CE 414: Prestressed Concrete
Lecture 9
Flexural Analysis (Contd. III)

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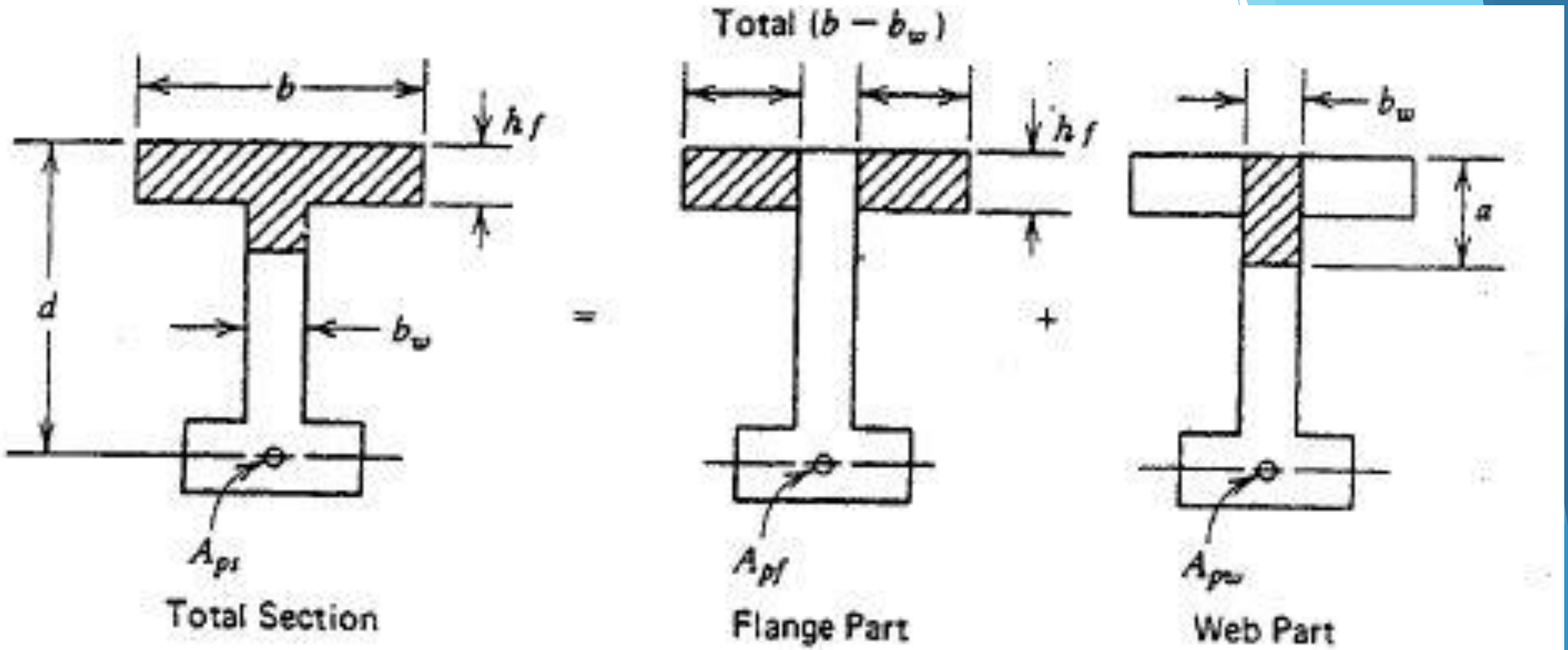

Fig. 5-18. Flanged section

sion and tension forces at ultimate. The commentary of the ACI Code contains equations for M_u to cover this case which it terms "flanged section."

$$M_u = \phi\left[A_{pw} f_{ps}\left(d - \frac{a}{2}\right) + 0.85 f'_c (b - b_w) h_f \left(d - \frac{h_f}{2}\right)\right] \qquad (5\text{-}25)$$

where

$$A_{pw} = A_{ps} - A_{pf} \qquad (5\text{-}26)$$

and

$$A_{pf} = 0.85 f'_c (b - b_w) h_f / f_{ps} \qquad (5\text{-}27)$$

EXAMPLE 5-9

The same I-shaped prestressed concrete beam as example 5-8 but the steel area is increased to $A_{ps}=3.67$ in.^{2} The effective steel stress remains 160 ksi. The c.g.s. of the strands is 4.5 in. above the bottom of the beam as shown in Fig. 5-19 along with the

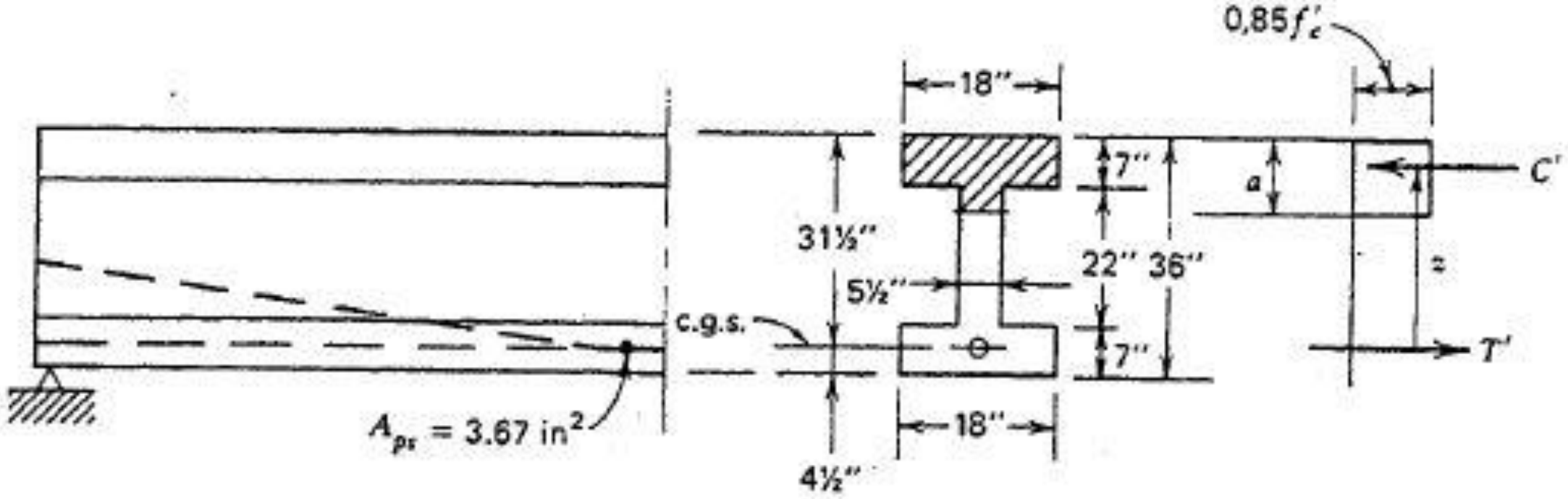

Fig. 5-19. Example 5-9.

shape of the cross section: material properties are same as example 5-8: $f_{pu}=270$ ksi, $f'_c=7000$ psi. Find the ultimate resisting moment for the section for design following the ACI Code. ($A_{ps}=2368$ mm^2, $f_{se}=1103$ N/mm^2, $f_{pu}=1862$ N/mm^2, and $f'_c=48$ N/mm^2)

Solution

$$\rho_p=\frac{3.67}{(18)(31.5)}=0.00647$$

Use equation 5-15 to estimate steel stress at ultimate.

$$f_{ps}=270{,}000\left[1-(0.5)(0.00647)\left(\frac{270{,}000}{7{,}000}\right)\right]$$

$$f_{ps}=236{,}000 \text{ psi}=236 \text{ ksi } (1627 \text{ N/mm}^2)$$

Check the reinforcement index after the flanged section is evaluated below. Referring to Fig. 5-18 and 5-19 determine the extent of the compression zone

$$T'(\text{total}) = (3.67)(236) = 866 \text{ k } (3{,}852 \text{ kN})$$

$$\text{Area of compression zone} = \frac{866}{0.85 f'_c} = 145.5 \text{ in.}^2 \ (93.87 \times 10^3 \text{ mm}^2)$$

$$\text{Flange area} = 18 \times 7 = 126.0 \text{ in.}^2 \ (81.29 \times 10^3 \text{ mm}^2)$$

$$\text{Web area below flange} = \overline{19.5 \text{ in.}^2} \ (12.58 \times 10^3 \text{ mm}^2)$$

$$a = 7 + \frac{19.5}{5.5} = 7 + 3.55 = 10.55 \text{ in. } (268 \text{ mm})$$

This verifies that the section is behaving as "flanged" as shown by Fig. 5-18 and M_u can now be evaluated.

Referring to Fig. 5-18 and using ACI Commentary equations

$$A_{pf} = (0.85)(7000)(18.0-5.5)(7)/236{,}000 = 2.21 \text{ in.}^2 \ (1426 \text{ mm}^2) \qquad (5\text{-}27)$$

$$A_{pw} = 3.67 - 2.21 = 1.46 \text{ in.}^2 \ (942 \text{ mm}^2) \qquad (5\text{-}26)$$

Check reinforcement index for the flanged section;

$$\rho_{pw} = A_{pw}/b_w d = 1.46/(5.5)(31.5) = 0.00843$$

$$\omega_{pw} = (0.00843)(236{,}000)/7000 = 0.284 < 0.30$$

$$M' \text{ for web part} = A_{pw} f_{ps}\left(d - \frac{a}{2}\right)$$

$$M'_{web} = (1.46)(236)\left(31.5 - \frac{10.55}{2}\right) = 9{,}040 \text{ in.-k } (1{;}021.5 \text{ kN} - \text{m})$$

$$M' \text{ for flange part} = 0.85 f'_c (b - b_w) h_f \left(d - \frac{h_f}{2}\right)$$

$$M'_{flange} = (0.85)(7.0)(18.0 - 5.5)(7)(31.5 - 7/2) = 14{,}580 \text{ in.-k } (1647.5 \text{ kN} - \text{m})$$

$$M'_{total} = 9040 + 14{,}580 = 23{,}620 \text{ in.-k } (2669 \text{ kN} - \text{m}) = M_n$$

we may write it in the form:

$$M_u = \phi[M'_{\text{web}} + M'_{\text{flange}}] = \phi[M'_{\text{total}}]$$

thus

$$M_u = (0.9)(23{,}620) = 21{,}260 \text{ in.-k } (2{,}402 \text{ kN} - \text{m})$$