

BAB III
LANDASAN TEORI

3.1 Rumus Analisis Balok Persegi – Tulangan Tunggal

3.1.1 Keruntuhan Tarik (*under-reinforced*)

$$a = \frac{A_s f_y}{0.85 f_c' b} \quad (3.1)$$

$$M_n = A_s f_y \left(d - \frac{a}{2} \right) \quad (3.2)$$

$$M_n = A_s f_y \left(d - 0.59 \frac{A_s f_y}{f_c' b} \right) \quad (3.3)$$

$$\rho = \frac{A_s}{b.d} \quad (3.4)$$

$$M_n = \rho b d^2 f_y \left(1 - 0.59 \rho \frac{f_y}{f_c'} \right) \quad (3.5a)$$

$$\frac{M_n}{b d^2 f_c'} = \rho \frac{f_y}{f_c'} \left(1 - 0.59 \rho \frac{f_y}{f_c'} \right) \quad (3.5b)$$

3.1.2 Keruntuhan Balans

$$c_b = \left(\frac{600}{600 + f_y} \right) d \quad (3.6)$$

$$a_b = \beta_1 \left(\frac{600}{600 + f_y} \right) d \quad (3.7)$$

$$A_{s_b} = \beta_1 \frac{f_c'}{f_y} \left(\frac{510}{600 + f_y} \right) \quad (3.8)$$

$$A_{s_{maks}} = 0.75 A_{s_b} = \beta_1 \frac{f_c'}{f_y} b d \left(\frac{382.5}{600 + f_y} \right) \quad (3.9)$$

3.1.3 Keruntuhan Tekan (*over-reinforced*)

$$f_s = \varepsilon_{cu} \left(\frac{d}{c} - 1 \right) E_s \quad (3.10a)$$

$$f_s = \varepsilon_{cu} \left(\frac{\beta_1 d}{a} - 1 \right) E_s \quad (3.10b)$$

$$0.85 f_c' ab = A_s \varepsilon_{cu} \left(\frac{\beta_1 d}{a} - 1 \right) E_s \quad (3.11a)$$

$$\left(\frac{0.85 f_c' b}{A_s \varepsilon_{cu} E_s} \right) = a^2 + a - \beta_1 d = 0 \quad (3.11b)$$

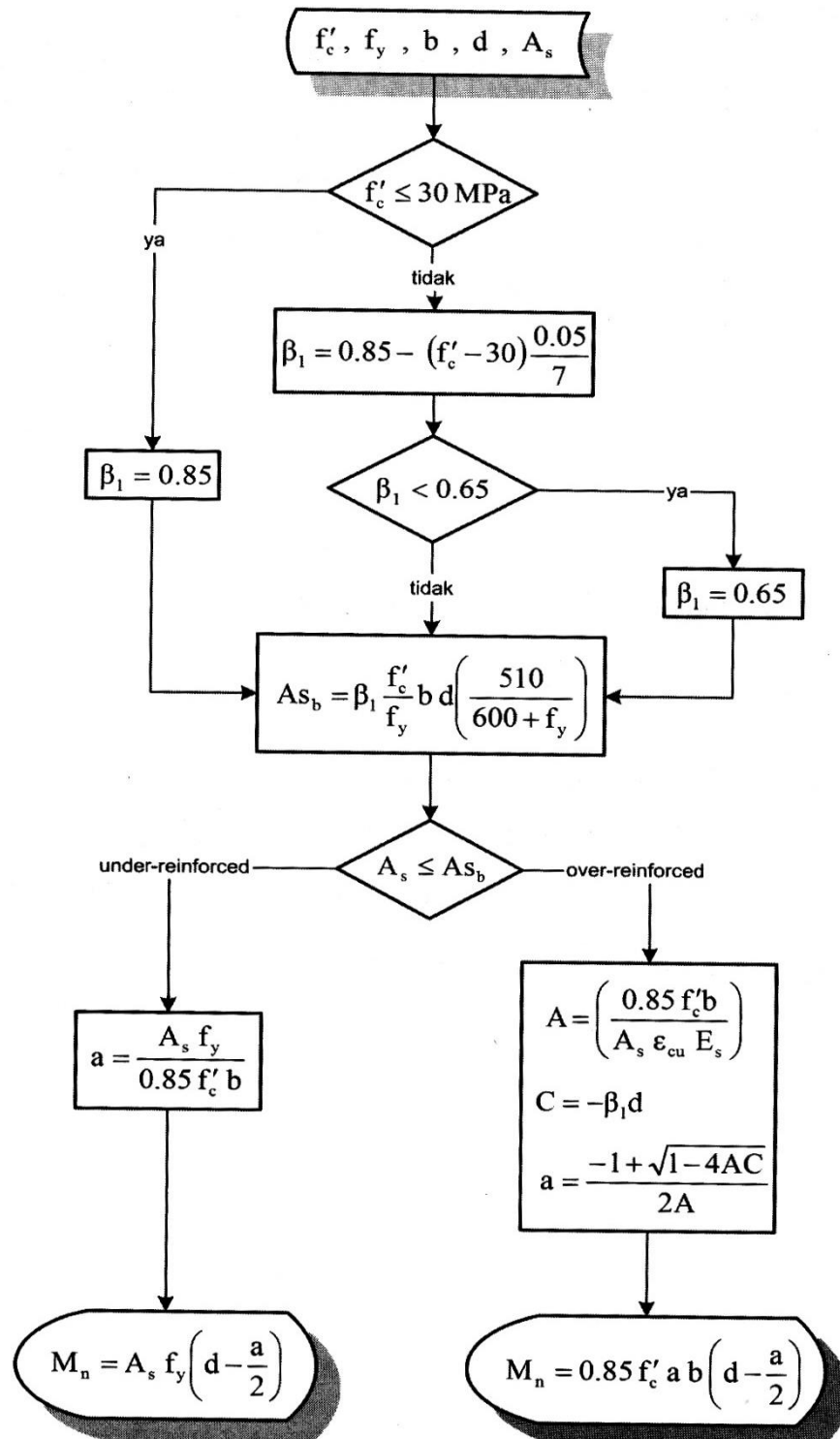
$$a = \frac{-1 + \sqrt{1 - 4AC}}{2A} \quad (3.12a)$$

$$A = \left(\frac{0.85 f_c' b}{A_s \varepsilon_{cu} E_s} \right) \quad (3.12b)$$

$$C = -\beta_1 d \quad (3.12c)$$

$$M_n = 0.85 f_c' ab \left(d - \frac{a}{2} \right) \quad (3.13)$$

3.1.4 Bagan Alir Analisis Manual Balok Persegi Tulangan Tunggal



Gambar 3.1. Momen Nominal Penampang Persegi dengan Tulangan Tunggal

3.2 Rumus Analisis Balok T – Tulangan Tunggal

3.2.1 Keruntuhan Balans

$$A_{s_b} = \frac{0.85f'_c}{f_y} \left(\beta_1 b_w \left(\frac{600d}{600 + f_y} \right) - (b_f - b_w)h_f \right) \quad (3.20)$$

3.2.2 Keruntuhan Tarik

$$a = \frac{A_s f_y - 0.85 f'_c (b_f - b_w) h_f}{0.85 f'_c} \quad (3.21)$$

$$M_n = C_{web} \left(d - \frac{a}{2} \right) + C_{flange} \left(d - \frac{h_f}{2} \right) \quad (3.22)$$

$$C_{web} = 0.85 f'_c a b_w \quad (3.22a)$$

$$C_{flange} = 0.85 f'_c (b_f - b_w) h_f \quad (3.22b)$$

3.2.3 Keruntuhan Tekan

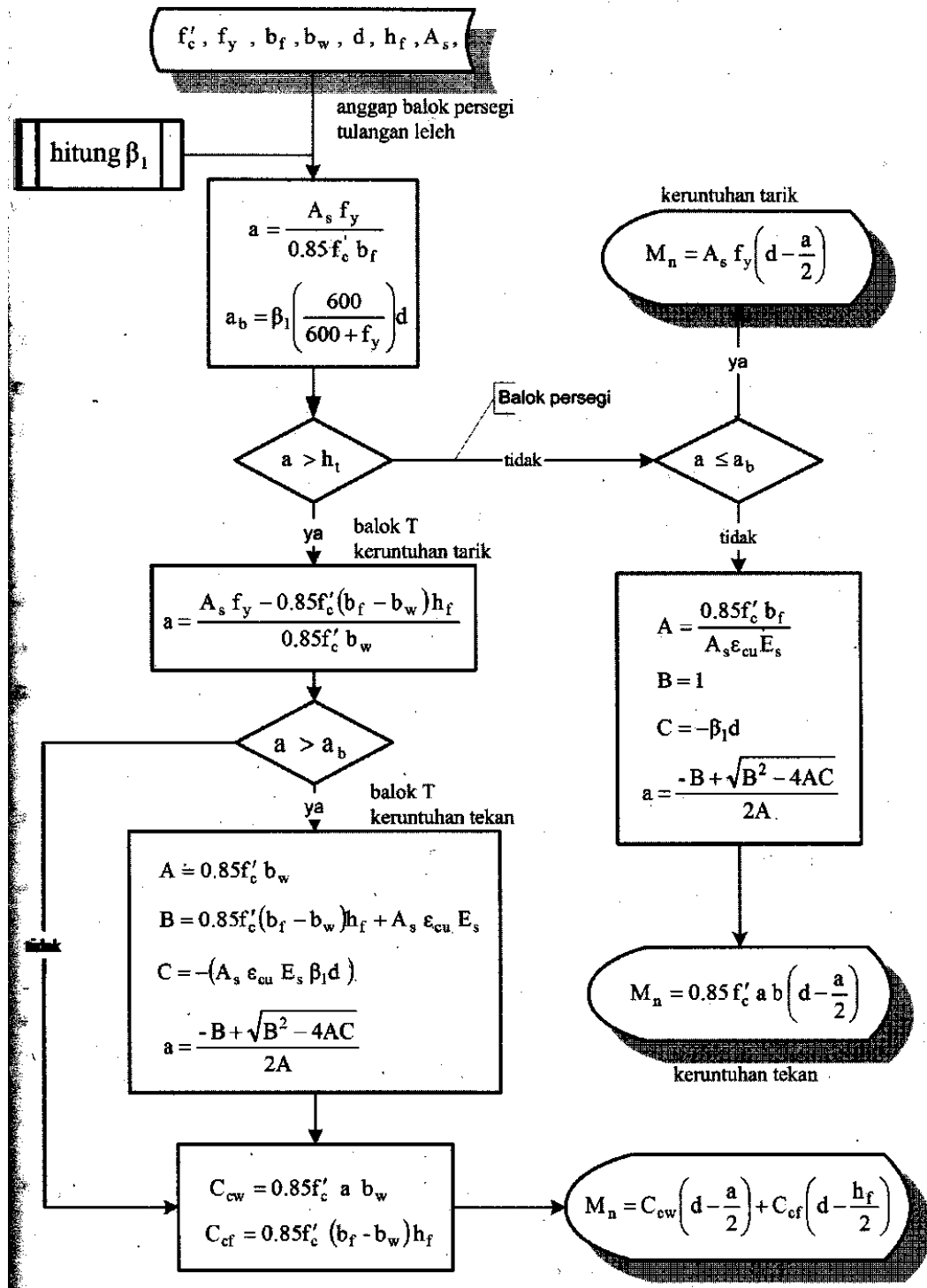
$$a = \frac{-B + \sqrt{B^2 - 4AC}}{2A} \quad (3.23)$$

$$A = 0.85 f'_c b_w \quad (3.23a)$$

$$B = 0.85 f'_c (b_f - b_w) h_f + A_s \varepsilon_{cu} E_s \quad (3.23b)$$

$$C = -(A_s \varepsilon_{cu} E_s \beta_1 d) \quad (3.23c)$$

3.2.4 Bagan Alir Analisis Balok T – Tulangan Tunggal



Gambar 3.2. Bagan Alir Analisis Balok "T"

3.3 Rumus Analisis Balok Persegi – Tulangan Ganda

3.3.1 Keruntuhan Tarik – Tulangan Desak Leleh

$$C_s = A_s' f_y \quad (3.23a)$$

$$C_c = 0.85 f_c' ab \quad (3.23b)$$

$$a = \frac{(A_s - A_s') f_y}{0.85 f_c' b} \quad (3.23)$$

$$a \geq \beta_1 \left(\frac{600 d'}{600 - f_y} \right) \quad (3.25a)$$

$$a \leq \beta_1 \left(\frac{600 d'}{600 + f_y} \right) \quad (3.25b)$$

$$a \leq 0.75 a_b \quad (3.25c)$$

$$M_n = C_c \left(d - \frac{a}{2} \right) + C_s (d - d') \quad (3.26)$$

3.3.2 Keruntuhan Tarik – Tulangan Desak Elastis

$$C_s = A_s' f_s = A_s' \varepsilon_{cu} E_s \left(1 - \beta_1 \frac{d'}{a} \right) \quad (3.27a)$$

$$C_c = 0.85 f_c' ab \quad (3.27b)$$

$$A = 0.85 f_c' b \quad (3.28a)$$

$$B = 600 A_s' - A_s' f_y \quad (3.28b)$$

$$C = -600 A_s' \beta_1 d' \quad (3.28c)$$

$$a = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A} \quad (3.28d)$$

3.3.3 Keruntuhan Desak – Tulangan Tarik Elastis

$$A = 0.85 f'_c b \quad (3.29a)$$

$$B = A_s f_y + 600 A_s \quad (3.29b)$$

$$C = -600 A_s \beta_1 d \quad (3.29c)$$

$$a = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A} \quad (3.29d)$$

3.3.4 Semua Tulangan (Bawah dan Atas) Tarik

$$a = \frac{(A_s + A'_s) f_y}{0.85 f'_c b} \quad (3.30)$$

$$M_n = (A_s - A'_s) f_y \left(d - \frac{a}{2} \right) \quad (3.31)$$

$$A_{s1} = A'_s \quad (3.32a)$$

$$T_{s1} = A_{s1} f_{s1} = A_{s1} \varepsilon_{cu} E_s \left(\frac{\beta_1 d'}{a} - 1 \right) \quad (3.32b)$$

$$T_s = A_s f_y \quad (3.32c)$$

$$A = 0.85 f'_c b \quad (3.33a)$$

$$B = A_{s1} \varepsilon_{cu} E_s - A_s f_y \quad (3.33b)$$

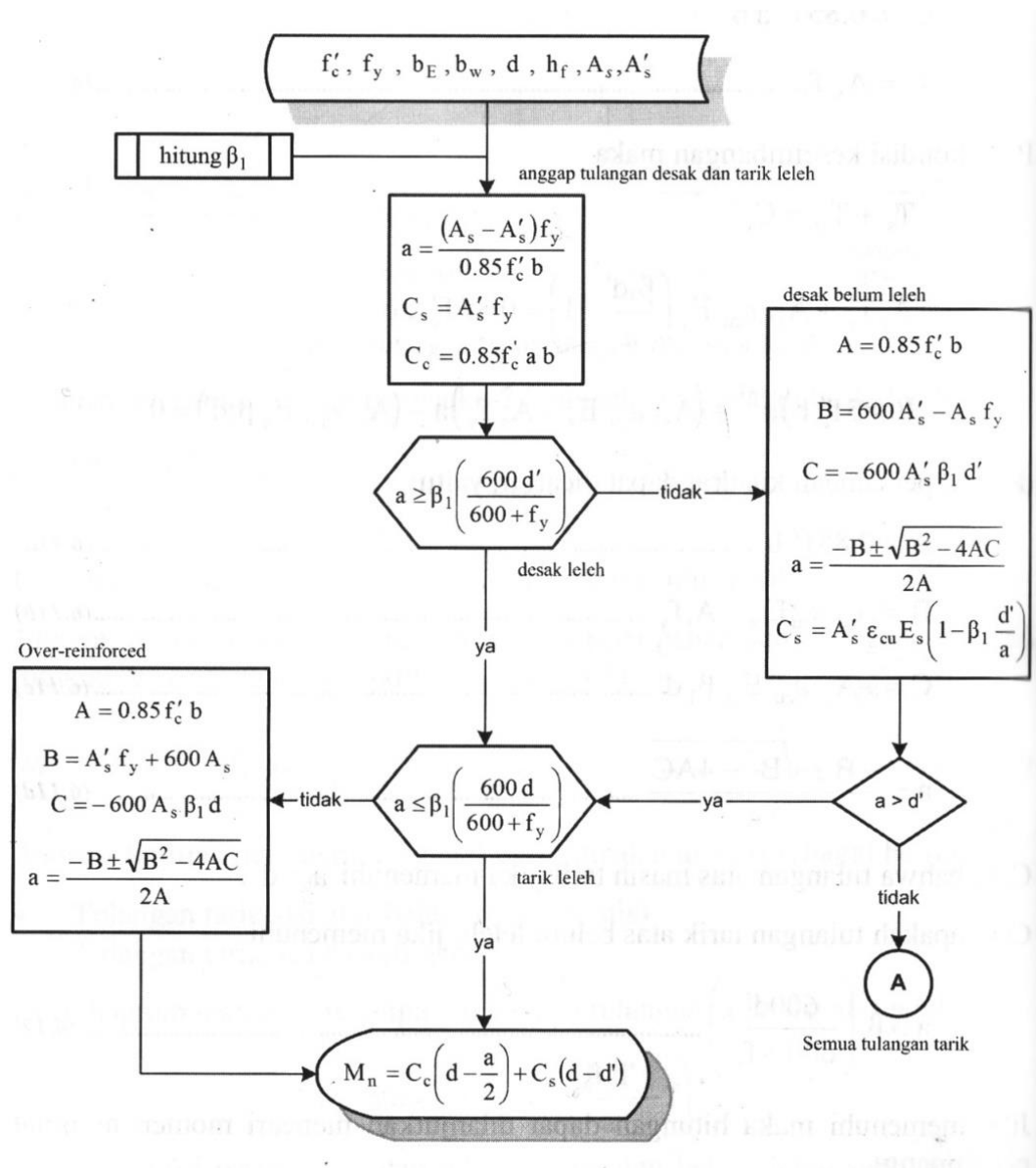
$$C = -A_{s1} \varepsilon_{cu} E_s \beta_1 d' \quad (3.33c)$$

$$a = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A} \quad (3.33d)$$

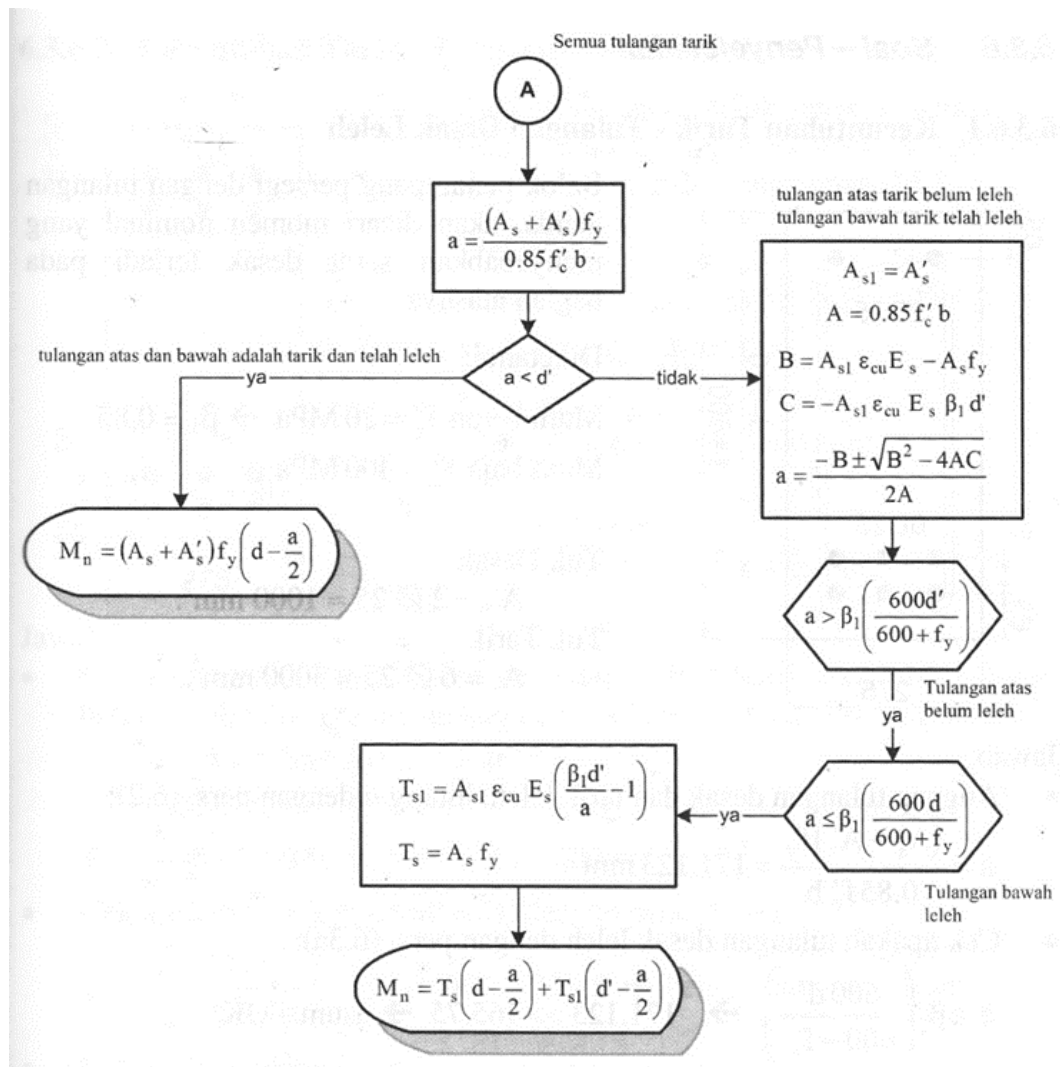
$$a > \beta_1 \left(\frac{600 d'}{600 + f_y} \right) \quad (3.33)$$

$$M_n = T_s \left(d - \frac{a}{2} \right) + T_{s1} \left(d' - \frac{a}{2} \right) \quad (3.35)$$

3.3.5 Bagan Alir Analisis Balok Persegi – Tulangan Ganda



Gambar 3.3. Bagan Alir Analisa Manual Balok Persegi



**Gambar 3.3. Bagan Alir Analisa Manual Balok Persegi –
Tulangan Ganda Tarik Semua**

3.4 Rumus Analisis Balok T – Tulangan Ganda

3.4.1 Keruntuhan Tarik – Tulangan Desak Leleh

$$C_{cw} = 0.85 f'_c a b_w \quad (3.36)$$

$$C_{cf} = 0.85 f'_c h_f (b_E - b_w) \quad (3.37)$$

$$C_{s1} = A'_s f_y \quad (3.38)$$

$$a = \frac{(A_s - A'_s) f_y - 0.85 f'_c h_f (b_E - b_w)}{0.85 f'_c b_w} \quad (3.39)$$

$$M_n = C_{cw} \left(d - \frac{a}{2} \right) + C_{cf} \left(d - \frac{ht}{2} \right) + C_{s1} (d - d') \quad (3.30)$$

3.4.2 Keruntuhan Tarik – Tulangan Desak Elastis

$$C_{s1} = A'_s f'_s = 600 A'_s \left(1 - \frac{\beta_1 d'}{a} \right) \quad (3.31)$$

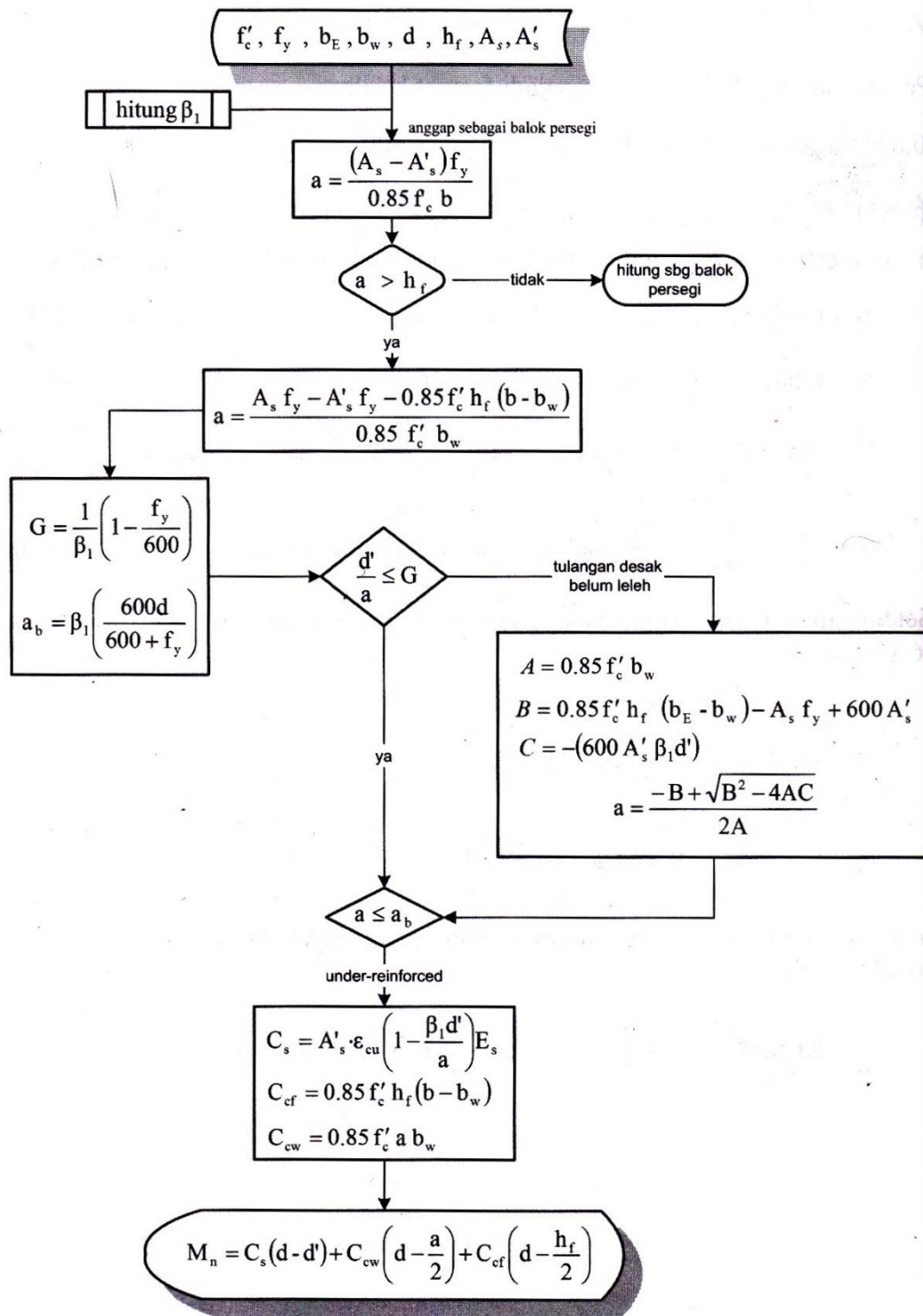
$$A = 0.85 f'_c b_w \quad (3.32a)$$

$$B = 0.85 f'_c h_f (b_E - b_w) - A_s f_y + 600 A'_s \quad (3.32b)$$

$$C = -(600 A'_s \beta_1 d') \quad (3.32c)$$

$$a = \frac{-B + \sqrt{B^2 - 4AC}}{2A} \quad (3.32d)$$

3.4.3 Bagan Alir Analisis Balok T – Tulangan Ganda



Gambar 3.5. Bagan Alir Analisa Balok T

3.5 Desain Balok Persegi – Tulangan Tunggal

3.5.1 Luas Tulangan Tarik Perlu

$$M_n = A_s f_y \left(d - \frac{A_s f_y}{1.7 f_c' b} \right) \quad (3.33a)$$

$$M_n = \rho b d^2 f_y \left(1 - \frac{\rho f_y}{1.7 f_c'} \right) \quad (3.33b)$$

$$\rho = \frac{0.85 f_c'}{f_y} \left[1 - \sqrt{1 - \frac{4 M_n}{1.7 f_c' b d^2}} \right] \quad (3.33a)$$

$$\rho = \frac{f_c'}{f_y} \left[0.85 - \sqrt{0.85^2 - Q} \right] \quad (3.33b)$$

$$Q = \left(\frac{1.7}{f_c'} \right) \frac{M_u}{\phi b d^2} \quad (3.35)$$

3.5.2 Persyaratan Tulangan Maksimum dan Minimum

$$A_s = \rho b d \quad (3.36a)$$

$$A_s = \left(\frac{f_c'}{f_y} \right) b d \left[0.85 - \sqrt{0.85^2 - Q} \right] \quad (3.36b)$$

3.5.3 Persyaratan Tulangan Maksimum dan Minimum

$$\rho_{maks} = \left(\frac{f_c'}{f_y} \right) b d \left[0.85 - \sqrt{0.85^2 - Q} \right] \quad (3.37)$$

$$\rho_{min} = \frac{\sqrt{f_c'}}{4 f_y} \quad (3.38a)$$

$$\rho_{min} = \frac{1.4}{f_y} \quad (3.38b)$$

3.5.4 Prosedur Perencanaan Geser Balok

1. Hitung gaya geser terfaktor V_u di titik kritis pada balok yang ditinjau, gunakan kombinasi beban, misal (gravitasi) $V_u = 1.2V_{DL} + 1.6V_{LL}$.
2. Hitung kuat geser penampang beton, ϕV_c , dimana $\phi = 0.75$

Jika hanya ada geser maka $V_c = \frac{1}{6}\sqrt{f'_c}b_wd$

Jika pada saat bersamaan pada penampang yang ditinjau timbul momen terfaktor M_u yang terjadi secara simultan dengan V_u , maka:

$$V_c = \left[\sqrt{f'_c} + 120\rho_w \frac{V_u d}{M_u} \right] \frac{b_w d}{7} \leq 0.3\sqrt{f'_c}b_w d$$

Dimana $\rho_w = \frac{A_s}{b_w d}$ dan $\frac{V_u d}{M_u} \leq 1.0$

3. Selanjutnya hitung $\frac{1}{2}\phi V_c$ dan evaluasi penampang sebagai berikut:
 - a. Jika $V_u \leq \frac{1}{2}\phi V_c$ maka tulangan sengkang tidak perlu
 - b. Jika $V_c = \frac{1}{2}\phi V_c < V_u \leq \phi V_c$ maka perlu sengkang minimum,

$$A_v \text{ min} = \frac{b_w s}{3f_y}$$

- c. Jika $V_u > \phi V_c$ maka perlu tulangan sengkang $V_s = \frac{V_u}{\phi} - V_c$

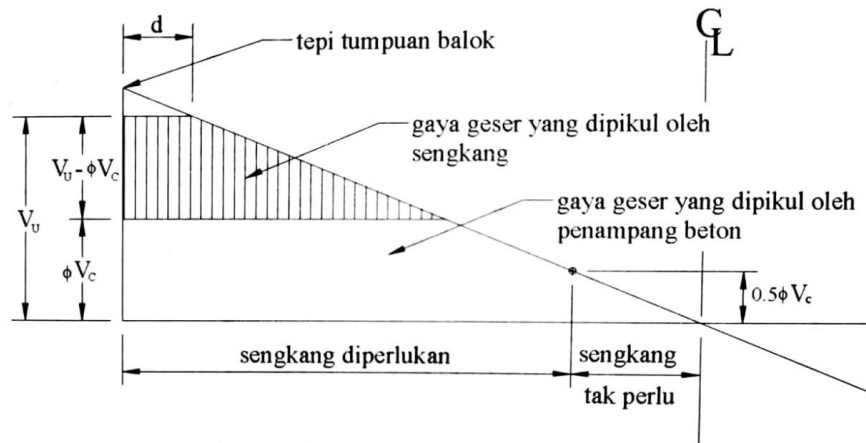
- d. Jika $V_s > \phi \frac{2}{3}\sqrt{f'_c}b_w d$ maka penampang harus diperbesar

4. Proporsikan sengkang yang diperlukan untuk memikul kelebihan gaya geser yang diperlukan. Untuk sengkang vertikal maka luas sengkang yang

diperlukan adalah $A_v = \frac{V_s s}{f_y d} \geq A_v \text{ min} = \frac{b_w s}{3f_y}$

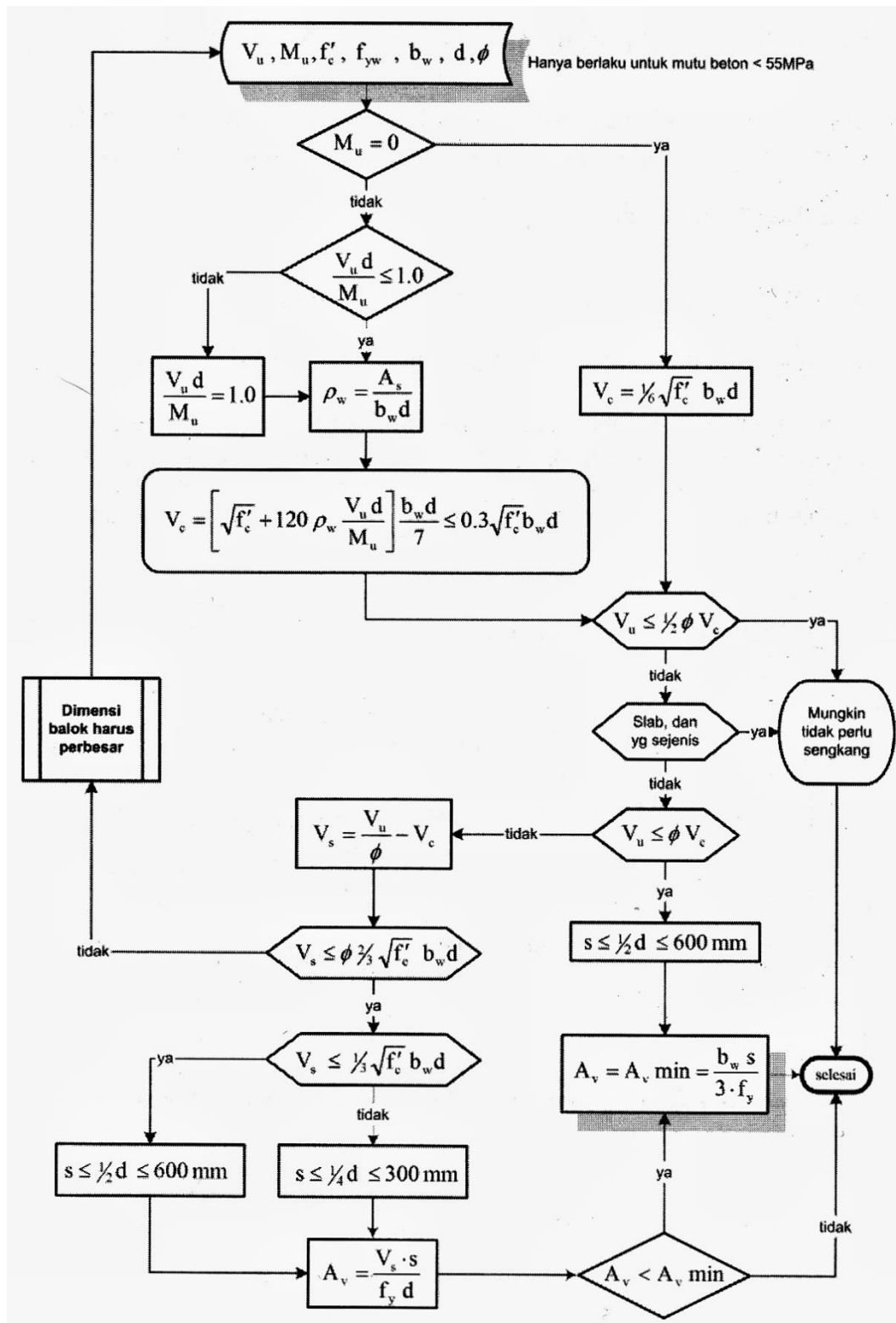
Jika $V_s > \phi \frac{2}{3}\sqrt{f'_c}b_w d$ maka $s \approx 0.5d \leq 600\text{mm}$,

5. Untuk membatasi lebar retak diagonal dan tetap tertutup rapat saat pengalihan gaya geser maka $f_{yv} \leq 300$ MPa (wire-mesh $f_{yv} \leq 550$ MPa).
6. Pembagian kuat geser balok beton bertulang digambarkan sebagai berikut:



Gambar 3.6. Ilustrasi kebutuhan sengkang pada balok (setengah bentang)

3.5.5 Bagan Alir Perencanaan Geser Balok



Gambar 3.7. Bagan Alir Perencanaan Geser Sengkang Vertikal