1.051 Structural Engineering Design

Recitation 4

Design Method for Singly Reinforced Concrete T-Sections In Accordance to the ACI-318

Reference: Chapter 8, 9, 10, 11 Building Code Requirements for Reinforced Concrete ACI-318 and Commentary (ACI-318R), American Concrete Institute, Box 19150, Redford Station, Detroit, Michigan 48219

Design Principle:

$$M_u \leq \Phi \cdot M_n \qquad \text{Equation (1)}$$

$$V_u \leq \Phi \cdot V_n \qquad \text{Equation (2)}$$

$$V_n = V_c + V_s \qquad \text{Equation (3)}$$

as in the design of rectangular beams (Recitation Notes 2 & 3).

Effective Flange Width (b_E) Definitions:

A. Interior Sections (Flanges on both sides of web)

Choose the smallest of the following:

(1) $b_E = \frac{L}{4}$

(2) $b_E = b_w + 16 \cdot t$

(3) $b_E = \text{center} - \text{to} - \text{center spacing of beams}$

B. Exterior Sections (L-Shaped Flange)

Choose the smallest of the following:

(1) $b_E = b_w + \frac{L}{12}$

(2) $b_E = b_w + 6 \cdot t$

(3) $b_E = b_w + \frac{1}{2}(\text{clear distance to next beam})$

C.

Isolated T-Sections

$$b_E \le 4 \cdot b_w$$

$$t \ge \frac{1}{2} b_w$$

where b_E = effective flange width
b_w = web width
L = span length of beam
t = flange thickness

Moment Equations:

Case 1: Neutral Axis within Flange ($a \le t$)

$$M_u \le \Phi \cdot \rho \cdot f_y \cdot b \cdot d^2 \cdot \left(1 - \frac{\rho \cdot f_y}{1.7 \cdot f_c^{'}}\right)$$

Flexure design is exactly the same as that of singly reinforced rectangular beams because the concrete tension zone is ignored entirely. Refer to Recitation Notes 2 for design procedures.

Case 2: Neutral Axis below Flange ($a \ge t$)

$$M_u \le \Phi \cdot \left[C_1 \cdot \left(d - \frac{a}{2}\right) + C_2 \cdot \left(d - \frac{t}{2}\right)\right]$$

where C_1 = $0.85 \cdot f_c^{'} \cdot b_w \cdot a$
C_2 = $0.85 \cdot f_c^{'} \cdot (b_E - b_w) \cdot t$
d = effective depth
t = flange thickness
a = $\dfrac{T - C_2}{0.85 \cdot f_c^{'} \cdot b_w}$
T = $A_s \cdot f_y$

Maximum Steel Provision:

$$A_{s,max} = 0.75 \cdot A_{s,b}$$

where $A_{s,b} = \dfrac{C_{1,b} + C_2}{f_y}$

$$C_{1,b} = 0.85 \cdot f_c' \cdot b_w \cdot a_b$$

$$C_2 = 0.85 \cdot f_c' \cdot (b_E - b_w) \cdot t$$

$$a_b = \beta_1 \cdot \left(\frac{0.003}{0.003 + \dfrac{f_y}{E_s}} \right) \cdot d$$

d = effective depth of beam

Shear Equations:

$$V_c = \left(1.9 \cdot \sqrt{f_c'} + 2500 \cdot \rho_w \frac{V_u \cdot d}{M_u} \right) \cdot b_w \cdot d$$

$$V_s = \frac{A_v \cdot f_y \cdot d}{s}$$

Shear design of T-sections shall conform to the design procedure of rectangular beams. Note that shear force is assumed to be resisted by the web only because the flange thickness is too thin to make significant contribution to shear resistance of a section. Refer to Recitation Notes 3 for shear design procedures.

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Basic Flexure Design Procedure:

1. Determine factored moment from given loading conditions
2. Determine effective width of flange
3. Find out whether the neutral axis is within flange or below flange
4. Locate the neutral axis position and hence the parameter “a” from the factored moment value
5. Determine required steel area
6. Check maximum steel provision allowed. If the required value is greater than the allowed value, increase section size. Otherwise, flexure design is complete and subsequent designs can be carried out (i.e. shear design and serviceability checks).