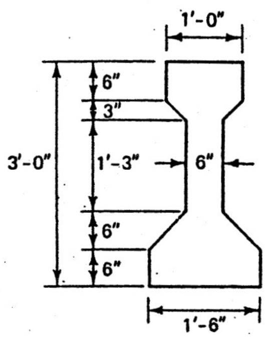
1.1. An AASHTO prestressed simply supported I beam has a span of 34 ft (10.4 m) and is 36 in. (91.4 cm) deep. Its cross section is shown in Figure 14.18. It is subjected to a live-load intensity $W_L = 3600$ plf (52.6 kN/m). Determine the required $\frac{1}{2}$-in.-diameter, stress-relieved, seven-wire strands to resist the applied gravity load and the self-weight of the beam, assuming that the tendon eccentricity at midspan is $e_c = 13.12$ in. (333 mm). Maximum permissible stresses are as follows:

$$f'_c = 6000 \text{ psi (41.4 MPa)}$$
$$f_c = 0.45 f'_c$$
$$= 2700 \text{ psi (26.7 MPa)}$$
$$f_t = 12\sqrt{f'_c} = 930 \text{ psi (6.4 MPa)}$$
$$f_{pu} = 270{,}000 \text{ psi (1862 MPa)}$$
$$f_{pi} = 189{,}000 \text{ psi (1303 MPa)}$$
$$f_{pe} = 145{,}000 \text{ psi (1000 MPa)}$$

The section properties, given these stresses, are

$$A_c = 369 \text{ in.}^2$$
$$I_g = 50{,}979 \text{ in.}^4$$
$$r^2 = \frac{I_c}{A_c} = 138 \text{ in.}^2$$
$$c_b = 15.83 \text{ in.}$$
$$S_b = 3220 \text{ in.}^3$$
$$S^t = 2527 \text{ in.}^3$$
$$W_D = 384 \text{ plf}$$
$$W_L = 3600 \text{ plf}$$



Solve the problem by each of the following methods:

(a) Basic concept
(b) C-line
(c) Load balancing

SOLUTION:–

1. SOLUTION USING THE P-I METHOD:–

STRESS DATA:

Span = 34 ft
W_L = 3600 plf
f'_c = 6,000 psi.
$f_c = 0.45 f'_c$ = 2,700 psi.
$f_t = 12\sqrt{f'_c}$ = 930 psi
f_{pu} = 270,000 psi
f_{pi} = 189,000 psi
f_{pe} = 145,000 psi

SECTION PROPERTIES:

$A_c = 369$ in^2
$I_g = 50{,}979$ in^4
$r^2 = I_g/A_c = 138$ in^2
$C_b = 15.83$ in
$C^t = 20.17$ in
$e_c = 13.12$ in
$S_t = 2527$ in^3
$S_b = 3{,}220$ in^3
$W_d = 384$ plf.

a) BASIC CONCEPT:–

Assume that 10 $\frac{1}{2}''$ dia. seven wire strand tendons are used to prestress

i) Initial Conditions at Prestressing:–

$$A_{ps} = 10(0.153) = 1.53 \text{ in}^2$$

$$P_i = A_{ps} \cdot f_{pi} = 1.53(189{,}000) = 289{,}170 \text{ lb.}$$

$$P_e = 1.53(145{,}000) = 221{,}850 \text{ lb.}$$

The midspan self-weight dead-load moment is

$$M_D = \frac{W_D \cdot l^2}{8} = \frac{384(34)^2}{8} \times 12 = 665{,}856 \text{ in-lb.}$$

$$f^t = \frac{-P_i}{A_c}\left(1 - \frac{e \cdot c_t}{r^2}\right) - \frac{M_D}{S_t} = -\frac{289{,}170}{369}\left(1 - \frac{13.12(20)}{138}\right) - \frac{665{,}856}{2527}$$

$$\therefore f^t = 456 \text{ psi (C)}$$

$$f_b = -\frac{P_i}{A_c}\left(1 + \frac{e \cdot c_b}{r^2}\right) + \frac{M_D}{S_b} = -\frac{289{,}170}{369}\left(1 + \frac{13.12(25.83)}{138}\right) - \frac{665{,}856}{3220}$$

$$\therefore f_b = -1{,}756 \text{ psi} = < f_{ci} = -2{,}880 \text{ psi allowed.}$$

ii) FINAL Conditions at Service Load:–

The midspan moment due to live load is:

$$M_L = \frac{w \cdot l^2}{8} = \frac{3600(34)^2}{8} \times 12 = 6{,}242{,}400 \text{ in-lb}$$

$$M_T = 665{,}856 + 6{,}242{,}400 = 6{,}908{,}256 \text{ in-lb.}$$

$$f^t = -\frac{P_e}{A_c}\left(1 - \frac{e \cdot c_t}{r^2}\right) - \frac{M_T}{S^t} = -\frac{221{,}850}{369}\left(1 - \frac{13.12(20.17)}{138}\right) - \frac{6{,}908{,}256}{2{,}527}$$

$$\boxed{f^t = -2{,}183 \text{ psi (C)}} < f_c = 2700 \text{ psi}$$

$$f_b = -\frac{P_e}{A_c}\left(1 + \frac{e.C_b}{r^2}\right) + \frac{M_T}{S_b} = -$$

$$= -\frac{221{,}850}{369}\left(1 + \frac{13.12(15.83)}{138}\right) + \frac{6{,}908{,}256}{3220}$$

$$= 639 \text{ psi (T)} < f_t = 930 \text{ psi} \quad \therefore \underline{\text{O.k.}}$$

b) <u>C-LINE METHOD:</u>

$P_e = 221{,}850$ lb.

$M_T = 6{,}908{,}256$ in-lb.

$$a = \frac{M_T}{P_e} = 31.1 \text{ in}$$

$$e' = a - e = 31.1 - 13.12 = 18.02 \text{ in}$$

$$f^t = -\frac{P_e}{A_c}\left(1 + \frac{e' \cdot C_t}{r^2}\right) = \frac{-221{,}850}{369}\left(1 + \frac{18.02 \times 20.17}{138}\right)$$

$$= -2{,}183 \text{ psi (C)}$$

$$f_b = -\frac{P_e}{A_c}\left(1 - \frac{e' \cdot C_b}{r^2}\right) = \frac{-221{,}850}{369}\left(1 - \frac{18.02 \times 20.17}{138}\right)$$

$$= 639 \text{ psi (T)}$$

c) <u>LOAD BALANCING METHOD:</u> =

$P' = P_e = 221{,}850$ lb.

$a = 13.12 \text{ in} = e = 1.09 \text{ ft}$

$$W_b = \frac{8.P'.a}{l^2} = \frac{8 \times 221{,}850 \times 1.09}{(34)^2} = 1{,}678.5 \text{ plf}$$

$$W_T = 384 + 3600 = 3{,}984 \text{ plf}$$

$$W_{ub} = 3{,}984 - 1{,}678.59 = 2{,}305.41 \text{ plf.}$$

$$M_{ub} = \frac{W_{ub} \cdot \ell^2}{8} = \frac{2305.41(34)^2}{8} \times 12 = 3{,}997{,}581 \text{ in-lb}$$

$$f^t = -\frac{P'}{A_c} - \frac{M_{ub}}{S^t} = -\frac{221{,}850}{369} - \frac{3{,}997{,}581}{2{,}527} = -2183 \text{ psi (C)}$$

$$f_b = \frac{-P'}{A_c} + \frac{M_{ub}}{S_b} = -\frac{221{,}850}{369} + \frac{3{,}997{,}581}{3220} = 639 \text{ psi (T)}$$

$$< f_t = 930 \text{ psi} \therefore \underline{\underline{ok}}$$