{ cm}^2$$

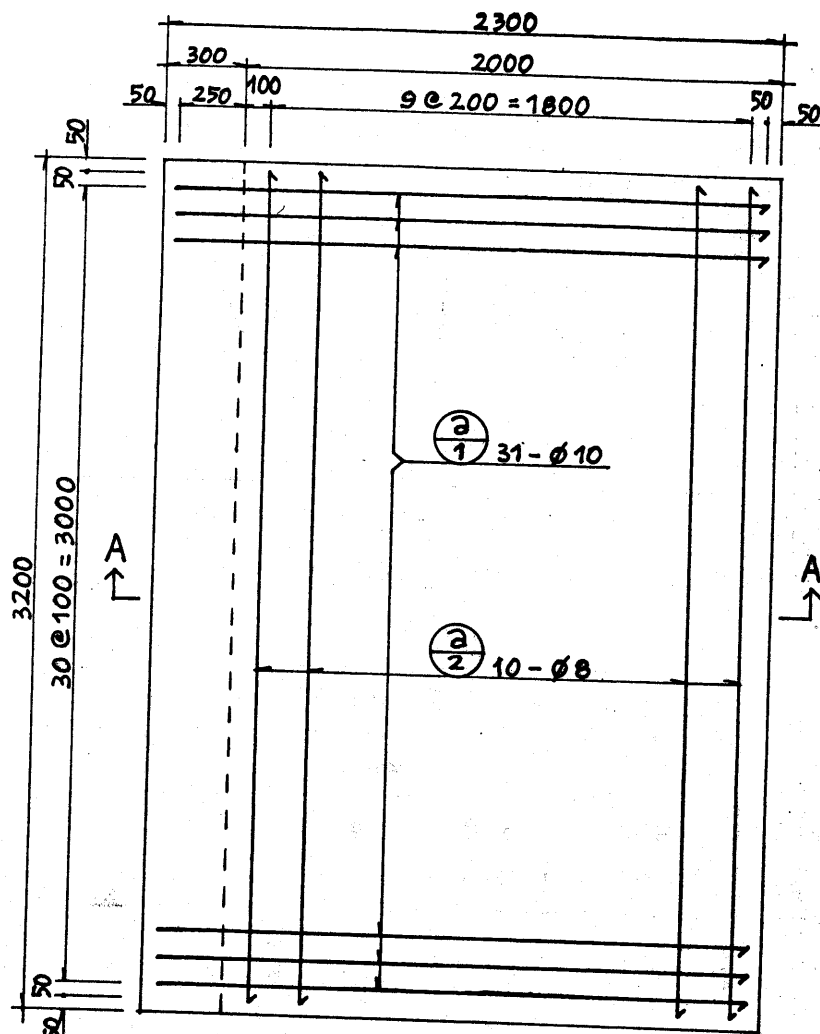
$$A_s^o = 0,002. 1000. 120 = 240 \text{ cm}^2$$

### Rekapitulasi :

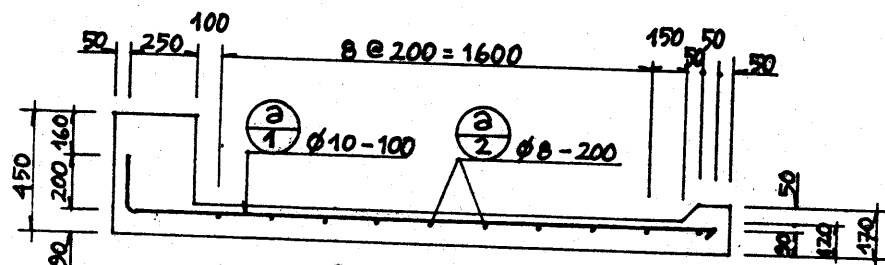
	Elastis	SK SNI '91
	mm <sup>2</sup>	mm <sup>2</sup>
tulang atas	956	828 → $\phi 12 - 120$
tulang bagi	191	240 → $\phi 8 - 200$

$L < 2$  m D10-120 / 16-100 / 8-200  
 $2 < L < 3$  D12-120 / 16-100 / 8-200  
 $L > 3$  lihat gambar

Lantai (120 mm)  
 $L < 1$  m D10-100  
 $L = 1,5$  m D12-75  
 $L = 2$  m D12-50  
 $L = 2,5$  m D16-50  
 $L > 3$  lihat plat, lihat stirrup



PELAT LEUFEL



POT. A-A

0 0,5 1 m

7. Pelat lantai (a) menumpu pada balok dan pelat kantilever (b) seperti gambar terlampir, mempunyai data sebagai berikut :

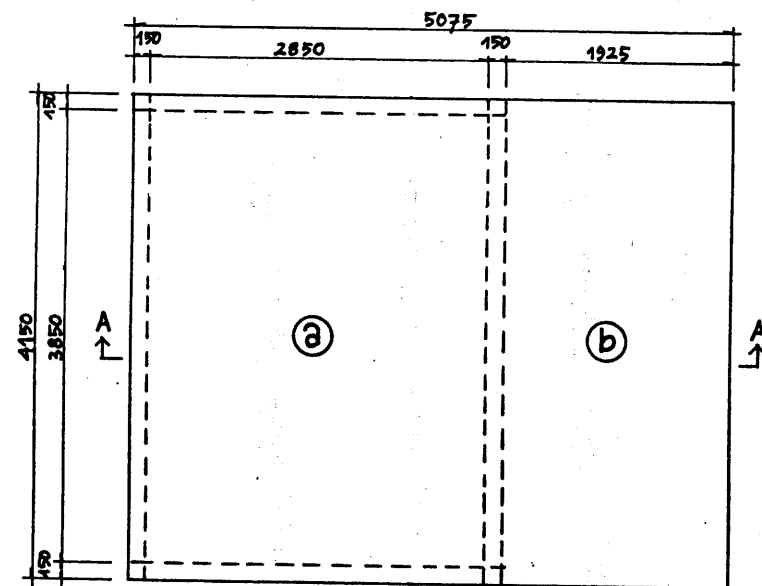
tebal pelat = 12 cm ; tegel dari keramik

tebal spesi = 2 cm ; beton K 200

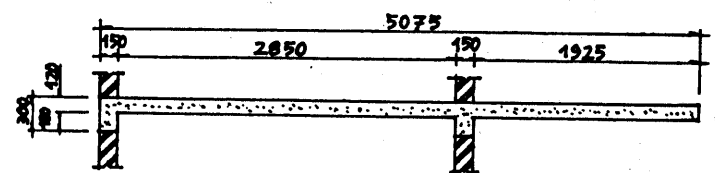
beban guna (a) =  $300 \text{ kg/m}^2$  ; besi tulangan U 32

beban guna (b) =  $100 \text{ kg/m}^2$

Hitung penulangan pelat (a) dan (b) pada pembebanan tetap.



DENAH



POT. A-A

### 7.1. ELASTIS.

$$K 200 \rightarrow \bar{\sigma}_b' = 0,33 \cdot 200 = 66 \text{ kg/cm}^2$$

$$n = \frac{330}{\sqrt{200}} = 23$$

$$U 32 \rightarrow \bar{\sigma}_a = 1850 \text{ kg/cm}^2$$

$$\phi_0 = \frac{1850}{23 \cdot 66} = 1,219$$

#### 7.1.1. Pembebanan.

##### a. Pelat a.

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

$$\text{spesi} = 2 \cdot 21 = 42$$

$$\text{keramik} = 1 \cdot 24 = 24$$

$$\text{beban guna} = 300$$

$$w_1 = 655 \text{ kg/m}^2$$

##### b. Pelat b.

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

$$\text{spesi} = 2 \cdot 21 = 42$$

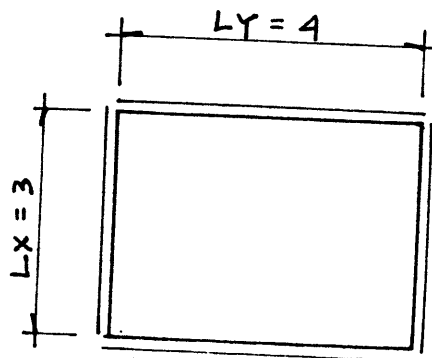
$$\text{keramik} = 1 \cdot 24 = 24$$

$$\text{beban guna} = 100$$

$$w_2 = 455 \text{ kg/m}^2$$

#### 7.1.2. Statika.

##### a. Pelat a.



$$Ly/Lx = 4/3 = 1,3$$

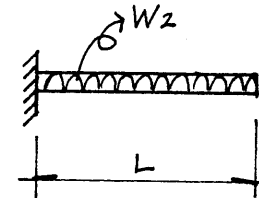
$$MLx = 0,001 \cdot 655 \cdot 3^2 \cdot 50 = 295 \text{ kgm (+)}$$

$$MTx = 295 \text{ kgm (-)}$$

$$MLy = 0,001 \cdot 655 \cdot 3^2 \cdot 38 = 224 \text{ kgm (+)}$$

$$MTy = 224 \text{ kgm (-)}$$

##### b. Pelat b.



$$MT = 1/2 \cdot 455 \cdot 2^2 = 910 \text{ kgm (-)}$$

#### 7.1.3. Penulangan.

##### a. Pelat a.

##### a.1. Lapangan x.

$$M = 295 \text{ kgm} ; b = 1 \text{ m}$$

$$d = 12 - 3 = 9 \text{ cm}$$

$$Ca = \frac{9}{\sqrt{\frac{23 \cdot 295}{1 \cdot 1850}}} = 4,699$$

$$\text{tulangan tunggal} : \delta = 0 \rightarrow \phi = 2,704 > \phi_0$$

$$nw = 0,050$$

$$\sigma_b' = \frac{1850}{23 \cdot 2,704} = 30 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$As = \frac{0,050}{23} 100 \cdot 9 = 1,96 \text{ cm}^2$$

$$As_{\min} = 0,25 \% 100 \cdot 12 = 3 \text{ cm}^2$$

##### a.2. Tumpuan x.

$$\text{sama dengan lapangan x} \rightarrow As = 1,96 \text{ cm}^2$$

$$As^{\circ} = 20 \% 3 = 0,6 \text{ cm}^2 \quad As_{\min} = 3 \text{ cm}^2$$

### a.3. Lapangan y.

$$M = 224 \text{ kgm} ; b = 1 \text{ m} ; d = 9 \text{ cm}$$

$$C_a = \frac{9}{\sqrt{\frac{23 \cdot 224}{1 \cdot 1850}}} = 5,392$$

$$\text{tulangan tunggal} : \delta = 0 \rightarrow \phi = 3,184 > \phi_0$$

$$nw = 0,040$$

$$\phi b' = \frac{1850}{23 \cdot 3,184} = 25 \text{ kg/cm}^2 < \bar{\phi} b'$$

$$A_s = \frac{0,040}{23} 100 \cdot 9 = 1,57 \text{ cm}^2$$

$$A_s \text{ min} = 0,25 \% 100 \cdot 12 = 3 \text{ cm}$$

### a.4. Tumpuan x.

$$\text{sama dengan lapangan x} \rightarrow A_s = 1,57 \text{ cm}^2$$

$$A_s \text{ min} = 3 \text{ cm}^2$$

$$A_s^o = 20 \% 3 = 0,6 \text{ cm}^2$$

### b. Pelat b.

$$M = 910 \text{ kgm} ; b = 1 \text{ m}$$

$$d = 12 - 3 = 9 \text{ cm}$$

$$C_a = \frac{9}{\sqrt{\frac{23 \cdot 910}{1 \cdot 1850}}} = 2,675$$

$$\text{tulangan tunggal} : \delta = 0 \rightarrow \phi = 1,320 > \phi_0$$

$$nw = 0,163$$

$$\phi b' = \frac{1850}{23 \cdot 1,320} = 61 \text{ kg/cm}^2 < \bar{\phi} b'$$

$$A_s = \frac{0,163}{23} 100 \cdot 9 = 6,38 \text{ cm}^2$$

$$A_s^o = 20 \% 6,38 = 1,28 \text{ cm}^2$$

### 7.2. SK SNI 1991.

$$K 200 \rightarrow f_c' = 200 \text{ kg/cm}^2 = 20 \text{ MPa}$$

$$U 32 \rightarrow f_y = 3200 \text{ kg/cm}^2 = 320 \text{ MPa}$$

$$\rho \text{ min} = \frac{1,4}{320} = 0,0043$$

$$\rho \text{ maks} = 0,75 \frac{0,85 \cdot 20}{320} 0,85 \frac{600}{600 + 320} = 0,022$$

### 7.2.1. Pembebanan.

#### a. Pelat a.

##### a.1. Beban mati.

$$\text{pelat} = 288 \text{ kg/m}^2$$

$$\text{spesi} = 42$$

$$\text{keramik} = 24$$

$$w_1 = 354 \text{ kg/m}^2$$

##### a.2. Beban hidup.

$$\text{beban guna} :$$

$$w_2 = 300 \text{ kg/m}^2$$

##### a.3. Beban berfaktor.

$$Wu_1 = 1,2 \cdot 354 + 1,6 \cdot 300 = 905 \text{ kg/m}$$

#### b. Pelat b.

##### b.1. Beban mati.

$$\text{pelat} = 288 \text{ kg/m}^2$$

$$\text{spesi} = 42$$

$$\text{keramik} = 24$$

$$w_3 = 354 \text{ kg/m}^2$$

##### b.2. Beban hidup.

$$\text{beban guna} :$$

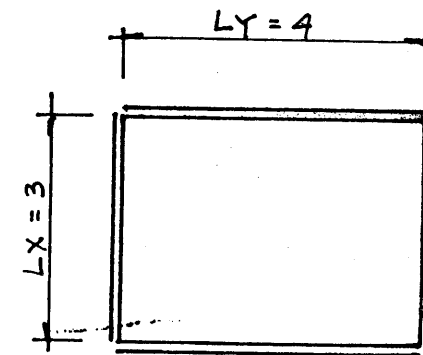
$$w_4 = 100 \text{ kg/m}^2$$

##### b.3. Beban berfaktor.

$$Wu_2 = 1,2 \cdot 354 + 1,6 \cdot 100 = 585 \text{ kg/m}^2$$

### 7.2.2. Statika.

#### a. Pelat a.





$$L_y/L_x = 4/3 = 1,3$$

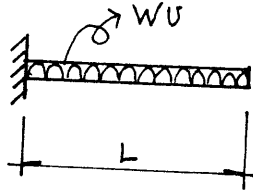
$$M_{uLx} = 0,001 \cdot 905 \cdot 3^2 \cdot 50 = 407 \text{ kgm (+)}$$

$$M_{uTx} = 407 \text{ kgm (-)}$$

$$M_{uLy} = 0,001 \cdot 905 \cdot 3^2 \cdot 38 = 310 \text{ kgm (+)}$$

$$M_{uTy} = 310 \text{ kgm (-)}$$

b. Pelat b.



$$M_u = 1/2 \cdot 585 \cdot 2^2 = 1170 \text{ kgm (-)}$$

7.2.3. Penulangan.

a. Pelat a.

a.1. Lapangan x.

$$M_u = 407 \text{ kgm} = 4,07 \text{ kNm} ; b = 1000 \text{ mm}$$

$$d = 120 - 30 = 90 \text{ mm} ; \phi = 0,8$$

$$R_n = \frac{4,07 \cdot 10^6}{0,8 \cdot 1000 \cdot 90^2} = 0,6281 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 0,6281}{20}} \right) = 0,032$$

$$\rho = 0,032 \frac{20}{320} = 0,002 < 0,0043$$

$$A_s = 0,0043 \cdot 1000 \cdot 90 = 387 \text{ mm}^2$$

a.2. Tumpuan x.

$$\text{sama dengan lapangan x} \rightarrow A_s = 387 \text{ mm}^2$$

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

a.3. Lapangan y.

$$M_u = 310 \text{ kgm} = 3,10 \text{ kNm} ; b = 1000 \text{ mm}$$

$$d = 90 \text{ mm} ; \phi = 0,8$$

$$R_n = \frac{3,10 \cdot 10^6}{0,8 \cdot 1000 \cdot 90^2} = 0,4784 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 0,4784}{20}} \right) = 0,0243$$

$$\rho = 0,0243 \frac{20}{320} = 0,0015 < 0,0043$$

$$A_s = 0,0043 \cdot 1000 \cdot 90 = 387 \text{ mm}^2$$

a.4. Tumpuan y.

$$\text{sama dengan lapangan y} \rightarrow A_s = 387 \text{ mm}^2$$

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

b. Pelat b.

$$M_u = 1170 \text{ kgm} = 11,70 \text{ kNm} ; b = 1000 \text{ mm}$$

$$d = 120 - 30 = 90 \text{ mm} ; \phi = 0,8$$

$$R_n = \frac{11,70 \cdot 10^6}{0,8 \cdot 1000 \cdot 90^2} = 1,8056 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 1,8056}{20}} \right) = 0,0957$$

$$\rho = 0,0957 \frac{20}{320} = 0,0060 > 0,0043$$

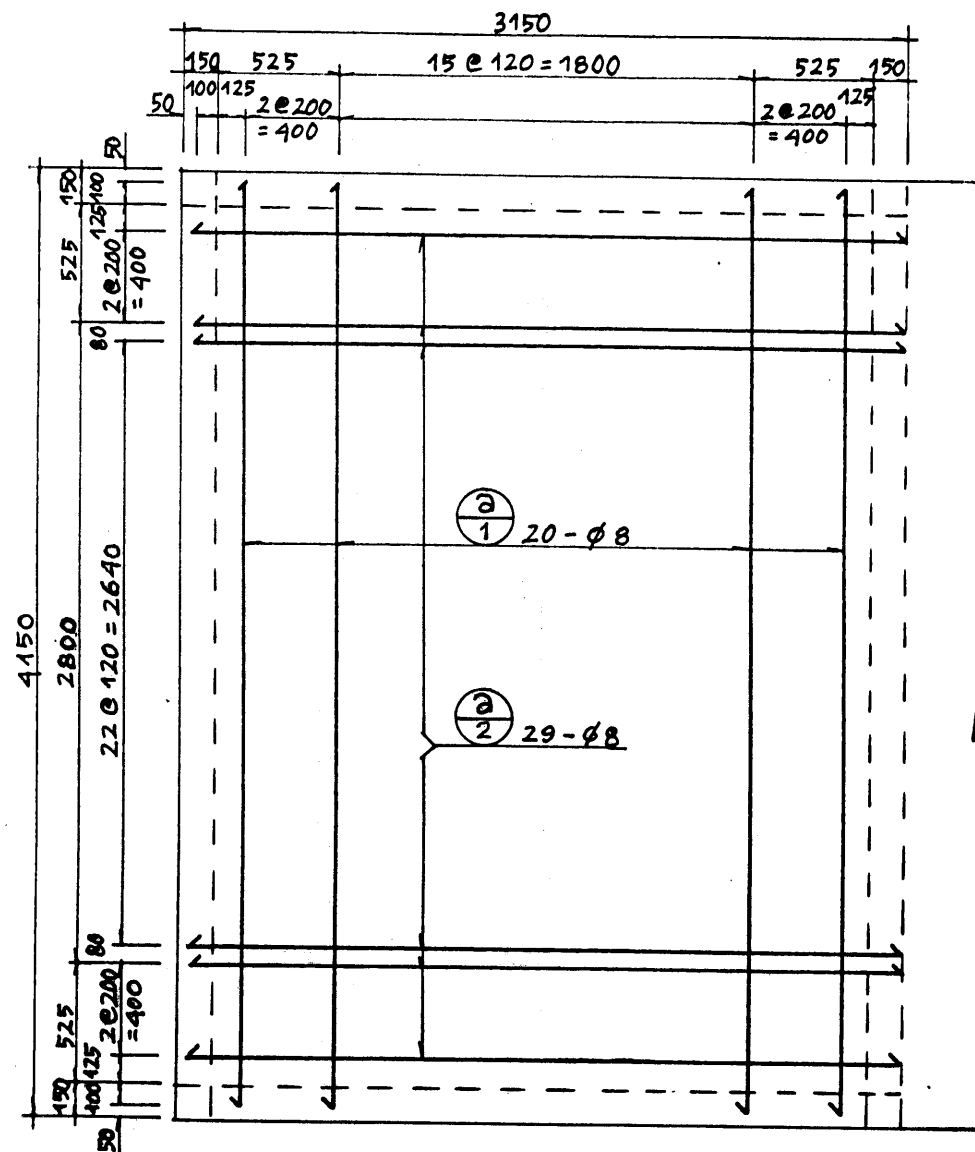
$$< 0,022$$

$$A_s = 0,006 \cdot 1000 \cdot 90 = 540 \text{ mm}^2$$

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

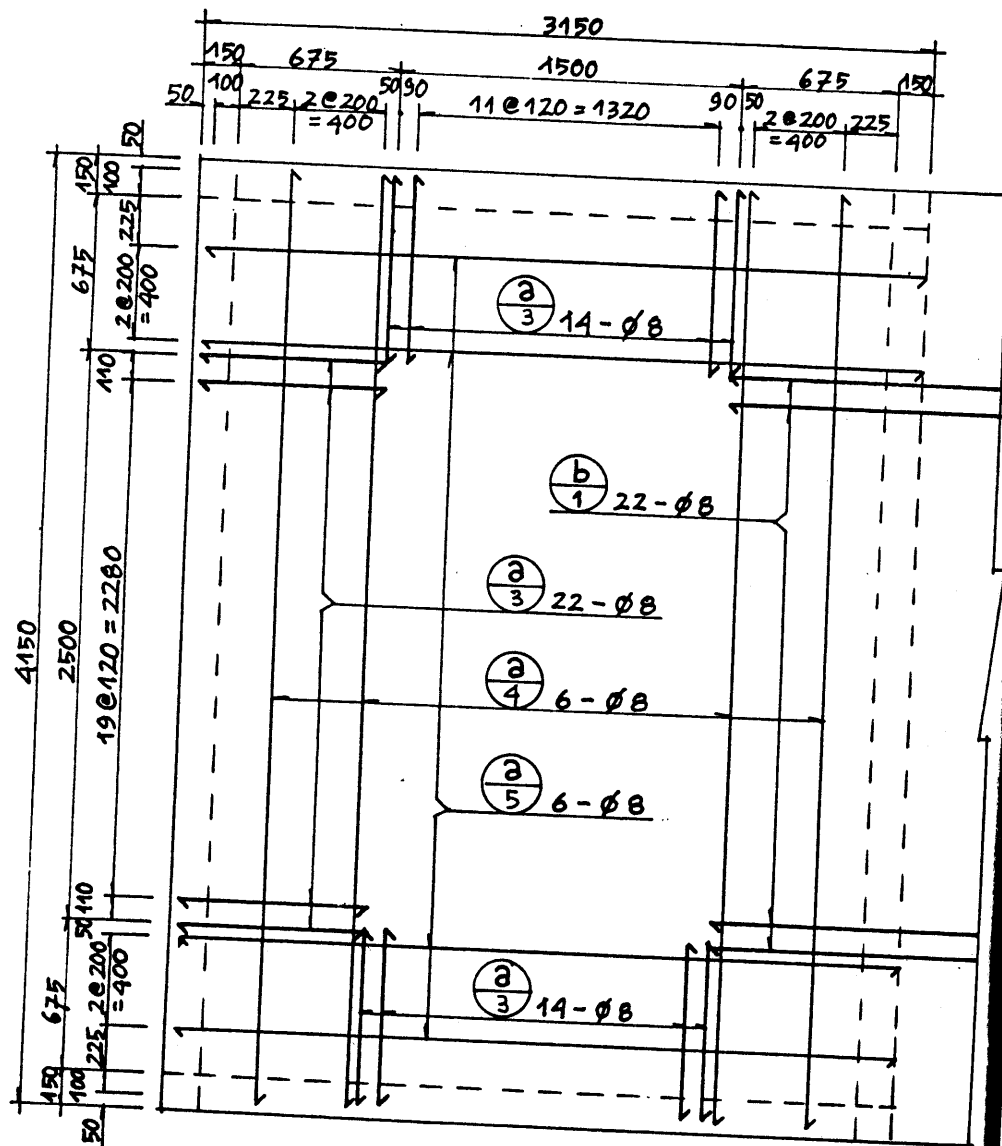
Rekapitulasi :

	Elastis	SK SNI '91
Pelat a		
	mm <sup>2</sup>	mm <sup>2</sup>
Lapangan x : tulang bawah	196	387 → $\phi$ 8 - 120
Tumpuan x : tulang atas	196	387 → $\phi$ 8 - 120
tulang bagi	39	240 → $\phi$ 8 - 200
Lapangan y : tulang bawah	157	387 → $\phi$ 8 - 120
Tumpuan y : tulang atas	157	387 → $\phi$ 8 - 120
tulang bagi	31	240 → $\phi$ 8 - 200
Pelat b		
Tumpuan : tulang atas	638	540 → $\phi$ 10 - 140
tulang bagi	128	240 → $\phi$ 8 - 200

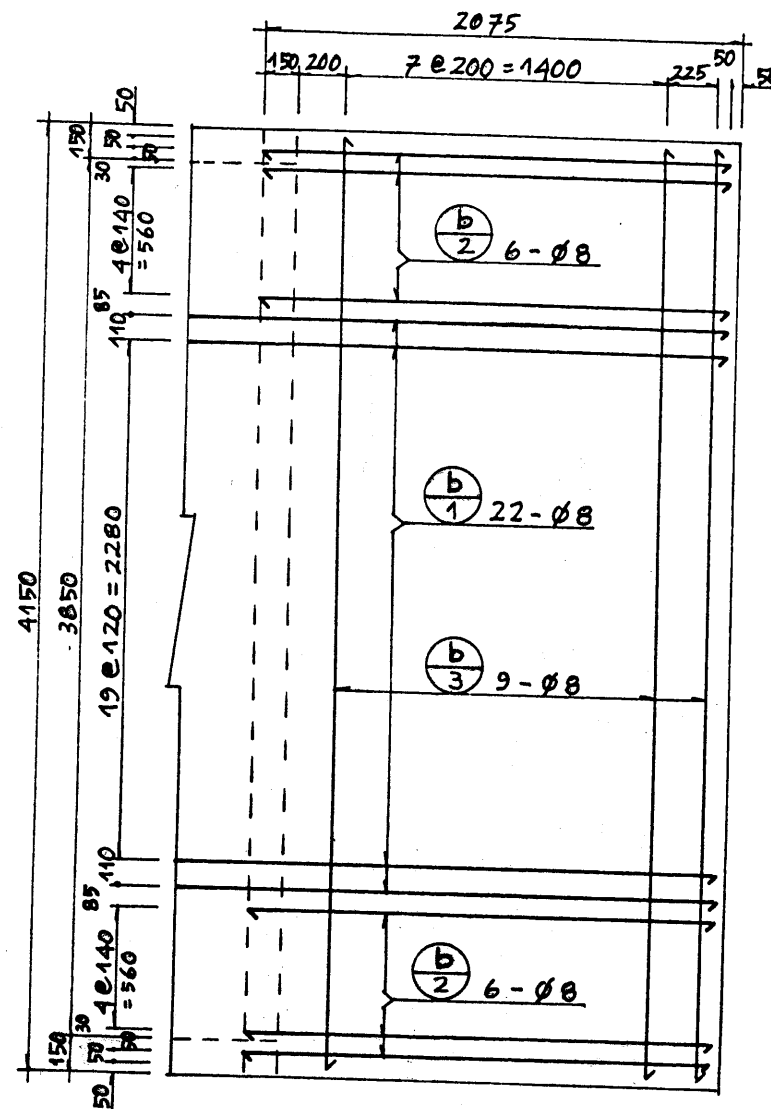
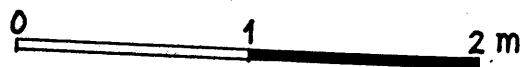


PELAT 2  
TULANG BAWAH





PELAT a  
TULANG ATAS



PELAT b  
TULANG ATAS



8. Balok dari beton bertulang menumpu pada dinding 1/2 batu, mempunyai data sebagai berikut :  
 beban mati (termasuk berat balok) = 1500 kg/m  
 beban guna = 500 kg/m  
 beton K 225 ; besi tulangan U 32  
 Hitung penulangan balok tersebut pada pembebanan tetap.

### 8.1. ELASTIS.

$$\begin{aligned} \text{K 225} \rightarrow \bar{\sigma}_b' &= 75 \text{ kg/cm}^2 ; n = 21 \\ \bar{\tau}_{bt} &= 6,5 \text{ kg/cm}^2 ; \bar{\tau}_{bs} = 10 \text{ kg/cm}^2 \\ \bar{\tau}_{bm,t} &= 16 \text{ kg/cm}^2 \end{aligned}$$

$$\text{U 32} \rightarrow \bar{\sigma}_a = 1850 \text{ kg/cm}^2$$

$$\phi_0 = \frac{1850}{21 \cdot 75} = 1,175$$

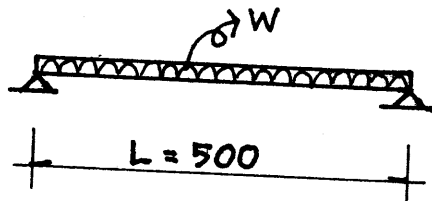
#### 8.1.1. Pembebanan.

$$\text{beban mati} = 1500 \text{ kg/m}$$

$$\text{beban guna} = 500$$

$$w = 2000 \text{ kg/m}$$

#### 8.1.2. Statika.



$$\text{tinggi balok} : h = 1/12 L$$

$$h = 1/12 \cdot 500 = 40 \text{ cm}$$

$$\text{lebar balok} : b = 1/2 h$$

$$b = 1/2 \cdot 40 = 20 \text{ cm}$$

$$M_{\text{Lap}} = 1/8 \cdot 2000 \cdot 5^2 = 6250 \text{ kgm (+)}$$

$$M_{\text{Tump}} = 1/24 \cdot 2000 \cdot 5^2 = 2083 \text{ kgm (-)}$$

$$Q = 1/2 \cdot 2000 \cdot 5 = 5000 \text{ kg}$$

### 8.1.3. Penulangan.

#### a. Lapangan.

$$M = 6250 \text{ kgm} ; b = 20 \text{ cm}$$

$$d = 40 - 5 = 35 \text{ cm}$$

$$C_a = \frac{35}{\sqrt{\frac{21 \cdot 6250}{0,2 \cdot 1850}}} = 1,858$$

$$\text{tulang rangkap} : \delta = 0,8 \rightarrow$$

$$\phi = 1,273 > \phi_0$$

$$\phi' = 2,529$$

$$nw = 0,106$$

$$\sigma_b' = \frac{1850}{21 \cdot 1,273} = 69 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$\sigma_a = \frac{1850}{2,529} = 1123 \text{ kg/cm}^2 < \bar{\sigma}_a$$

$$A_s = \frac{0,106}{21} 20 \cdot 35 = 11,20 \text{ cm}^2$$

$$A_s' = 0,8 \cdot 11,20 = 8,96 \text{ cm}^2$$

$$A_{s \text{ min}} = \frac{12}{2780} 20 \cdot 35 = 3,02 \text{ cm}^2$$

#### b. Tumpuan.

$$M = 2083 \text{ kgm} ; b = 20 \text{ cm} ; d = 35 \text{ cm}$$

$$C_a = \frac{35}{\sqrt{\frac{21 \cdot 2083}{0,2 \cdot 1850}}} = 3,311$$

$$\text{tulangan rangkap} : \delta = 0,2 \rightarrow$$

$$\phi = 1,817 > \phi_0$$

$$\phi' = 2,529$$

$$nw = 0,106$$

$$\sigma_b' = \frac{1850}{21 \cdot 1,817} = 48 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$\sigma_a = \frac{1850}{2,529} = 732 \text{ kg/cm}^2 < \bar{\sigma}_a$$

$$A_s = \frac{0,106}{21} 20 \cdot 35 = 3,53 \text{ cm}^2$$

$$A_s' = 0,2 \cdot 3,53 = 0,71 \text{ cm}^2$$

$$A_{s \text{ min}} = 3,02 \text{ cm}^2$$

c. Geser.

$$Q = 5000 \text{ kg} ; b = 20 \text{ cm} ; d = 35 \text{ cm}$$

$$\tau_b = \frac{8 \cdot 5000}{7 \cdot 20 \cdot 35} = 8,16 \text{ kg/cm}^2 > 6,5 \text{ kg/cm}^2$$

$$< 10 \text{ kg/cm}^2$$

$$< 16 \text{ kg/cm}^2$$

Tegangan geser sisa ( $\tau_{bs}$ ) di tahan oleh tulang geser :

$$\tau_{bs} = 8,16 - 6,5 = 1,66 \text{ kg/cm}^2$$

- sengkang :  $\phi 6 \rightarrow A_s = 0,57 \text{ cm}^2$  (2 kaki)  
as = 15 cm (jarak sengkang)

$$\tau_s = \frac{0,57 \cdot 1850}{15 \cdot 20} = 3,52 \text{ kg/cm}^2 > \tau_{bs} \rightarrow \text{ok}$$

8.2. SK SNI 1991.

$$K 225 \rightarrow f_c' = 225 \text{ kg/cm}^2 = 22,5 \text{ MPa}$$

$$U 32 \rightarrow f_y = 3200 \text{ kg/cm}^2 = 320 \text{ MPa}$$

$$\rho_{\text{min}} = \frac{1,4}{320} = 0,0044$$

$$\rho_{\text{maks}} = 0,75 \frac{0,85 \cdot 22,5}{320} 0,85 \frac{600}{600 + 320} = 0,02$$

8.2.1. Pembebanan.

a. Beban mati.

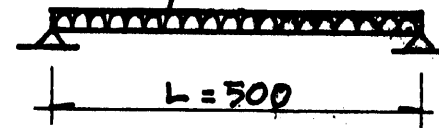
$$\text{balok} : w_1 = 1500 \text{ kg/m}$$

b. Beban hidup.

$$\text{beban guna} : w_2 = 500 \text{ kg/m}$$

c. Beban berfaktor.

$$W_u = 1,2 \cdot 1500 + 1,6 \cdot 500 = 2600 \text{ kg/m}$$



$$M_u \text{ Lap} = 1/8 \cdot 2600 \cdot 5^2 = 8125 \text{ kgm (+)}$$

$$M_u \text{ Tump} = 1/24 \cdot 2600 \cdot 5^2 = 2708 \text{ kgm (-)}$$

$$V_u = 1/2 \cdot 2600 \cdot 5 = 6500 \text{ kg}$$

0.2.3. Penulangan.

a. Lapangan.

$$M_u = 8125 \text{ kgm} = 81,25 \text{ kNm} ; b = 200 \text{ mm}$$

$$d = 400 - 50 = 350 \text{ mm} ; \phi = 0,8$$

$$R_n = \frac{81,25 \cdot 10^6}{0,8 \cdot 200 \cdot 350^2} = 4,1454 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 4,1454}{22,5}} \right) = 0,2102$$

$$\rho = 0,2102 \frac{22,5}{320} = 0,0148 > 0,0044$$

$$< 0,0248$$

$$A_s = 0,0148 \cdot 200 \cdot 350 = 1036 \text{ mm}^2$$

$$A_s' = 0,2 \cdot 1036 = 207 \text{ mm}^2$$

b. Tumpuan.

$$M_u = 2708 \text{ kgm} = 27,08 \text{ kNm} ; b = 200 \text{ mm}$$

$$d = 350 \text{ mm} ; \phi = 0,8$$

$$R_n = \frac{27,08 \cdot 10^6}{0,8 \cdot 200 \cdot 350^2} = 1,3816 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 1,3816}{22,5}} \right) = 0,0638$$

$$\rho = 0,0638 \frac{22,5}{320} = 0,0045 > 0,0044$$

$$< 0,0248$$

$$A_s = 0,0045 \cdot 200 \cdot 350 = 314 \text{ mm}^2$$

$$A_s' = 0,2 \cdot 314 = 63 \text{ mm}^2$$

c. Geser.

$$V_u = 6500 \text{ kg} = 65 \text{ kN} \quad ; \quad b = 200 \text{ mm}$$

$$d = 350 \text{ mm} \quad ; \quad \phi = 0,6$$

$$V_c = 1/6 \sqrt{f_c} b d$$

$$= 1/6 \sqrt{22,5} \cdot 200 \cdot 350 \cdot 10^{-3} = 55,34 \text{ kN}$$

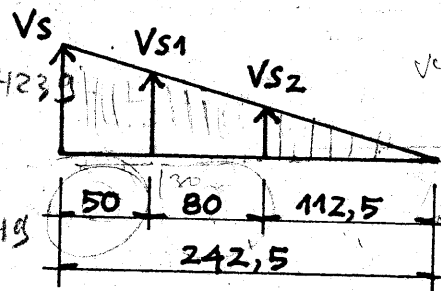
$$= 5534 \text{ kg}$$

$$V_n = \frac{V_u}{\phi} = \frac{6500}{0,6} = 10833 \text{ kg} > V_c \rightarrow$$

perlu tulang geser

$$V_s = V_n - V_c$$

$$= 10833 - 5534 = 5299 \text{ kg}$$



$$V_{s1} = \frac{5299 \cdot 192,5}{242,5} = 4206 \text{ kg}$$

$$V_{s2} = \frac{5299 \cdot 112,5}{242,5} = 2458 \text{ kg}$$

- sengkang :  $\phi 6 \rightarrow A_v = 0,57 \text{ cm}^2$  (2 kaki)

$s = 10 \text{ cm}$  (jarak sengkang)

$L_1 = 50 \text{ cm}$

$$V_{sa} = \frac{A_v f_y d}{s}$$

$$= \frac{0,57 \cdot 3200 \cdot 35}{10} = 6384 \text{ kg} > V_s \rightarrow \text{ok}$$

- sengkang :  $\phi 6 \rightarrow A_v = 0,57 \text{ cm}^2$  (2 kaki)

$s = 15 \text{ cm}$  (jarak sengkang)

$L_2 = 80 \text{ cm}$

$$V_{sb} = \frac{0,57 \cdot 3200 \cdot 35}{15} = 4256 \text{ kg} > V_{s1} \rightarrow \text{ok}$$

- sengkang :  $\phi 6 \rightarrow A_v = 0,57 \text{ cm}^2$  (2 kaki)

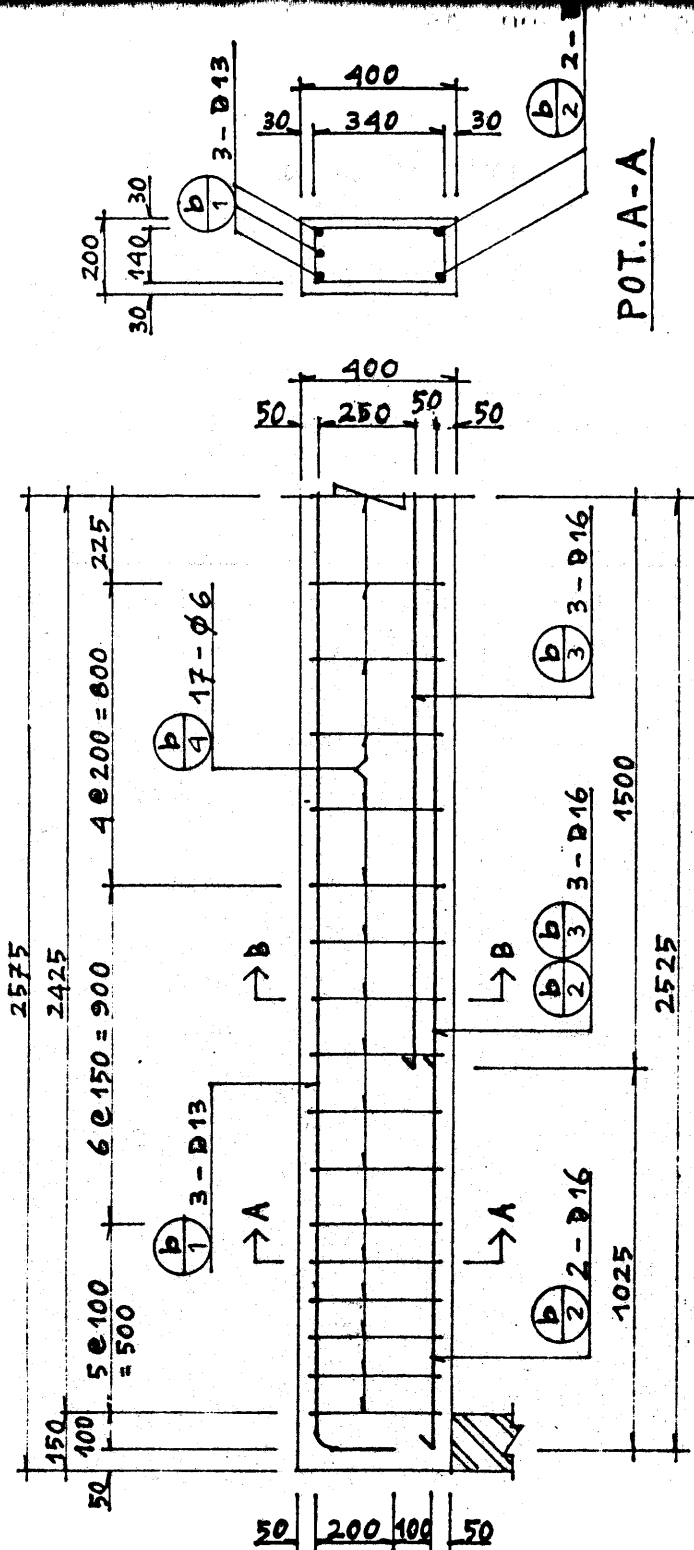
$s = 20 \text{ cm}$  (jarak sengkang)

$L_3 = 112,5 \text{ cm}$

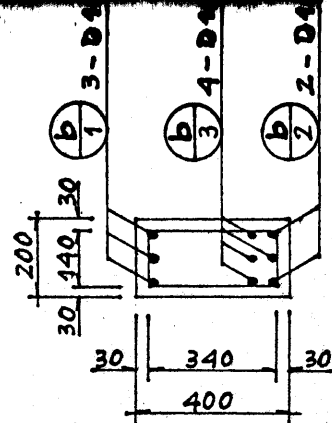
$$V_{sc} = \frac{0,57 \cdot 3200 \cdot 35}{20} = 3192 \text{ kg} > V_{s2} \rightarrow \text{ok}$$

Rekapitulasi :

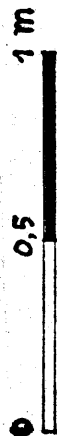
	Elastis	SK SNI '91
	mm <sup>2</sup>	mm <sup>2</sup>
Lapangan :		
tulang bawah	1120	1036 $\rightarrow 6 - D16$
tulang atas	896	207 $\rightarrow 3 - D13$
Tumpuan :		
tulang atas	353	314 $\rightarrow 3 - D13$
tulang bawah	71	63 $\rightarrow 2 - D16$
Geser :		
sengkang		$\phi 6 - 100$
		$\phi 6 - 150$
		$\phi 6 - 200$



POT. A-A



BALOK



9. Soal No-8 balok menumpu pada kolom praktis.

9.1. ELASTIS.

$$K 225 \rightarrow \bar{\sigma}_{b'} = 75 \text{ kg/cm}^2 ; n = 21$$

$$\bar{\tau}_{bt} = 6,5 \text{ kg/cm}^2 ; \bar{\tau}_{bs} = 10 \text{ kg/cm}^2$$

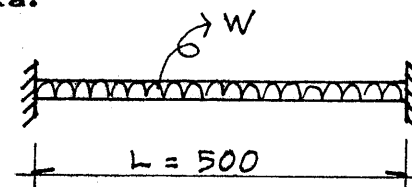
$$\bar{\tau}_{bm,t} = 16 \text{ kg/cm}^2 ; \varphi_0 = 1,175$$

$$U 32 \rightarrow \bar{\sigma}_a = 1850 \text{ kg/cm}^2$$

9.1.1. Pembebanan.

$$W = 2000 \text{ kg/m}$$

9.1.2. Statika.



$$M_{\text{Lap}} = 1/12 \cdot 2000 \cdot 5^2 = 4167 \text{ kgm (+)}$$

$$M_{\text{Tump}} = 1/18 \cdot 2000 \cdot 5^2 = 2778 \text{ kgm (-)}$$

$$Q = 1/2 \cdot 2000 \cdot 5 = 5000 \text{ kg}$$

9.1.3. Penulangan.

a. Lapangan.

$$M = 4167 \text{ kgm} ; b = 20 \text{ cm} ; d = 35 \text{ cm}$$

$$C_a = \frac{35}{\sqrt{\frac{21 \cdot 4167}{0,2 \cdot 1850}}} = 2,276$$

$$\text{tulangan rangkap} : \delta = 0,4 \rightarrow$$

$$\varphi = 1,273 > \varphi_0 ; \varphi' = 1,647 ; n_w = 0,288$$

$$\sigma_{b'} = \frac{1850}{21 \cdot 1,273} = 69 \text{ kg/cm}^2 < \bar{\sigma}_{b'}$$

$$\sigma_a = \frac{1850}{1,647} = 1123 \text{ kg/cm}^2 < \bar{\sigma}_a$$

$$A_s = \frac{0,288}{21} \cdot 20 \cdot 35 = 7,60 \text{ cm}^2$$

$$As' = 0,4 \cdot 7,60 = 3,04 \text{ cm}^2$$

$$As_{\min} = 3,02 \text{ cm}^2$$

b. Tumpuan.

$$M = 2778 \text{ kgm} ; b = 20 \text{ cm} ; d = 35 \text{ cm}$$

$$Ca = \frac{35}{\sqrt{\frac{21 \cdot 2778}{0,2 \cdot 1850}}} = 2,787$$

$$\text{tulangan rangkap} : \delta = 0,2 \rightarrow$$

$$\varphi = 1,5 > \varphi_0 ; \varphi' = 2 ; n_w = 0,148$$

$$\sigma_b' = \frac{1850}{21 \cdot 1,5} = 59 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$\sigma_a = \frac{1850}{2} = 925 \text{ kg/cm}^2 < \bar{\sigma}_a$$

$$As = \frac{0,148}{21} 20 \cdot 35 = 4,93 \text{ cm}^2$$

$$As' = 0,2 \cdot 4,93 = 0,99 \text{ cm}^2$$

$$As_{\min} = 3,02 \text{ cm}^2$$

c. Geser.

$$Q = 5000 \text{ kg} ; b = 20 \text{ cm} ; d = 35 \text{ cm}$$

$$\tau_b = \frac{8 \cdot 5000}{7 \cdot 20 \cdot 35} = 8,16 \text{ kg/cm}^2 > 6,5 \text{ kg/cm}^2$$

$$< 10 \text{ kg/cm}^2$$

$$< 16 \text{ kg/cm}^2$$

tegangan geser sisa ( $\tau_{bs}$ ) ditahan oleh tulang geser.

$$\tau_{bs} = 8,16 - 6,5 = 1,66 \text{ kg/cm}^2$$

$$\text{- sengkang : } \phi 6 \rightarrow Av = 0,57 \text{ cm}^2 \text{ (2 kaki)}$$

$$as = 15 \text{ cm (jarak sengkang)}$$

$$\tau_s = \frac{0,57 \cdot 1850}{15 \cdot 20} = 3,52 \text{ kg/cm}^2 > \tau_{bs} \rightarrow \text{ok}$$

0.2. SK SNI 1991.

$$K 225 \rightarrow f_c' = 225 \text{ kg/cm}^2 = 22,5 \text{ MPa}$$

$$U 32 \rightarrow f_y = 3200 \text{ kg/cm}^2 = 320 \text{ MPa}$$

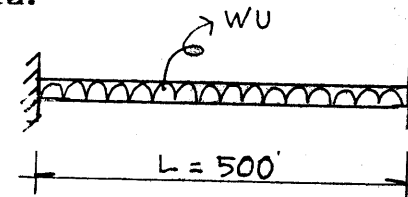
$$\rho_{\min} = \frac{1,4}{320} = 0,0044$$

$$\rho_{\max} = 0,75 \frac{0,85 \cdot 22,5}{320} 0,85 \frac{600}{600 + 320} = 0,0248$$

0.2.1. Pembebanan.

$$W_u = 2600 \text{ kg/m}$$

0.2.2. Statika.



$$Mu_{\text{Lap}} = 1/12 \cdot 2600 \cdot 5^2 = 5417 \text{ kgm (+)}$$

$$Mu_{\text{Tump}} = 1/18 \cdot 2600 \cdot 5^2 = 3611 \text{ kgm (-)}$$

$$Vu = 1/2 \cdot 2600 \cdot 5 = 6500 \text{ kg}$$

0.2.3. Penulangan.

a. Lapangan.

$$Mu = 5417 \text{ kgm} = 54,17 \text{ kNm} ; b = 200 \text{ mm}$$

$$d = 350 \text{ mm} ; \varphi = 0,8$$

$$R_n = \frac{54,17 \cdot 10^6}{0,8 \cdot 200 \cdot 350^2} = 2,7638 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 2,7638}{22,5}} \right) = 0,1333$$

$$\rho = 0,1333 \frac{22,5}{320} = 0,0094 > 0,0044$$

$$< 0,0248$$

$$As = 0,0094 \cdot 200 \cdot 350 = 656 \text{ mm}^2$$

$$As' = 0,4 \cdot 656 = 262 \text{ mm}^2$$



## b. Tumpuan.

$$\begin{aligned} \mu &= 3611 \text{ kgm} = 36,11 \text{ kNm} ; b = 200 \text{ mm} \\ d &= 350 \text{ mm} ; \phi = 0,8 \end{aligned}$$

$$R_n = \frac{36,11 \cdot 10^6}{0,8 \cdot 200 \cdot 350^2} = 1,8423 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 1,8423}{22,5}} \right) = 0,0863$$

$$\rho = 0,0863 \frac{22,5}{320} = 0,0061 > 0,0044$$

$$< 0,0246$$

$$A_s = 0,0061 \cdot 200 \cdot 350 = 425 \text{ mm}^2$$

$$A_s' = 0,2 \cdot 425 = 85 \text{ mm}^2$$

## c. Geser.

$$\begin{aligned} V_u &= 6500 \text{ kg} ; b = 200 \text{ mm} ; d = 350 \text{ mm} \\ \phi &= 0,6 ; V_c = 5534 \text{ kg} ; V_n = 10833 \text{ kg} \end{aligned}$$

$V_n > V_c \rightarrow$  perlu tulang geser.

$$V_s = 5299 \text{ kg} ; V_{s1} = 4206 \text{ kg} ; V_{s2} = 2458 \text{ kg}$$

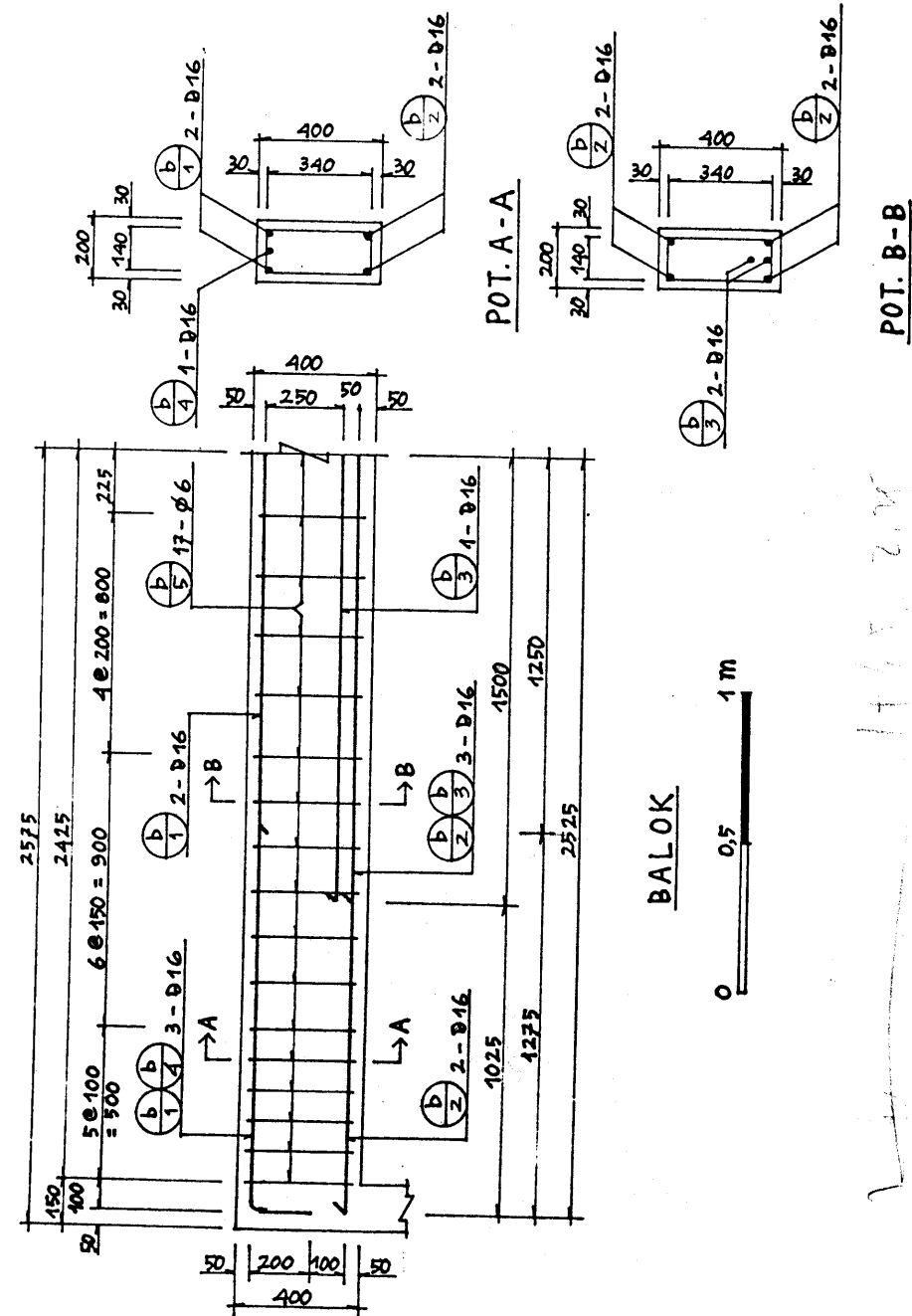
- sengkang :  $\phi 6 - 100 \rightarrow L_1 = 50 \text{ cm}$

- sengkang :  $\phi 6 - 150 \rightarrow L_2 = 80 \text{ cm}$

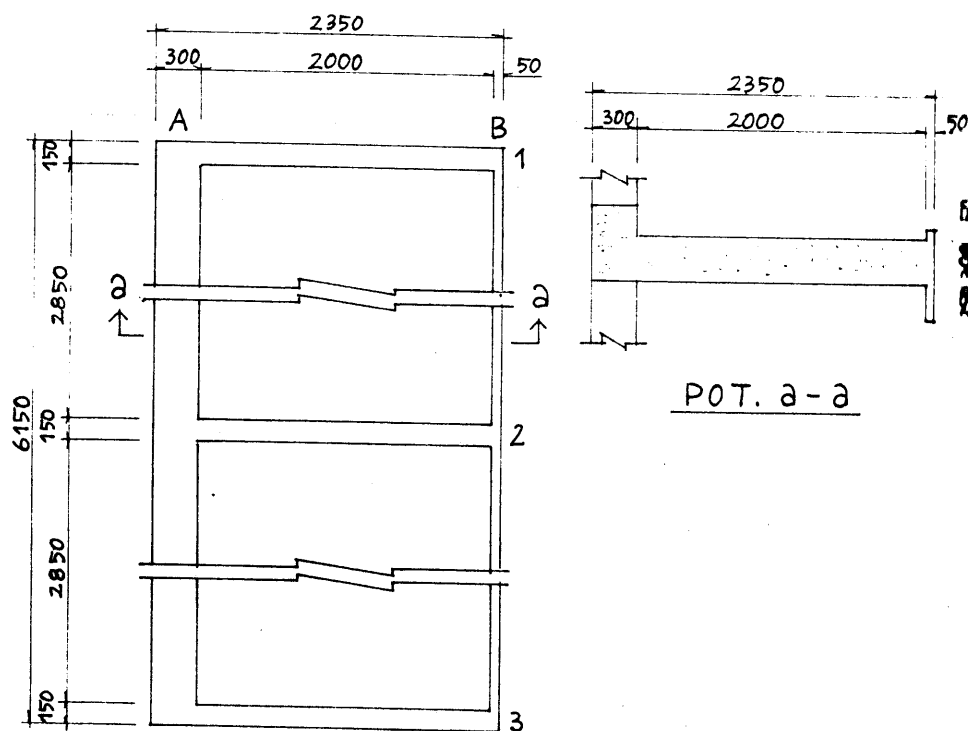
- sengkang :  $\phi 6 - 200 \rightarrow L_3 = 112,5 \text{ cm}$

Rekapitulasi :

	Elastis	SK SNI 1991
	mm <sup>2</sup>	mm <sup>2</sup>
Lapangan :		
tulang bawah	760	656 $\rightarrow 4 - D16$
tulang atas	304	262 $\rightarrow 2 - D16$
Tumpuan :		
tulang atas	493	425 $\rightarrow 3 - D16$
tulang bawah	99	85 $\rightarrow 2 - D16$
Geser :		$\phi 6 - (100 ; 150 ; 200)$



10. Balok kantilever seperti gambar terlampir, mempunyai data sebagai berikut :
- penutup atap dari seng gelombang  
tinggi air hujan = 5 cm  
beban guna =  $100 \text{ kg/m}^2$   
ukuran balok =  $15/30 \text{ cm}^2$   
beton K 225 ; besi tulangan U 32  
Hitung penulangan balok pada pembebanan tetap.



DENAH

### 10.1. ELASTIS.

$$\begin{aligned} \text{K 225} &\rightarrow \bar{\sigma}_b' = 75 \text{ kg/cm}^2 ; n = 21 \\ \bar{\tau}_{bt} &= 6,5 \text{ kg/cm}^2 ; \bar{\tau}_{bs} = 10 \text{ kg/cm}^2 \\ \bar{\tau}_{bm,t} &= 16 \text{ kg/cm}^2 ; \varphi_0 = 1,175 \\ \text{U 32} &\rightarrow \bar{\sigma}_a = 1850 \text{ kg/cm}^2 \end{aligned}$$

#### 10.1.1. Pembebanan.

##### a. Balok 1-A-B & 3-A-B.

##### a.1. Beban terbagi rata.

$$\begin{aligned} \text{seng gelombang} &= 1,5 \cdot 20 = 30 \text{ kg/m} \\ \text{air hujan} &= 0,05 \cdot 1000 \cdot 1,5 = 75 \\ \text{balok} &= 0,15 \cdot 0,30 \cdot 2400 = 108 \\ \text{plafon} &= 1,5 \cdot 15 = 23 \\ \text{beban guna} &= 1,5 \cdot 100 = 150 \end{aligned}$$

---


$$w_1 = 390 \text{ kg/m}$$

##### a.2. Beban terpusat.

$$\text{plasias : } P_1 = 0,05 \cdot 0,6 \cdot 2400 \cdot 1,5 = 110 \text{ kg}$$

##### b. Balok 2-A-B.

##### b.1. Beban terbagi rata.

$$\begin{aligned} \text{seng gelombang} &= 3 \cdot 20 = 60 \text{ kg/m} \\ \text{air hujan} &= 0,05 \cdot 1000 \cdot 3 = 150 \\ \text{balok} &= 0,15 \cdot 0,30 \cdot 2400 = 108 \\ \text{plafon} &= 3 \cdot 15 = 23 \\ \text{beban guna} &= 3 \cdot 100 = 300 \end{aligned}$$

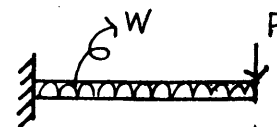
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$$w_2 = 665 \text{ kg/m}$$

##### b.2. Beban terpusat.

$$\text{plasias : } P_2 = 0,05 \cdot 0,6 \cdot 2400 \cdot 3 = 220 \text{ kg}$$

#### 10.1.2. Statika.



a. Balok 1-A-B & 3-A-B.

$$M = 1/2 \cdot 390 \cdot 2^2 + 110 \cdot 2 = 1000 \text{ kgm } (-)$$

$$Q = 390 \cdot 2 + 110 = 690 \text{ kg}$$

b. Balok 2-A-B.

$$M = 1/2 \cdot 665 \cdot 2^2 + 220 \cdot 2 = 1770 \text{ kgm } (-)$$

$$Q = 665 \cdot 2 + 220 = 1550 \text{ kg}$$

10.1.3. Penulangan.

a. Balok 1-A-B & 3-A-B.

a.1. Tumpuan.

$$M = 1000 \text{ kgm} ; b = 15 \text{ cm}$$

$$d = 30 - 5 = 25 \text{ cm}$$

$$Ca = \frac{25}{\sqrt{\frac{21 \cdot 1000}{0,15 \cdot 1850}}} = 2,874$$

$$\text{tulangan rangkap} : \delta = 0,2 \rightarrow$$

$$\phi = 1,532 > \phi_0 ; \phi' = 2,051$$

$$nw = 0,143$$

$$\sigma_b' = \frac{1850}{21 \cdot 1,532} = 58 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$\sigma_a = \frac{1850}{2,051} = 902 \text{ kg/cm}^2 < \bar{\sigma}_a$$

$$As = \frac{0,143}{21} 15 \cdot 25 = 2,55 \text{ cm}^2$$

$$As' = 0,2 \cdot 2,55 = 0,51 \text{ cm}^2$$

$$As_{\min} = \frac{12}{2780} 15 \cdot 25 = 1,62 \text{ cm}^2$$

a.2. Geser.

$$Q = 890 \text{ kg} ; b = 15 \text{ cm} ; d = 25 \text{ cm}$$

$$\tau_b = \frac{8 \cdot 890}{7 \cdot 15 \cdot 25} = 2,71 \text{ kg/cm}^2 < 6,5 \text{ kg/cm}^2$$

→ tanpa tulang geser (sengkang praktis).

b. Balok 2-A-B.

b.1. Tumpuan.

$$M = 1770 \text{ kgm} ; b = 15 \text{ cm} ; d = 25 \text{ cm}$$

$$Ca = \frac{25}{\sqrt{\frac{21 \cdot 1770}{0,15 \cdot 1850}}} = 2,160$$

$$\text{tulangan rangkap} : \delta = 0,4 \rightarrow$$

$$\phi = 1,222 > \phi_0 ; \phi' = 1,571$$

$$nw = 0,247$$

$$\sigma_b' = \frac{1850}{21 \cdot 1,222} = 72 \text{ kg/cm}^2 < \bar{\sigma}_b'$$

$$\sigma_a = \frac{1850}{1,571} = 1178 \text{ kg/cm}^2 < \bar{\sigma}_a$$

$$As = \frac{0,247}{21} 15 \cdot 25 = 4,41 \text{ cm}^2$$

$$As' = 0,4 \cdot 4,41 = 1,76 \text{ cm}^2$$

$$As_{\min} = 1,62 \text{ cm}^2$$

b.2. Geser.

$$Q = 1550 \text{ kg} ; b = 15 \text{ cm} ; d = 25 \text{ cm}$$

$$\tau_b = \frac{8 \cdot 1550}{7 \cdot 15 \cdot 25} = 4,72 \text{ kg/cm}^2 < 6,5 \text{ kg/cm}^2$$

→ tanpa tulang geser (sengkang praktis).

10.2. SK SNI 1991.

$$K 225 \rightarrow f_c' = 225 \text{ kg/cm}^2 = 22,5 \text{ MPa}$$

$$U 32 \rightarrow f_y = 3200 \text{ kg/cm}^2 = 320 \text{ MPa}$$

$$\rho_{\min} = \frac{1,4}{320} = 0,0044$$

$$\rho_{\max} = 0,75 \frac{0,85 \cdot 22,5}{320} 0,85 \frac{600}{600 + 320} = 0,0246$$

10.2.1. Pembebanan.

a. Balok 1-A-B & 3-A-B.

a.1. Beban terbagi rata.

a.1.1. Beban mati.

$$\text{seng gelombang} = 1,5 \cdot 20 = 30 \text{ kg/m}$$

$$\text{balok} = 0,15 \cdot 0,30 \cdot 2400 = 108$$

$$\text{plafon} = 1,5 \cdot 15 = 23$$

$$w_1 = 161 \text{ kg/m}$$

a.1.2. Beban hidup.

$$\text{air hujan} = 0,05 \cdot 1000 \cdot 1,5 = 75 \text{ kg/m}$$

$$\text{beban guna} = 1,5 \cdot 1000 = 150$$

$$w_2 = 225 \text{ kg/m}$$

a.1.3. Beban berfaktor.

$$Wu_1 = 1,2 \cdot 161 + 1,6 \cdot 225 = 555 \text{ kg/m}$$

a.2. Beban terpusat.

$$P_1 = 0,05 \cdot 0,6 \cdot 2400 \cdot 1,5 = 110 \text{ kg}$$

a.2.1. Beban berfaktor.

$$Pu_1 = 1,2 \cdot 110 = 135 \text{ kg}$$

b. Balok 2-A-B.

b.1. Beban terbagi rata.

b.1.1. Beban mati.

$$\text{seng gelombang} = 3 \cdot 20 = 60 \text{ kg/m}$$

$$\text{balok} = 0,15 \cdot 0,30 \cdot 2400 = 108$$

$$\text{plafon} = 3 \cdot 15 = 45$$

$$w_3 = 213 \text{ kg/m}$$

b.1.2. Beban hidup.

$$\text{air hujan} = 0,05 \cdot 1000 \cdot 3 = 150 \text{ kg/m}$$

$$\text{beban guna} = 3 \cdot 100 = 300$$

$$w_4 = 450 \text{ kg/m}$$

b.1.3. Beban berfaktor.

$$Wu_2 = 1,2 \cdot 213 + 1,6 \cdot 450 = 980 \text{ kg/m}$$

b.2. Beban terpusat.

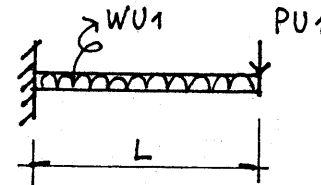
$$P_2 = 0,05 \cdot 0,6 \cdot 2400 \cdot 3 = 220 \text{ kg}$$

b.2.1. Beban berfaktor.

$$Pu_2 = 1,2 \cdot 220 = 265 \text{ kg}$$

10.2.2. Statika.

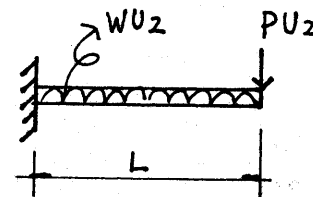
a. Balok 1-A-B & 3-A-B.



$$Mu = 1/2 \cdot 555 \cdot 2^2 + 135 \cdot 2 = 1380 \text{ kgm (-)}$$

$$Vu = 555 \cdot 2 + 135 = 1245 \text{ kg}$$

b. Balok 2-A-B.



$$Mu = 1/2 \cdot 980 \cdot 2^2 + 265 \cdot 2 = 2490 \text{ kgm (-)}$$

$$Vu = 980 \cdot 2 + 265 = 2225 \text{ kg}$$

10.2.3. Penulangan.

a. Balok 1-A-B & 3-A-B.

a.1. Tumpuan.

$$Mu = 1380 \text{ kgm} = 13,80 \text{ kNm} ; b = 150 \text{ mm}$$

$$d = 300 - 50 = 250 \text{ mm} ; \rho = 0,8$$

$$Rn = \frac{13,80 \cdot 10^6}{0,8 \cdot 150 \cdot 250^2} = 1,84 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 1,84}{22,5}} \right) = 0,0861$$

$$\rho = 0,0861 \frac{22,5}{320} = 0,0061 > 0,0044$$

$$< 0,0246$$

$$As = 0,0061 \cdot 150 \cdot 250 = 227 \text{ mm}^2$$

$$As' = 0,2 \cdot 227 = 45 \text{ mm}^2$$

#### a.2. Geser.

$$Vu = 1245 \text{ kg} ; b = 150 \text{ mm}$$

$$d = 250 \text{ mm} ; \phi = 0,6$$

$$Vc = 1/6 \sqrt{22,5} \cdot 150 \cdot 250 \cdot 10^{-3} = 29,65 \text{ kN}$$

$$= 2965 \text{ kg}$$

$$Vn = \frac{Vu}{\phi} = \frac{1245}{0,6} = 2075 \text{ kg} < Vc \rightarrow$$

sengkanng praktis.

#### b. Balok 2-A-B.

##### b.1. Tumpuan.

$$Mu = 2490 \text{ kgm} = 24,90 \text{ kNm} ; b = 150 \text{ mm}$$

$$d = 250 \text{ mm} ; \phi = 0,8$$

$$Rn = \frac{24,90 \cdot 10^6}{0,8 \cdot 150 \cdot 250^2} = 3,32 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 3,32}{22,5}} \right) = 0,1632$$

$$\rho = 0,1632 \frac{22,5}{320} = 0,0115 > 0,0044$$

$$< 0,0246$$

$$As = 0,0115 \cdot 150 \cdot 250 = 431 \text{ mm}^2$$

$$As' = 0,4 \cdot 431 = 173 \text{ mm}^2$$

##### b.2. Geser.

$$Vu = 2225 \text{ kg} ; b = 150 \text{ mm}$$

$$d = 250 \text{ mm} ; \phi = 0,6$$

$$Vc = 2965 \text{ kgm}$$

$$Vn = \frac{Vu}{\phi} = \frac{2225}{0,6} = 3708 \text{ kg} > Vc \rightarrow$$

perlu tulang geser.

$$Vs = 3708 - 2965 = 743 \text{ kg}$$

$$- \text{sengkanng} : \phi 6 \rightarrow Av = 0,57 \text{ cm}^2 \text{ (2 kaki)}$$

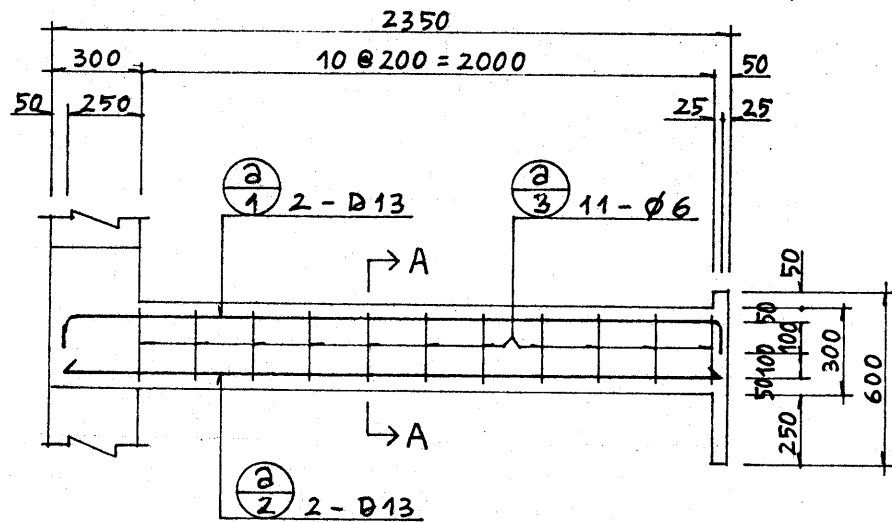
$$fy = 3200 \text{ kg/cm}^2 ; s = 20 \text{ cm}$$

$$Vsa = \frac{Av fy d}{s} = \frac{0,57 \cdot 3200 \cdot 25}{20}$$

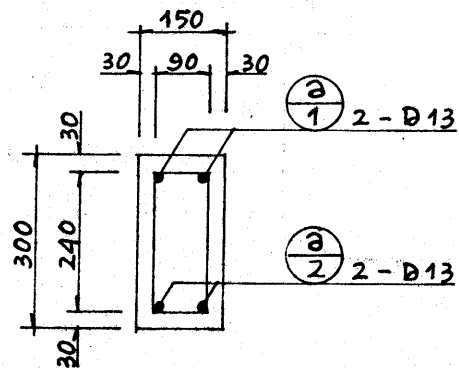
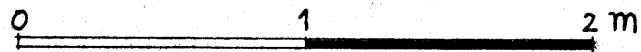
$$= 2280 \text{ kg} > Vs = 743 \text{ kg} \rightarrow \text{ok}$$

Rekapitulasi :

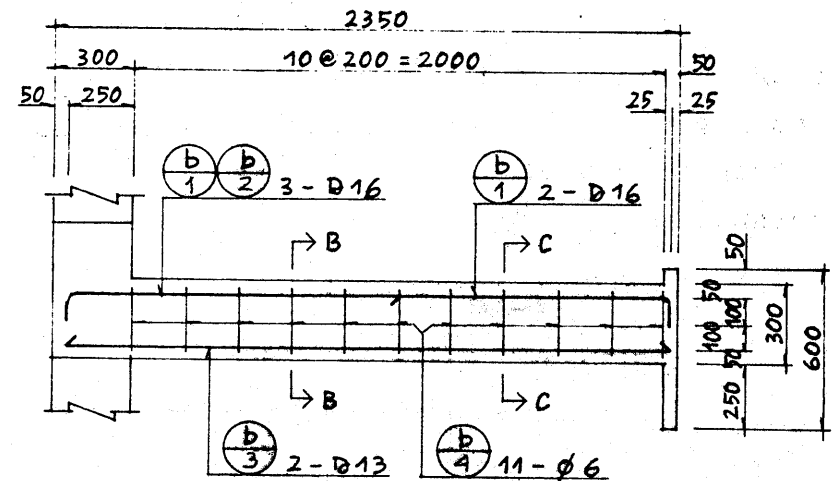
	Elastis	SK SNI 1991
	mm <sup>2</sup>	mm <sup>2</sup>
Balok 1-A-B & 3-A-B		
Tumpuan :		
tulang atas	255	227 → 2 - D13
tulang bawah	51	45 → 2 - D13
Geser :		φ 6 - 200
Balok 2-A-B		
Tumpuan :		
tulang atas	441	431 → 3 - D16
tulang bawah	176	173 → 2 - D13
Geser :		φ 6 - 200



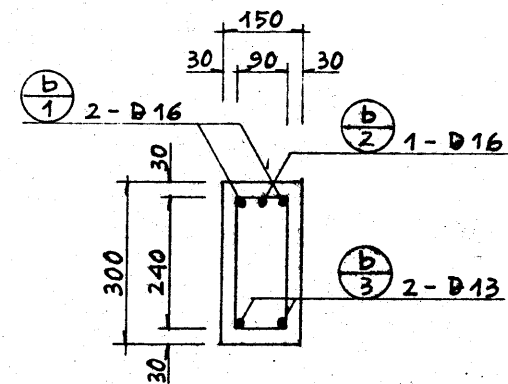
BALOK 1-A-B & 3-A-B



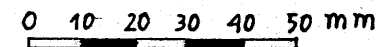
POT. A-A



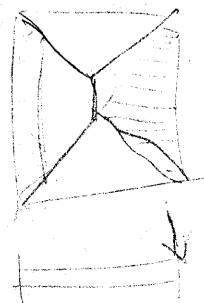
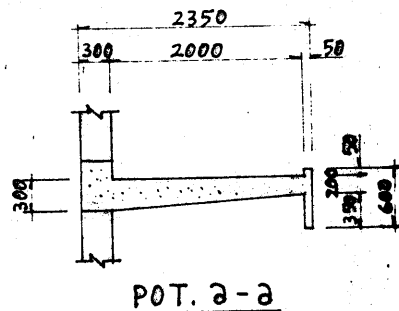
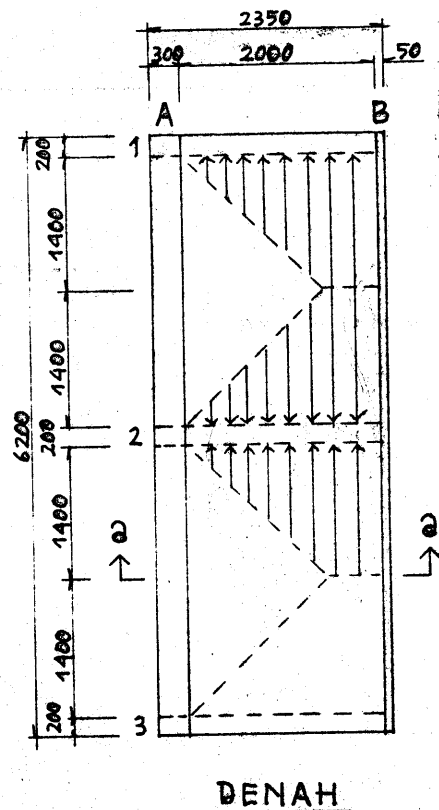
BALOK 2-A-B



POT. B-B



11. Balok kantilever seperti gambar terlampir mempunyai data sebagai berikut :
- tebal pelat = 8 cm ; beton K 200  
tinggi air hujan = 5 cm ; besi tulangan U 24  
beban guna = 100 kg/m<sup>2</sup>  
Hitung penulangan balok tersebut pada pembebanan tetap.



### 11.1. ELASTIS.

$$\begin{aligned} K 200 &\rightarrow \bar{\sigma}_b' = 0,33 \cdot 200 = 66 \text{ kg/cm}^2 \\ \bar{\tau}_{bt} &= 0,43 \sqrt{200} = 6,08 \text{ " } \\ \bar{\tau}_{bs} &= 0,68 \sqrt{200} = 9,62 \text{ " } \\ \bar{\tau}_{bm,t} &= 1,08 \sqrt{200} = 15,27 \text{ " } \\ n &= \frac{300}{\sqrt{200}} = 23 \end{aligned}$$

$$U 24 \rightarrow \bar{\sigma}_a = 1400 \text{ kg/cm}^2$$

$$\rho_0 = \frac{1400}{23 \cdot 66} = 0,922$$

#### 11.1.1. Pembebanan.

##### a. Balok 1-A-B dan 3-A-B.

##### a.1. Beban terbagi rata.

$$\text{pelat} = 0,08 \cdot 0,9 \cdot 1,5 \cdot 2400 = 260 \text{ kg/m}$$

$$\text{air hujan} = 0,05 \cdot 0,9 \cdot 1,5 \cdot 1000$$

$$= 68$$

$$\text{balok} = 1/2 (0,3 + 0,2) 0,2 \cdot 2400$$

$$= 120$$

$$\text{beban guna} = 0,9 \cdot 1,5 \cdot 100 = 135$$

$$w_1 = 590 \text{ kg/m}$$

##### a.2. Beban terpusat.

$$\text{plasia} : P_1 = 0,05 \cdot 0,6 \cdot 1,5 \cdot 2400 = 110 \text{ kg}$$

##### b. Balok 2-A-B.

##### b.1. Beban terbagi rata.

$$\text{pelat} = 0,08 \cdot 0,9 \cdot 1,5 \cdot 2 \cdot 2400 = 516 \text{ kg/m}$$

$$\text{air hujan} = 0,05 \cdot 0,9 \cdot 1,5 \cdot 2 \cdot 1000$$

$$= 135$$

$$\text{balok} = 1/2 (0,3 + 0,2) 0,2 \cdot 2400$$

$$= 120$$

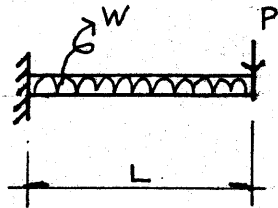
$$\text{beban guna} = 0,9 \cdot 1,5 \cdot 2 \cdot 100 = 270$$

$$w_2 = 1045 \text{ kg/m}$$

### b.2. Beban terpusat.

$$\text{plasia : } P_z = 0,05 \cdot 0,6 \cdot 1,5 \cdot 2 \cdot 2400 \\ = 220 \text{ kg}$$

#### 11.1.2. Statika.



##### a. Balok 1-A-B dan 3-A-B.

$$M = 1/2 \cdot 590 \cdot 2^2 + 110 \cdot 2 = 1400 \text{ kgm (-)}$$

$$Q = 590 \cdot 2 + 110 = 1290 \text{ kg}$$

##### b. Balok 3-A-B.

$$M = 1/2 \cdot 1045 \cdot 2^2 + 220 \cdot 2 = 2530 \text{ kgm (-)}$$

$$Q = 1045 \cdot 2 + 220 = 2310 \text{ kg}$$

#### 11.1.3. Penulangan.

##### a. Balok 1-A-B dan 3-A-B.

###### a.1. Tumpuan.

$$M = 1400 \text{ kgm} ; b = 20 \text{ cm}$$

$$d = 30 - 5 = 25 \text{ cm}$$

$$C_a = \frac{25}{\sqrt{\frac{23 \cdot 1400}{0,2 \cdot 1400}}} = 2,331$$

$$\text{tulangan rangkap : } \delta = 0,2 \rightarrow$$

$$\phi = 1,198 > \phi_o$$

$$\phi' = 1,535$$

$$n_w = 0,218$$

$$\sigma_{b'} = \frac{1400}{23 \cdot 1,198} = 51 \text{ kg/cm}^2 < \bar{\sigma}_{b'}$$

$$\sigma_a = \frac{1400}{1,535} = 912 \text{ kg/cm}^2 < \bar{\sigma}_a$$

$$A_s = \frac{0,218}{23} 20 \cdot 25 = 4,74 \text{ cm}^2$$

$$A_s' = 0,2 \cdot 4,74 = 0,95 \text{ cm}^2$$

$$A_{s \text{ min}} = \frac{12}{2080} 20 \cdot 25 = 2,88 \text{ cm}^2$$

###### a.2. Geser.

$$Q = 1290 \text{ kg} ; b = 20 \text{ cm} ; d = 25 \text{ cm}$$

$$\tau_b = \frac{8 \cdot 1290}{7 \cdot 20 \cdot 25} = 2,95 \text{ kg/cm}^2 < 6,08 \text{ kg/cm}^2$$

→ sengkang praktis.

##### b. Balok 2-A-B.

###### b.1. Tumpuan.

$$M = 2530 \text{ kgm} ; b = 20 \text{ cm} ; d = 25 \text{ cm}$$

$$C_a = \frac{25}{\sqrt{\frac{23 \cdot 2530}{0,2 \cdot 1400}}} = 1,734$$

$$\text{tulangan rangkap : } \delta = 0,6 \rightarrow$$

$$\phi = 1,083 > \phi_o$$

$$\phi' = 1,368$$

$$n_w = 0,395$$

$$\sigma_{b'} = \frac{1400}{23 \cdot 1,083} = 56 \text{ kg/cm}^2 < \bar{\sigma}_{b'}$$

$$\sigma_a = \frac{1400}{1,368} = 1023 \text{ kg/cm}^2 < \bar{\sigma}_a$$

$$A_s = \frac{0,395}{23} 20 \cdot 25 = 8,59 \text{ cm}^2$$

$$A_s' = 0,6 \cdot 8,59 = 5,15 \text{ cm}^2$$

$$A_{s \text{ min}} = 2,88 \text{ cm}^2$$

###### b.2. Geser.

$$Q = 2310 \text{ kg} ; b = 20 \text{ cm} ; d = 25 \text{ cm}$$

$$\tau_b = \frac{8 \cdot 2310}{7 \cdot 20 \cdot 25} = 5,28 \text{ kg/cm}^2 < 6,08 \text{ kg/cm}^2$$

→ sengkang praktis.



## 11.2. SK SNI 1991.

$$K\ 200 \rightarrow f_c' = 200\text{ kg/cm}^2 = 20\text{ MPa}$$

$$U\ 24 \rightarrow f_y = 2400\text{ kg/cm}^2 = 240\text{ MPa}$$

$$\rho_{\min} = \frac{1,4}{240} = 0,0058$$

$$\rho_{\max} = 0,75 \frac{0,85 \cdot 20}{240} 0,85 \frac{600}{600 + 240} = 0,0328$$

### 11.2.1. Pembebanan.

#### a. Balok 1-A-B dan 3-A-B.

##### a.1. Beban terbagi rata.

###### a.1.1. Beban mati.

$$\text{pelat} = 260\text{ kg/m}$$

$$\text{balok} = 120$$

$$w_1 = 380\text{ kg/m}$$

##### a.1.2. Beban hidup.

$$\text{air hujan} = 68\text{ kg/m}$$

$$\text{beban guna} = 135$$

$$w_2 = 203\text{ kg/m}$$

##### a.1.3. Beban berfaktor.

$$Wu_1 = 1,2 \cdot 380 + 1,6 \cdot 203 = 780\text{ kg/m}$$

##### a.2. Beban terpusat.

###### a.2.1. Beban mati.

$$\text{plasias} : P_1 = 110\text{ kg}$$

##### a.2.2. Beban berfaktor.

$$Pu_1 = 1,2 \cdot 110 = 135\text{ kg}$$

#### b. Balok 2-A-B.

##### b.1. Beban terbagi rata.

###### b.1.1. Beban mati.

$$\text{pelat} = 518\text{ kg/m}$$

$$\text{balok} = 120$$

$$w_3 = 538\text{ kg/m}$$

##### b.1.2. Beban hidup.

$$\text{air hujan} = 135\text{ kg/m}$$

$$\text{beban guna} = 270$$

$$w_4 = 405\text{ kg/m}$$

##### b.1.3. Beban berfaktor.

$$Wu_2 = 1,2 \cdot 538 + 1,6 \cdot 405 = 1295\text{ kg/m}$$

##### b.2. Beban terpusat.

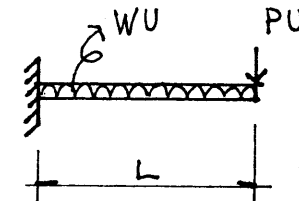
###### b.2.1. Beban mati.

$$\text{plasias} : P_2 = 220\text{ kg}$$

##### b.2.2. Beban berfaktor.

$$Puz = 1,2 \cdot 220 = 265\text{ kg}$$

### 11.2.2. Statika.



#### a. Balok 1-A-B dan 3-A-B.

$$Mu = 1/2 \cdot 780 \cdot 2^2 + 135 \cdot 2 = 1630\text{ kgm (-)}$$

$$Vu = 780 \cdot 2 + 135 = 1695\text{ kg}$$

#### b. Balok 2-A-B.

$$Mu = 1/2 \cdot 1295 \cdot 2^2 + 265 \cdot 2 = 3120\text{ kgm (-)}$$

$$Vu = 1295 \cdot 2 + 265 = 2855\text{ kg}$$

### 11.2.3. Penulangan.

#### a. Balok 1-A-B dan 3-A-B.

##### a.1. Tumpuan.

$$Mu = 1830\text{ kgm} = 18,30\text{ kNm} ; \phi = 0,8$$

$$b = 200\text{ mm} ; d = 300 - 50 = 250\text{ mm}$$

$$R_n = \frac{18,30 \cdot 10^6}{0,8 \cdot 200 \cdot 250^2} = 1,83\text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 1,83}{20}} \right) = 0,087$$

$$\rho = 0,087 \frac{20}{240} = 0,0081 > 0,0058$$

$$< 0,0323$$

$$A_s = 0,0081 \cdot 200 \cdot 250 = 404 \text{ mm}^2$$

$$A_s' = 0,2 \cdot 404 = 81 \text{ mm}^2$$

#### a.2. Geser.

$$V_u = 1695 \text{ kg} = 16,95 \text{ kN} ; b = 200 \text{ mm}$$

$$d = 250 \text{ mm} ; \phi = 0,6$$

$$V_c = 1/6 \sqrt{20} \cdot 200 \cdot 250 \cdot 10^{-9} = 37,27 \text{ kN}$$

$$= 3727 \text{ kg}$$

$$V_n = \frac{1695}{0,6} = 2825 \text{ kg} < V_c \rightarrow$$

senggang praktis.

#### b. Balok 2-A-B.

##### b.1. Tumpuan.

$$M_u = 3120 \text{ kgm} = 31,20 \text{ kNm} ; \phi = 0,8$$

$$b = 200 \text{ mm} ; d = 300 - 50 = 250 \text{ mm}$$

$$R_n = \frac{31,20 \cdot 10^6}{0,8 \cdot 200 \cdot 250^2} = 3,12 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 3,12}{20}} \right) = 0,1738$$

$$\rho = 0,1738 \frac{20}{240} = 0,0145 > 0,0058$$

$$< 0,0323$$

$$A_s = 0,0145 \cdot 200 \cdot 250 = 724 \text{ mm}^2$$

$$A_s' = 0,2 \cdot 724 = 145 \text{ mm}^2$$

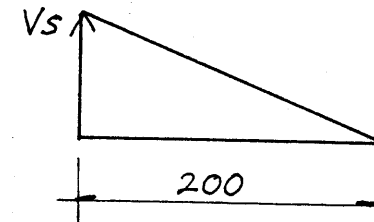
##### b.2. Geser.

$$V_u = 2855 \text{ kg} = 28,55 \text{ kN} ; b = 200 \text{ mm}$$

$$d = 250 \text{ mm} ; \phi = 0,6 ; V_c = 3727 \text{ kg}$$

$$V_n = \frac{2855}{0,6} = 4758 \text{ kg} > V_c \rightarrow$$

perlu tulang geser.



$$V_s = 4758 - 3727 = 1031 \text{ kg}$$

- sengkang :  $\phi 6 \rightarrow$

$$A_v = 0,57 \text{ mm}^2 \text{ (2 kaki)}$$

$$f_y = 2400 \text{ kg/cm}^2$$

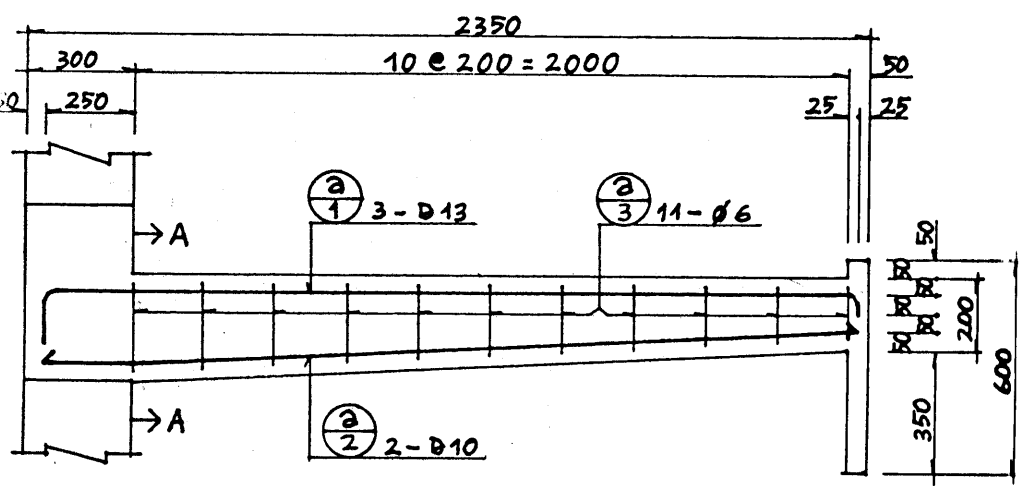
$$s = 20 \text{ cm (jarak sengkang)}$$

$$V_{sa} = \frac{0,57 \cdot 2400 \cdot 25}{20} = 1710 \text{ kg} > V_s \rightarrow \text{ok}$$

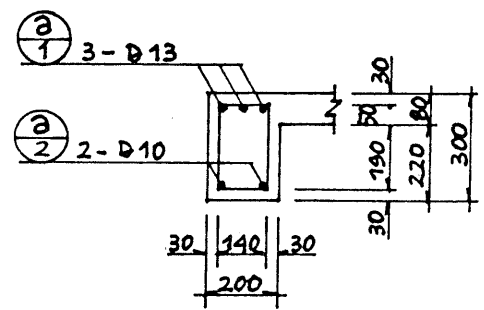
Rekapitulasi :

	ELASTIS	SK SNI 1991
	mm <sup>2</sup>	mm <sup>2</sup>
Balok 1-A-B & 3-A-B		
Tumpuan :		
tulang atas	474	300 $\rightarrow$ 3 - D13
tulang bawah	95	60 $\rightarrow$ 2 - D10
Geser :		$\phi 6 - 200$
Balok 2-A-B		
Tumpuan :		
tulang atas	859	724 $\rightarrow$ 6 - D13
tulang bawah	515	145 $\rightarrow$ 2 - D13
Geser :		$\phi 6 - 200$

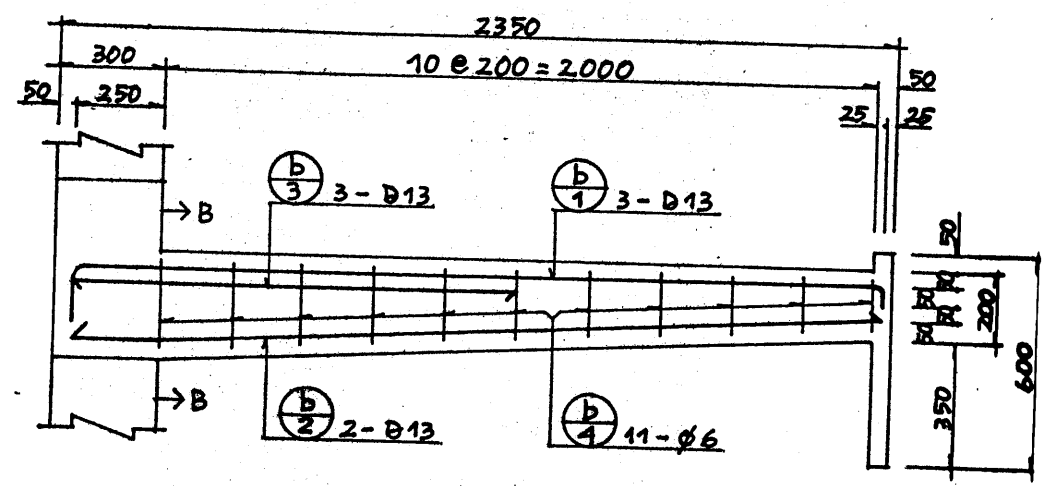
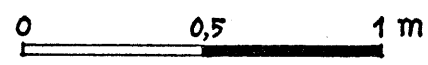
$$1710 \rightarrow \phi 8 - 200 = 4265 > 1710$$



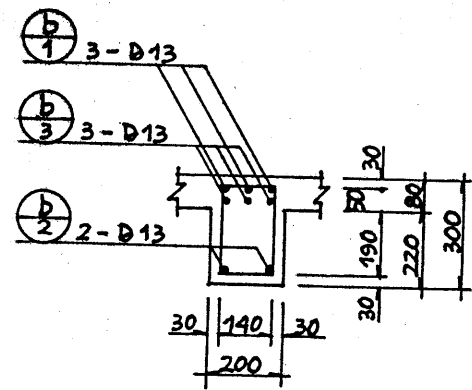
BALOK 1-A-B & 3-A-B



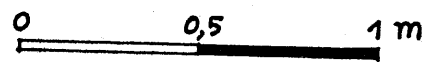
POT. A-A



BALOK 2-A-B

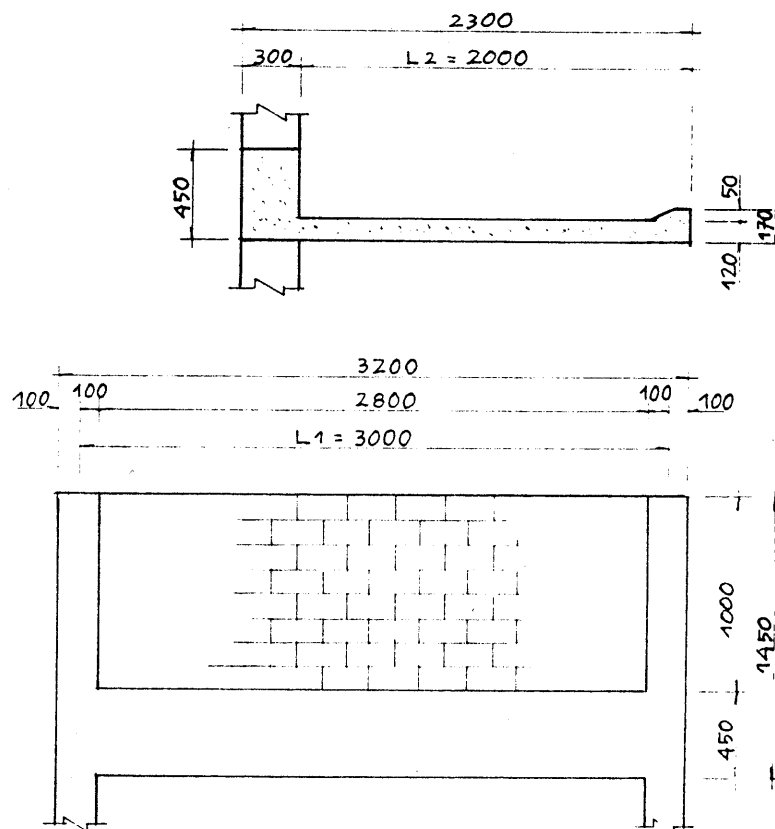


POT. B-B



$A_v = \frac{(V_u / 2) - 1.5}{f_y}$   
 $= 0$

12. Balok kantilever seperti gambar terlampir mempunyai data sebagai berikut :
- tebal pelat = 8 cm ; beton K 200
- tinggi air hujan = 5 cm ; besi tulangan U 24
- beban guna = 100 kg/m<sup>2</sup>
- Hitung penulangan balok tersebut pada pembebanan tetap.



### 12.1. ELASTIS.

K 200  $\rightarrow \bar{\sigma}_b' = 75 \text{ kg/cm}^2$  ;  $n = 21$

Geser lentur : Geserlentur dengan puntir :

$\bar{\tau}_{bt} = 6,5 \text{ kg/cm}^2$

$\bar{\tau}_{bs} = 10 \text{ kg/cm}^2$

$\bar{\tau}_{bm,t} = 16 \text{ kg/cm}^2$

$\bar{\tau}_{bt} = 8 \text{ kg/cm}^2$

$\bar{\tau}_{bs} = 13 \text{ kg/cm}^2$

$\bar{\tau}_{bm,t} = 20 \text{ kg/cm}^2$

U 24  $\rightarrow \bar{\sigma}_a = 1400 \text{ kg/cm}^2$

$\phi_0 = \frac{1400}{21 \cdot 75} = 0,889$

#### 12.1.1. Pembebanan.

##### a. Pelat leufel.

pelat =  $\frac{0,12 + 0,17}{2} \cdot 2400 = 348 \text{ kg/m}^2$

air hujan =  $0,05 \cdot 1000 = 50$

beban guna = 100

$w_1 = 500 \text{ kg/m}^2$

##### b. Balok latei.

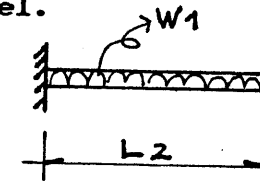
balok =  $0,30 \cdot 0,45 \cdot 2400 = 324 \text{ kg/m}$

dinding =  $1 \cdot 250 = 250$

$w_2 = 575 \text{ kg/m}$

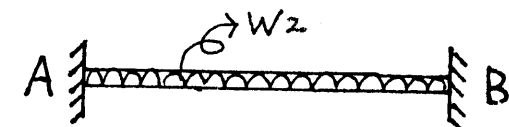
#### 12.1.2. Statika.

##### a. Pelat leufel.



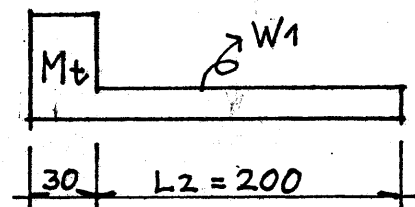
$M = 1/2 \cdot 500 \cdot 2^2 = 1000 \text{ kgm} (-)$

##### b. Balok latei.



$$M_{Lap} = 1/11. 575. 3^2 = 470 \text{ kgm (+)}$$

$$M_{Tump} = 1/16. 575. 3^2 = 288 \text{ kgm (-)}$$



$$Q = 1/2 w_2 L_1 = 1/2. 575. 3 = 863 \text{ kg}$$

$$m_t = w_1 L_2 \left( \frac{1}{2} L_2 + \frac{0,3}{2} \right)$$

$$= 500. 2 \left( \frac{1}{2}. 2 + \frac{0,3}{2} \right) = 1150 \text{ kgm/m}$$

$$M_{tA} = M_{tB} = m_t \frac{1}{2} L_1$$

$$= 1150. \frac{1}{2}. 3 = 1725 \text{ kgm}$$

### 12.1.3. Penulangan.

#### a. Pelat leufel.

$$M = 1000 \text{ kgm} ; b = 1 \text{ m}$$

$$d = 12 - 3 = 9 \text{ cm}$$

$$C_a = \frac{9}{\sqrt{\frac{21. 1000}{1. 1400}}} = 2,324$$

$$\text{tulangan tunggal} : \delta = 0 \rightarrow$$

$$\varphi = 1,088 > \varphi_0 ; n_w = 0,220$$

$$\sigma_{b'} = \frac{1400}{21. 1,088} = 61 \text{ kg/cm}^2 < \bar{\sigma}_b$$

$$A_s = \frac{0,220}{21} 100. 9 = 9,43 \text{ cm}^2$$

$$A_{s \min} = 0,25 \% 100. 12 = 3 \text{ cm}^2$$

$$A_s^o = 20 \% 9,43 = 1,89 \text{ cm}^2$$

#### b. Balok latei.

##### b.1. Lapangan.

$$M = 470 \text{ kgm} ; b = 30 \text{ cm}$$

$$d = 45 - 5 = 40 \text{ cm}$$

$$C_a = \frac{40}{\sqrt{\frac{21. 470}{0,3. 1400}}} = 8,251$$

$$\text{tulangan rangkap} : \delta = 0,2 \rightarrow$$

$$\varphi = 5,25 > \varphi_0$$

$$\varphi' = 14$$

$$n_w = 0,015$$

$$\sigma_{b'} = \frac{1400}{21. 5,25} = 13 \text{ kg/cm}^2 < \bar{\sigma}_b$$

$$\sigma_a = \frac{1400}{14} = 100 \text{ kg/cm}^2 < \bar{\sigma}_a$$

$$A_s = \frac{0,015}{21} 30. 40 = 0,86 \text{ cm}^2$$

$$A_{s'} = 0,2. 0,86 = 0,17 \text{ cm}^2$$

$$A_{s \min} = \frac{12}{2080} 30. 40 = 6,92 \text{ cm}^2$$

##### b.2. Tumpuan.

$$\text{sama dengan lapangan} : A_s = 0,86 \text{ cm}^2$$

$$A_{s'} = 0,17 \text{ cm}^2$$

$$A_{s \min} = 6,92 \text{ cm}^2$$

##### b.3. Geser.

$$Q = 863 \text{ kg} ; b = 30 \text{ cm} ; d = 40 \text{ cm}$$

$$\tau_b = \frac{8. 863}{7. 30. 40} = 0,82 \text{ kg/cm}^2 < 6,5 \text{ kg/cm}^2$$

$\rightarrow$  sengkang praktis.

##### b.4. Torsi.

$$M_{tA} = M_{tB} = 1725 \text{ kgm} ; b = 30 \text{ cm}$$

$$h = 45 \text{ cm}$$

$$h > b \rightarrow \chi = 3 + \frac{2,8}{0,45 + \frac{h}{b}}$$

$$= 3 + \frac{2,8}{0,45 + \frac{45}{30}} = 4,33$$

$$\tau_b' = \chi \frac{MtA}{h_b^2} = 4,33 \frac{172500}{45 \cdot 30^2}$$

$$= 18,44 \text{ kg/cm}^2$$

$$\tau_b + \tau_b' = 0,62 + 18,44$$

$$= 19,26 \text{ kg/cm}^2 > 8 \text{ kg/cm}^2$$

$$> 13 \quad "$$

$$< 20 \quad "$$

—> perlu tulang torsi.

Luas teras :

$$F_t = 24 \cdot 35 = 840 \text{ cm}^2$$

Keliling teras :

$$U_t = (24 + 35) 2 = 118 \text{ cm}$$

$$\tau_b'' = \frac{MtA}{b F_t}$$

$$= \frac{172500}{30 \cdot 840} = 6,85 \text{ kg/cm}^2$$

$$\tau_b + \tau_b'' = 0,82 + 6,85 = 7,67 \text{ kg/cm}^2$$

- sengkang :

$$\phi 8 \rightarrow A_s = 2,01 \text{ cm}^2 \text{ (4 kaki)}$$

$$s = 10 \text{ cm (jarak sengkang)}$$

$$b = 30 \text{ cm}$$

$$\tau_s = \frac{2,01 \cdot 1400}{30 \cdot 10}$$

$$= 9,38 \text{ kg/cm}^2 > 7,67 \text{ kg/cm}^2 \rightarrow \text{ok}$$

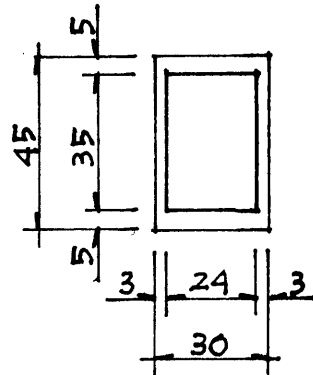
#### b.5. Tulangan memanjang.

$$MtA = MtB = 1725 \text{ kgm} ; U_t = 118 \text{ cm}$$

$$F_t = 840 \text{ cm}^2$$

$$A_s \text{ mem} = \frac{MtA U_t}{2 \sigma_a F_t} = \frac{172500 \cdot 118}{2 \cdot 1400 \cdot 840}$$

$$= 8,65 \text{ cm}^2$$



## 12.2. SK SNI 1991.

$$K 225 \rightarrow f_c' = 225 \text{ kg/cm}^2 = 22,5 \text{ MPa}$$

$$U 24 \rightarrow f_y = 2400 \text{ kg/cm}^2 = 240 \text{ MPa}$$

### 12.2.1. Pembebanan.

#### a. Pelat leufel.

##### a.1. Beban mati.

$$\text{pelat} : w_1 = 348 \text{ kg/m}^2$$

##### a.2. Beban hidup.

$$\text{air hujan} = 50 \text{ kg/m}^2$$

$$\text{beban guna} = 100$$

$$w_2 = 150 \text{ kg/m}^2$$

##### a.3. Beban berfaktor.

$$Wu_1 = 1,2 \cdot 348 + 1,6 \cdot 150 = 660 \text{ kg/m}^2$$

#### b. Balok latei.

##### b.1. Beban mati.

$$\text{dinding} = 250 \text{ kg/m}$$

$$\text{balok} = 324$$

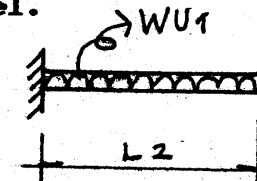
$$w_3 = 574 \text{ kg/m}$$

##### b.2. Beban berfaktor.

$$Wu_2 = 1,2 \cdot 574 = 690 \text{ kg/m}$$

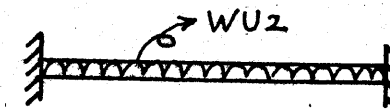
### 12.2.2. Statika.

#### a. Pelat leufel.



$$M_u = 1/2 \cdot 660 \cdot 2^2 = 1320 \text{ kgm (-)}$$

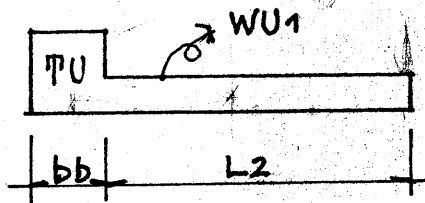
#### b. Balok latei.



$$Mu_{Lap} = 1/11. 690. 3^2 = 565 \text{ kgm (+)}$$

$$Mu_{Tump} = 1/18. 690. 3^2 = 345 \text{ kgm (-)}$$

$$Vu = 1/2. 690. 3 = 1035 \text{ kg}$$



$$mut = 660. 2 \left( \frac{1}{2} \cdot 2 + \frac{0,3}{2} \right) = 1518 \text{ kgm/m}$$

$$Tu = 1518 \cdot \frac{3}{2} = 2277 \text{ kgm}$$

### 12.2.3. Penulangan.

$$\rho_{min} = \frac{1,4}{240} = 0,0058$$

$$\rho_{maks} = 0,75 \cdot \frac{0,85 \cdot 22,5}{240} \cdot 0,85 \cdot \frac{600}{600 + 240} = 0,0362$$

#### a. Pelat leufel.

$$Mu = 1320 \text{ kgm} = 13,20 \text{ kNm} ; b = 1000 \text{ mm}$$

$$d = 120 - 30 = 90 \text{ mm} ; \phi = 0,8$$

$$Rn = \frac{13,20 \cdot 10^6}{0,8 \cdot 1000 \cdot 90^2} = 2,037 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 2,037}{22,5}} \right) = 0,096$$

$$\rho = 0,096 \cdot \frac{22,5}{240} = 0,009 > 0,0058 < 0,0362$$

$$As = 0,009 \cdot 1000 \cdot 90 = 810 \text{ mm}^2$$

#### b. Balok latei.

##### b.1. Lapangan.

$$Mu = 565 \text{ kgm} = 5,65 \text{ kNm} ; b = 300 \text{ mm}$$

$$d = 450 - 50 = 400 \text{ mm} ; \phi = 0,8$$

$$Rn = \frac{5,65 \cdot 10^6}{0,8 \cdot 300 \cdot 400^2} = 0,1471 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 0,1471}{22,5}} \right) = 0,0066$$

$$\rho = 0,0066 \cdot \frac{22,5}{240} = 0,0006 < 0,0058$$

$$As = 0,0006 \cdot 300 \cdot 400 = 696 \text{ mm}^2$$

$$As' = 0,2 \cdot 696 = 139 \text{ mm}^2$$

##### b.2. Tumpuan.

$$Mu = 345 \text{ kgm} = 3,45 \text{ kNm} ; b = 300 \text{ mm}$$

$$d = 400 \text{ mm} ; \phi = 0,8$$

$$Rn = \frac{3,45 \cdot 10^6}{0,8 \cdot 300 \cdot 400^2} = 0,0898 \text{ MPa}$$

$$W = 0,85 \left( 1 - \sqrt{1 - \frac{2,353 \cdot 0,0898}{22,5}} \right) = 0,004$$

$$\rho = 0,004 \cdot \frac{22,5}{240} = 0,0004 < 0,0058$$

$$As = 0,0004 \cdot 300 \cdot 400 = 696 \text{ mm}^2$$

$$As' = 0,2 \cdot 696 = 139 \text{ mm}^2$$

##### b.3. Geser lentur.

$$Vu = 1035 \text{ kg} = 10,35 \text{ kN} ; b = 0,3 \text{ m}$$

$$Tu = 2277 \text{ kgm} = 22,77 \text{ kNm} ; h = 0,45 \text{ m}$$

$$d = 0,4 \text{ m} ; \phi = 0,6$$

$$C_t = \frac{b d}{b^2 h} = \frac{d}{b h} = \frac{0,4}{0,3 \cdot 0,45} = 2,96 \text{ m}$$

$$V_c = \frac{1/6 \sqrt{f_c'} b d}{\sqrt{1 + (2,5 C_t \frac{T_u}{V_u})^2}}$$

$$= \frac{1/6 \sqrt{22,5 \cdot 300 \cdot 400 \cdot 10^{-9}}}{\sqrt{1 + (2,5 \cdot 2,96 \frac{22,77}{10,35})^2}}$$

$$= 5,81 \text{ kN} = 581 \text{ kg}$$

$$\phi V_c = 0,6 \cdot 851 = 349 \text{ kg} < V_u \rightarrow$$

perlu tulang geser.

$$V_s = 1035 - 349 = 686 \text{ kg}$$

- sengkang :  $s = 10 \text{ cm}$  (jarak sengkang)

$$d = 40 \text{ cm} ; f_y = 2400 \text{ kg/cm}^2$$

$$A_v = \frac{686 \cdot 10}{2400 \cdot 40} = 0,07 \text{ cm}^2 = 7 \text{ mm}^2$$

#### b. 4. Torsi.

$$b = x = 300 \text{ mm} ; h = y = 450 \text{ mm}$$

$$C_t = 2,96 \text{ m} ; T_u = 22,77 \text{ kNm}$$

$$V_u = 10,35 \text{ kN}$$

$$T_c = \frac{1/15 \sqrt{f_c'} \sum x^2 y}{\sqrt{1 + (0,4 \frac{V_u}{C_t T_u})^2}}$$

$$= \frac{1/15 \sqrt{22,5 \cdot 300^2 \cdot 450 \cdot 10^{-6}}}{\sqrt{1 + (0,4 \frac{10,35}{2,96 \cdot 22,77})^2}}$$

$$= 12,78 \text{ kNm} = 1278 \text{ kgm}$$

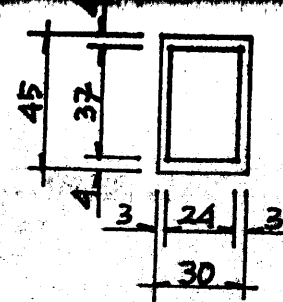
$$\phi T_c = 0,6 \cdot 1278 = 767 \text{ kgm}$$

$$T_s = T_u - \phi T_c = 2277 - 767 = 1510 \text{ kgm}$$

$$T_n = T_c + T_s = 1278 + 1510 = 2788 \text{ kgm}$$

$$\phi T_n = 0,6 \cdot 2788 = 1673 \text{ kgm} < T_u \rightarrow$$

perlu tulang torsi.



$$x_1 = 300 - 2 \cdot 30 = 240 \text{ mm} = 24 \text{ cm}$$

$$y_1 = 450 - 2 \cdot 40 = 370 \text{ mm} = 37 \text{ cm}$$

$$a_t = \frac{2 + \frac{y_1}{x_1}}{3} = \frac{2 + \frac{370}{240}}{3} = 1,18 < 1,5 \rightarrow \text{ok}$$

- sengkang :  $\phi 10 \rightarrow$

$$s = 10 \text{ cm (jarak sengkang)}$$

$$A_t = \frac{T_s \cdot s}{a_t x_1 y_1 f_y} = \frac{151000 \cdot 10}{1,18 \cdot 24 \cdot 37 \cdot 2400}$$

$$= 0,60 \text{ cm}^2 = 60 \text{ mm}^2$$

#### b. 5. Tulangan memanjang.

$$A_L = 2 A_t \left( \frac{x_1 + y_1}{s} \right)$$

$$= 2 \cdot 60 \left( \frac{240 + 370}{100} \right) = 732 \text{ mm}^2$$

$$A_v = \frac{V_u}{f_y} = \frac{1035}{2400} = 0,43$$

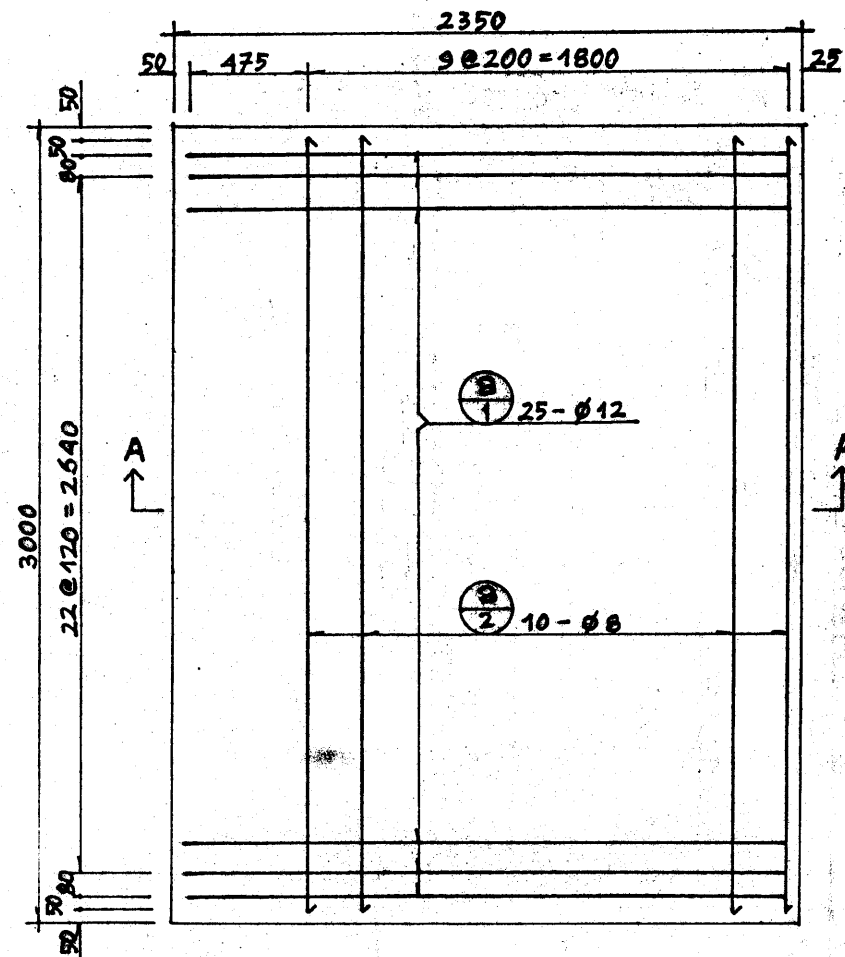
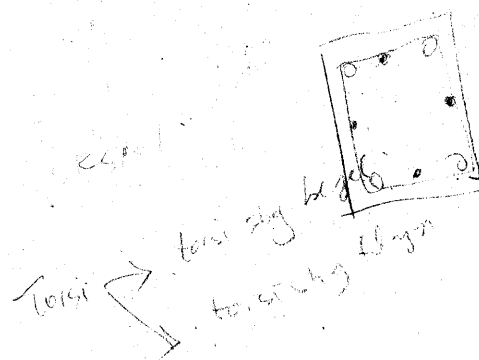
$$V_c = \frac{1}{6} \sqrt{f_c'} b d$$

$$V_s = 2 \cdot \frac{A_s \cdot f_y \cdot d}{s}$$

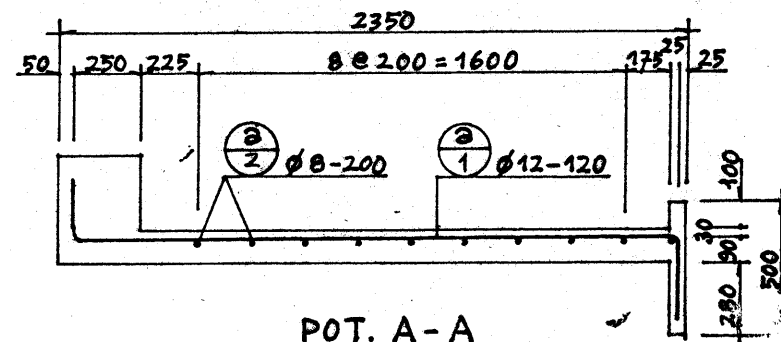


# Rekapitulasi :

	ELASTIS	SK SNI 1991
	mm <sup>2</sup>	mm <sup>2</sup>
	Pelat leufel	
Tumpuan :		
tulang atas	943	810 → $\phi$ 10 - 100
tulang bagi	189	240 → $\phi$ 8 - 200
	Balok latei	
Lapangan :		
tulang bawah	86	696 → 4 - D16
tulang atas	17	139 → 2 - D16
Tumpuan :		
tulang atas	86	696 → 4 - D16
tulang bawah	17	139 → 2 - D16
Tulangan memanjang	865	732 → 4 - D16
Geser torsi		$\phi$ 10 - 100

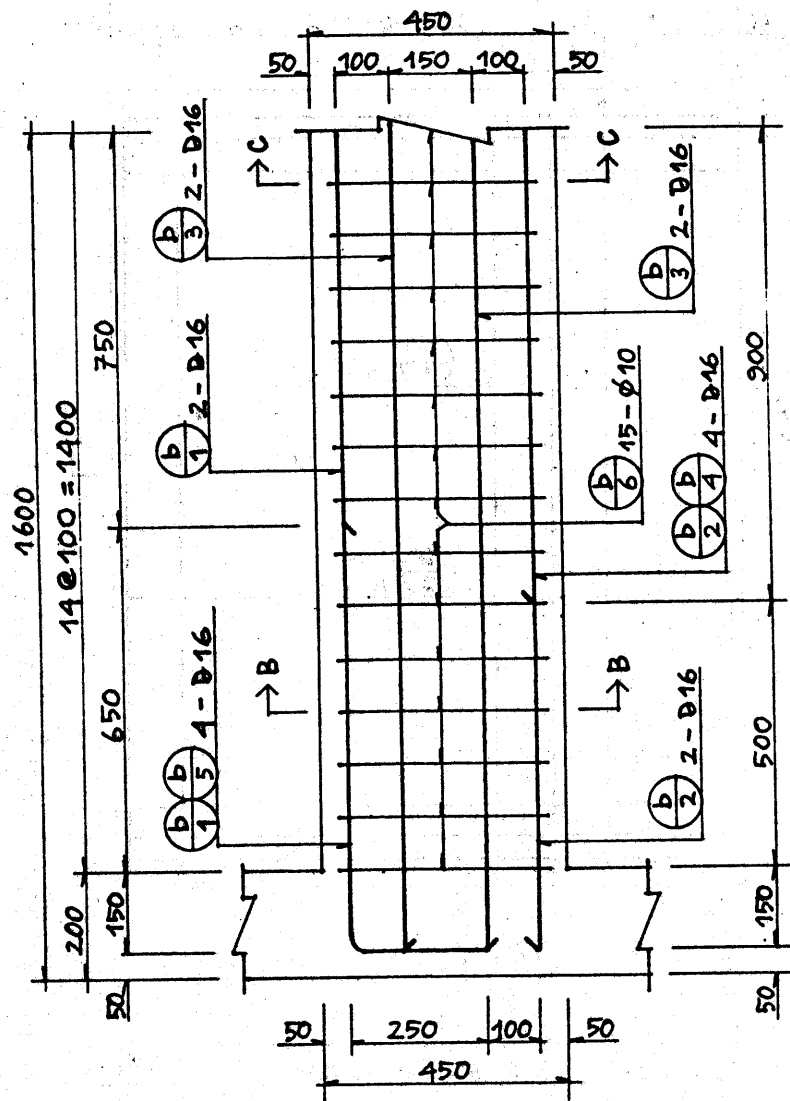


DENAH

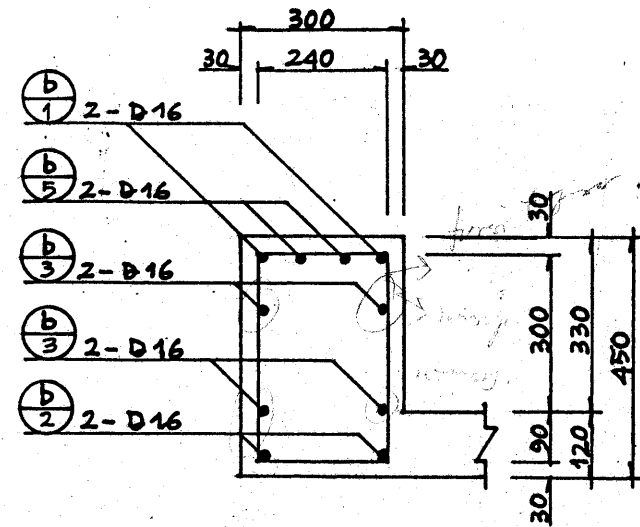


POT. A-A

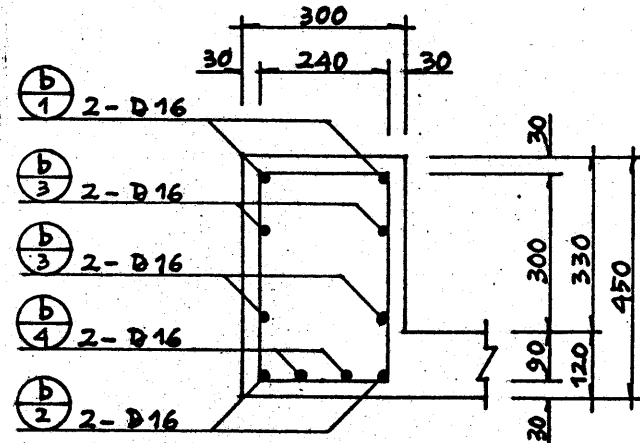




BALOK LATEI



POT. B-B



POT. C-C

