Design of Beams

1 MODULE NO. 1: ULTIMATE FLEXURE STRENGTH (R-SECTION)

1.1 Inputs

1.1.1 Material Properties

- ✓ Concrete compressive strength (f_{cu})
- ✓ Reduction factor of concrete compressive strength (γ_c=1.50)
- ✓ Yield strength of longitudinal reinforcing steel bars (f_y)
- ✓ Reduction factor of reinforcing steel yield strength(γ_s=1.15)
- ✓ Modulus of elasticity of reinforcing steel bars (E_s = 200,000 N/mm^2)

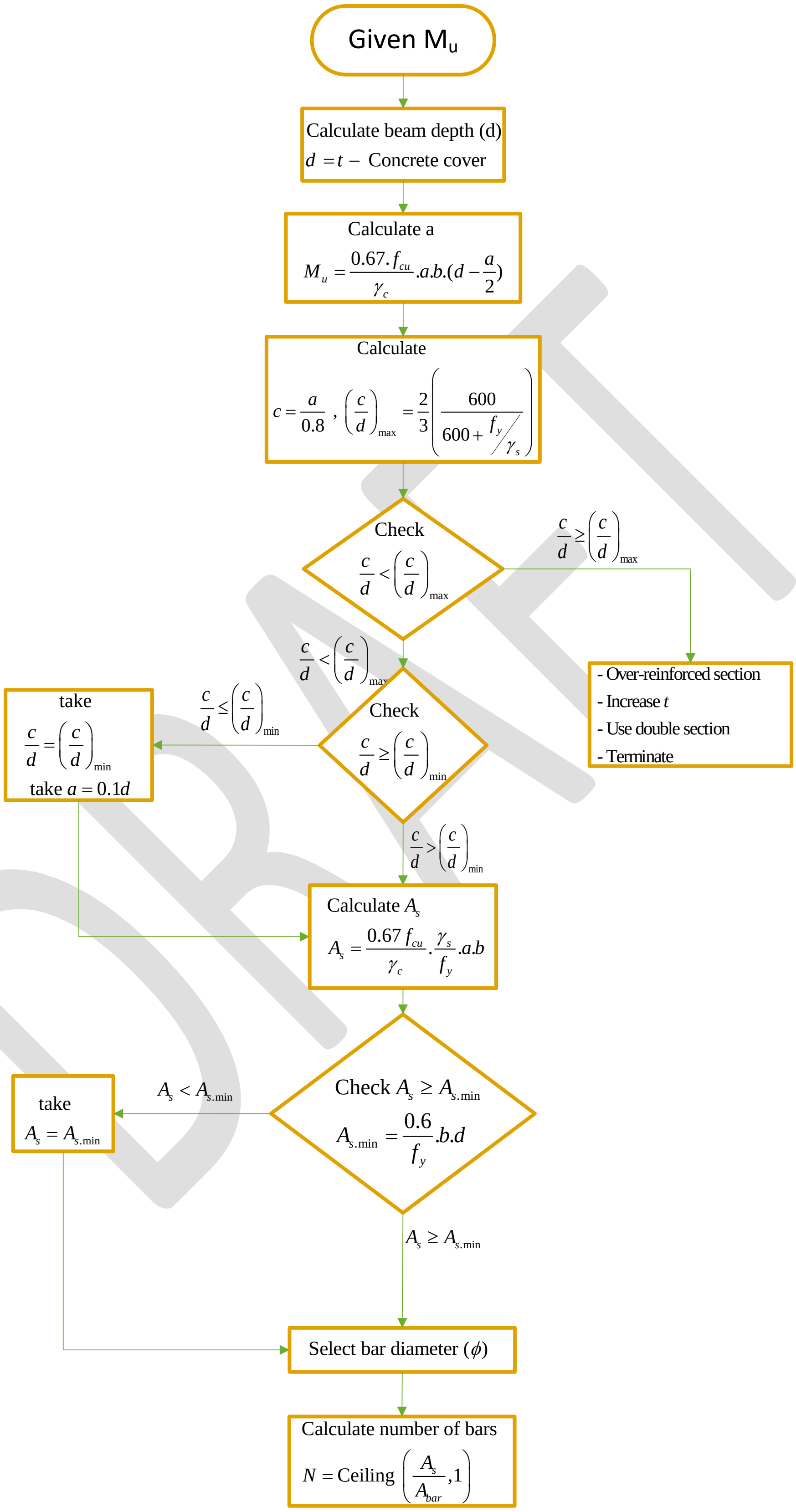
1.1.2 Section Definition

- ✓ Beam width (b)
- ✓ Beam total depth (t)
- ✓ Concrete cover

1.1.3 Internal Forces

- ✓ Ultimate Factored Moment from analysis (M_u)

1.2 Calculation Procedure



1.3 Design Outputs

- ✓ Beam total depth (t).
- ✓ Diameter of bars.
- ✓ Number of bars.

1.4 Example of Calculations using Mathcad

1.1 Input

1.1.1 Material Properties

$f_{cu} := 30 \dfrac{N}{mm^2}$ Concrete compressive strength

$f_y := 360 \dfrac{N}{mm^2}$ Yield strength of reinforcing steel bar

$E_s := 200000 \dfrac{N}{mm^2}$ Modulus of easticity of steel

$\gamma_c := 1.5$ Concrete strength reduction factor

$\gamma_s := 1.15$ Steel strength reduction factor

1.1.2 Section Definition

$b := 250\ mm$ Beam width

$t := 700\ mm$ Total beam depth

$conc.cover := 50\ mm$ Concrete Cover

1.1.3 Internal Forces

$M_u := 300\ kN \cdot m$ Ultimate Factored Moment from analysis

1.2 Calculation Procedure

$d := t - conc.cover = 650\ mm$

$a := 1\ mm$

$$a := \text{root}\left(M_u - 0.67 \frac{f_{cu}}{\gamma_c} \cdot a \cdot b \cdot \left(d - \frac{a}{2}\right), a\right)$$

$a = 156.649\ mm$

$c := \dfrac{a}{0.8} = 195.8\ mm$

c/d= $f_{c1} := \text{if}\left(\dfrac{c}{d} \geq \dfrac{2}{3} \cdot \dfrac{0.003}{0.003 + \dfrac{f_y}{\gamma_s \cdot E_s}}, \text{“Over reinforced section, increase ts”}, \dfrac{c}{d}\right)$

$f_{c1} = 0.301$

$c := \text{if}(c < 0.125 \cdot d, 0.125 \cdot d, c)$

$c = 195.811\ mm$

$a := 0.8 \cdot c = 156.649\ mm$

$A_s := 0.67 \cdot \frac{f_{cu}}{\gamma_c} \cdot \frac{\gamma_s}{f_y} \cdot a \cdot b = \left(2 \cdot 10^3\right)\ mm^2$ Calculate As required

$A_{smin} := \frac{0.6\ \frac{N}{mm^2} \cdot b \cdot d}{f_y} = 271\ mm^2$ Check As >= Asmin

$A_s := \textbf{if}\left(A_s < A_{smin}, A_{smin}, A_s\right)$

$A_s = \left(2 \cdot 10^3\right)\ mm^2$

$\phi 6 := 28.3\ mm^2$

$\phi 8 := 50.3\ mm^2$

$\phi 10 := 78.5\ mm^2$

$\phi 12 := 113\ mm^2$

$\phi 14 := 154\ mm^2$

$\phi 16 := 201\ mm^2$

$\phi 18 := 254\ mm^2$

$\phi 20 := 314\ mm^2$

$\phi 22 := 380\ mm^2$

$\phi 25 := 491\ mm^2$

$\phi 28 := 616\ mm^2$

$\phi 32 := 804\ mm^2$

$\phi 38 := 1134\ mm^2$

$N := \frac{A_s}{\phi 16} = 8.3$

$N := \mathrm{Ceil}(N, 1) = 9$

1.3 Output

$t = 700\ mm$

$b = 250\ mm$

Use $N = 9\ \ \phi 16$