Construction of Design Aids for SLABS, RECTANGULAR BEAMS AND T-BEAMS.

Design of Singly Reinforced Sections

$C = T$

Equilibrium

$0.85 f'_c ab = A_s f_y$

ACI Equilibrium

$A_s = \rho bd$

$a = \rho d \dfrac{f_y}{0.85 f'_c}$

$\phi M_n = \phi \rho bd f_y (d - 0.5a)$

$R = \dfrac{\phi M_n}{bd^2} = \phi \rho f_y (1 - \dfrac{\rho f_y}{1.7 f'_c})$

$\phi M_n \geq M_u$

Use of Computer for construction of charts

- Set up an excel worksheet
- Enter steel ratios starting from ρ_{min} to ρ_{max} with a suitable interval in Column A
- For a given set of materials, Obtain the value of *R* in Column B
- Same can be repeated for same f'_c and another value of f_y
- Plot an XY Chart with appropriate grids and titles

Minimum and Maximum Steels

$\rho_{min} = 3\dfrac{\sqrt{f'_c}}{f_y} \geq \dfrac{200}{f_y}(Eng),$ ...

Ensures Composite Action based on cracking phenomenon

$\rho_{max} = \dfrac{3}{4}\rho_b = 0.75$ ... $\dfrac{87000}{87000 + f_y}$ Eng

Ensures Ductile failure at all if it occurs

$\rho_{max} =$ ... $\dfrac{f'_c}{f_y} \dfrac{600}{600 + f_y}$ SI

$R \ vs \ (\phi, \rho, f_y, f_c^{'})$

$$R = \phi \rho f_y \left(1 - \frac{\rho f_y}{1.7 f_c^{'}}\right)$$

$$R = \frac{\phi M_n}{bd^2} = \frac{M_u}{bd^2}$$

Design of Structures

Use of Charts

1. To find the Capacity of Section

Section properties, Steel Area & Material Properties are Known

2. To Determine the Steel Area

a. Section & Material Properties are Known

b. Only Material Properties are Known

Design of Structures

Use of Charts (1)

To find the Capacity of Section when Section & Material Properties , Steel Area are known

1. **Obtain** $\rho = A_s/bd$
2. **Enter Appropriate Chart, read** R **for above** ρ
3. $\phi M_n = Rbd^2$

Design of Structures

CAPACITY

$b = 300mm$

$d = 450mm$

$A_s = 1800mm^2$

$f_c^{'} = 20MPa$

$f_y = 280MPa$

Given

$$\rho = \frac{1800}{300 \times 450} = 0.0133 \Rightarrow R = 3.0 N - mm/mm^3$$

$$\phi M_n = Rbd^2 = 3 \times 300 \times 450^2 \ N - mm$$
$$= 182.25 \ kN - m$$

Design of Structures

Use of Charts (2a)

To find the Steel Area when Section & Material Properties are Known

1. **Obtain** $R = M_u/bd^2$
2. **Enter Appropriate Chart; read ρ for above R**
3. $A_s = \rho bd$

Design of Structures

Steel Area (a)

$b = 300mm$
$d = 450mm$
$M_u = 182.25kN - m$

$f_c^{'} = 20MPa$
$f_y = 280MPa$

Given

$$R = \frac{182.25 \times 10^6}{300 \times 450^2} = 3.0N - mm/mm^3$$

$\rho = 0.0133$ (from Chart)

$$A_s = \rho bd = 0.0133 \times 300 \times 450$$
$$= 1800\, mm^2$$

Design of Structures

Use of Charts (2b)

To find the Steel Area when only Material Properties are Known

1. **Select a ρ around 50% of given range**
2. **Read R from Chart**
3. $bd^2 = M_u/R$
4. **Decide b from other consideration, get d**
5. **Obtain h, round d and get A_s as in (2a)**

Design of Structures

Steel Area (b)

$M_u = 182.25kN - m$

$f_c^{'} = 20MPa$
$f_y = 280MPa$

Given

$\rho = 0.015 \Rightarrow R = 3.30$ (from Chart)

$$bd^2 = \frac{182.25 \times 10^6}{3.3} \Rightarrow d = 429\ with\ b = 300mm$$

$$h = 429 + 0.5(25) + 40 = 482mm$$
$$= 500mm(say) \Rightarrow d = 500 - 40 - 25/2 = 447$$

Design of Structures

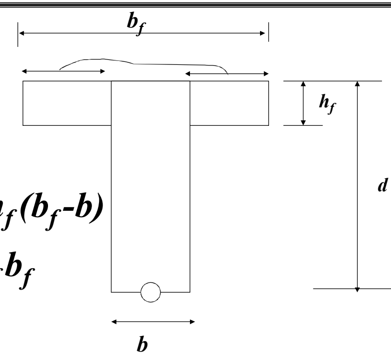
Steel Area (b)

$$R = \frac{182.25\times10^6}{300\times447^2} = 3.04$$

$$R = 3.04 \Rightarrow \rho = 0.0135 \quad \text{(from Chart)}$$
$$A_s = 0.0135\times300\times447$$
$$= 1810 mm^2$$

Design of Structures

DESIGN OF T SECTIONS



$A_{pf}=h_f(b_f-b)$

$A_{ff}=h_f b_f$

Design of Structures

DESIGN OF T SECTIONS

If *a* < *h* —

If $a < h_f$, the section may be designed as rectangular sections with $b=b_f$

Therefore the design charts and methods for Rectangular Beams are applicable

When $a > h_f$, T section design will be carried out using R_T charts

Design of Structures

Construction of R_T Charts

$A_{pf} + A_w = A_C$: Concrete Area

$A_s = A_{sf} + A_{sw}$: Steel Area for flange, Web

$$0.85 f_c' h_f (b_f - b) = A_{sf} f_y$$

$$\frac{A_{sf}}{h_f(b_f-b)} = \Omega = \frac{0.85 f_c'}{f_y} = \frac{A_{sff}}{h_f b_f}$$

Ω is function of material properties only

Design of Structures

Construction of R_T Charts

$$\phi M_n = \phi M_f + \phi M_w$$

$$\phi M_f = \phi 0.85 f_c^{'}(b_f - b)h_f(d - 0.5h_f)$$

$$\frac{\phi M_f}{Ad} = \phi 0.85 f_c^{'}(1 - 0.5\frac{h_f}{d}) = R_T$$

$$A = (b_f - b)h_f \Leftrightarrow A_{sf}$$

$$A = b_f h_f \Leftrightarrow A_{sff}$$

***R_T* is function of *h_f/d* and concrete strength only**

Design of Structures

Design of T Section

Find the capacity of Full Flange and compare with M_u

$$\frac{h_f}{d} \Rightarrow \frac{\phi M_f}{Ad} = R_T \text{ (from Chart)}$$

$$\phi M_{ff} = R_T \times A_{ff} d$$

$$\phi M_{ff} < M_u \text{ (needs T design)}$$

Otherwise use R charts

Design of Structures

Design of T Section

if $\phi M_{ff} < M_u$ obtain ϕM_{pf}

$$\frac{h_f}{d} \Rightarrow \frac{\phi M_f}{Ad} = R_T \text{ (from Chart)}$$

$$\phi M_{pf} = R_T \times (b_f - b)h_f d$$

$$A_{sf} = \frac{0.85 f_c^{'}}{f_y}(b_f - b)h_f$$

Design of Structures

Design of T Section

$$\phi M_w = M_u - \phi M_{pf}$$

$$R = \frac{\phi M_w}{bd^2} \quad \text{Use R Charts to get } A_{sw}$$

$$A_s = A_{sf} + A_{sw}$$

Design of Structures

Capacity of T Section

$b_f = 500, h_f = 125mm$

$b = 250, \ d = 500mm$

$A_s = 5000mm^2$

$f_c' = 20MPa, f_y = 280MPa$

Given

Design of Structures

Capacity of T Section

Does it require a T section Analysis?

$Determine \ A_{sff} \ (Steel \ for \ full \ flange)$

$A_{sff} = \Omega \times (b_f \ h_f)$

$= \frac{0.85 \times 20}{280} 500 \times 125 = 3795mm^2$

$3795 < A_s = 5000mm^2$

Requires T section Analysis

Design of Structures

Capacity of T Section

$Determine \ A_{sf} \ (Steel \ for \ projected \ flange)$

$A_{sf} = \Omega \times (b_f - b) \ h_f$

$= \frac{0.85 \times 20}{280} 250 \times 125 = 1897mm^2$

$Determine \ \phi M_{pf} \ (Cap \ of \ projected \ flange)$

$\frac{h_f}{d} = \frac{125}{500} = 0.25 \Rightarrow R_T = 13.48$

$\phi M_{pf} = 13.48 \times 500 \times 125 \times 250 = 210.625kN\text{-}m$

Design of Structures

Capacity of T Section

$Determine \ A_{sw} \ (Steel \ for Web)$

$A_{sw} = A_s - A_{sf} = 5000 - 1897 = 3103mm^2$

$Determine \ \phi M_w \ (Cap \ of \ Web \ by \ R \ Charts)$

$\rho = 3103/500/250 = 0.0248 \Rightarrow R = 5$

$\phi M_w = 5 \times 250 \times 500^2 = 312.5kN\text{-}m$

$\phi M_n = \phi M_{pf} + \phi M_w = 523.13kN - m$

Design of Structures

Design of T Section

$b_f = 500, h_f = 125mm$

$b = 250, \quad d = 500mm$

$M_u = 520kN - m$

$f_c^{'} = 20MPa, f_y = 280MPa$

Given

Design of Structures

Design of T Section

Is it a T section Design?

$Determine\ \phi M_{ff}\ (Cap\ fo\ full\ flange)$

$\gamma = \dfrac{h_f}{d} = 0.25 \Rightarrow R_T = 13.48$

$\phi M_{ff} = 13.48 \times 500 \times (125 \times 500) = 421.25kN - m$

$\phi M_{ff} < M_u$ Requires T Design

Design of Structures

Design of T Section

$Determine\ A_{sf}\ (Steel\ for\ projected\ flange)$

$A_{sf} = \Omega \times (b_f - b)\, h_f$

$= \dfrac{0.85 \times 20}{280} 250 \times 125 = 1897mm^2$

$Determine\ \phi M_{pf}\ (Cap\ of\ projected\ flange)$

$\dfrac{h_f}{d} = \dfrac{125}{500} = 0.25 \Rightarrow R_T = 13.48$

$\phi M_{pf} = 13.48 \times 500 \times 125 \times 250 = 210.625kN\text{-}m$

Design of Structures

Design of T Section

$Determine\ \phi M_w\ (Req\ \ from\ Web\ )$

$\phi M_w = 500 - 212.625 = 287.375kN - m$

$R = \dfrac{287.375 \times 10^6}{250 \times 500^2} = 4.6N - mm / mm^3$

$R = 4.6 \Rightarrow \rho = 0.0223$

$A_{sw} = 0.0223 \times 250 \times 500 = 2788mm^2$

$A_s = 1897 + 2788 = 4685mm^2$

Design of Structures

END of PART I