INSTRUCTOR'S SOLUTIONS MANUAL

PRESTRESSED CONCRETE

A Fundamental Approach

Fifth Edition Update
ACI, AASHTO, IBC 2009 Codes Version

EDWARD G. NAWY

Prentice Hall

Upper Saddle River Boston Columbus San Francisco New York

Indianapolis London Toronto Sydney Singapore Tokyo Montreal

Dubai Madrid Hong Kong Mexico City Munich Paris Amsterdam Cape Town

Vice President and Editorial Director, ECS: *Marcia J. Horton*
Senior Editor: *Holly Stark*
Associate Editor: *Dee Bernhard*
Editorial Assistant: *Keri Rand*
Director of Team-Based Project Management: *Vince O'Brien*
Senior Managing Editor: *Scott Disanno*
Senior Operations Supervisor: *Alan Fischer*
Operations Specialist: *Lisa McDowell*
Cover Designer: *Bruce Kenselaar*

About the Cover: The new I-35W bridge, Minneapolis, Minnesota. Designed for the Minnesota Department of Transportation by FIGG, this new bridge incorporates aesthetics selected by the community using a theme of "Arches–Water–Reflection" to complement the site across the Mississippi River. Curved, 70′ tall concrete piers meet the sweeping parabolic arch of the 504′ precast, prestressed concrete main span over the river to create a modern bridge. The new 10-lane interstate bridge was constructed by Flatiron-Manson, JV and opened to traffic on September 18, 2008. The bridge was designed and built in 11 months. The bridge incorporates the first use of LED highway lighting, the first major use in the United States of nanotechnology cement that cleans the air (gateway sculptures) and "smart bridge" technology with 323 sensors embedded throughout the concrete to provide valuable data for the future. The photograph of the new I-35W bridge is courtesy of FIGG.

Prentice Hall
is an imprint of

PEARSON

www.pearsonhighered.com

10 9 8 7 6 5 4 3 2 1

ISBN-13: 978-0-13-608151-7
ISBN-10: 0-13-608151-7

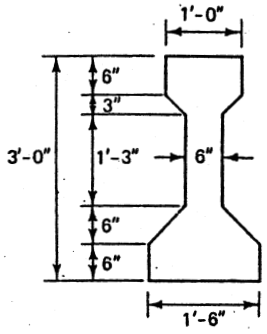
TABLE OF CONTENTS

ACKNOWLEDGMENTS

Grateful acknowledgment to Joe Davis, PhD, Rutgers University, for his input to the development of this edition's Solutions Manual. Thanks are also due to Engineer Anand A. Bhatt, MS, Rutgers, for his input to the development of the previous edition's Manual, part of which, not affected by the ACI 318 Code changes, is retained in this edition.

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 ½-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 psi (41.4 MPa)
$f_c = 0.45 f'_c$
= 2700 psi (26.7 MPa)
$f_t = 12\sqrt{f'_c}$ = 930 psi (6.4 MPa)
f_{pu} = 270,000 psi (1862 MPa)
f_{pi} = 189,000 psi (1303 MPa)
f_{pe} = 145,000 psi (1000 MPa)



The section properties, given these stresses, are

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

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

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

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

The midspan self-weight dead-load moment is

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

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

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

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

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

ii) FINAL Conditions at Service Load:-

The midspan moment due to live load is:

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

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

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

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

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

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

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

b) C-LINE METHOD:

$P_e = 221{,}850 \text{ lb}$.

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

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

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

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

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

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

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

c) LOAD BALANCING METHOD: =

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

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

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

$$w_T = 384 + 3600 = 3984 \text{ plf}$$

$$w_{ub} = 3984 - 1{,}678.59 = 2{,}305.41 \text{ plf}.$$

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

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

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

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

2) S. I. System:-

a) Basic Concept:-

Assume that ten 12.7 mm dia seven wire strand tendons are used to prestres.

i) Initial Conditions at Prestressing:-

$A_{ps} = 10(99) = 990\ mm^2$

$P_i = A_{ps} \cdot f_{pi} = 990(1303) = 1290\ KN$

$P_e = 990(1000) = 990\ KN$

The midspan self-weight dead load moment

$$M_D = \frac{W_D l^2}{8} = \frac{5.60(10.4)^2}{8} = 75.7\ KN\text{-}M.$$

$$f^t = -\frac{P_i}{A_c}\left(1 - \frac{e.C^t}{r^2}\right) - \frac{M_D}{S^t}$$

$$= -\frac{1290}{2381}\left(1 - \frac{33.3(51.2)}{891}\right) - \frac{75.7\times10^2}{41410} = 3.1\ MPa$$

$$f_b = -\frac{P_i}{A_c}\left(1 + \frac{e.C_b}{r^2}\right) + \frac{M_D}{S_b} = -\frac{1290}{2381}\left(1 - \frac{33.3(51.2)}{891}\right) + \frac{75.7\times10^2}{52766}$$

$$= -12.1\ MPa < -19.9\ MPa \quad \therefore \underline{O.K.}$$

Final Conditions at Service Load:-

The midspan moment due to live load is

$$M_L = \frac{52.6(10.4)^2}{8} = 711\ KN\text{-}M.$$

$$M_T = 75.7 + 711 = 787\ KN\text{-}M.$$

$$f^t = -\frac{P_e}{A_c}\left(1 - \frac{eC^t}{r^2}\right) - \frac{M_T}{S^t}$$

$$= -\frac{990}{2381}\left(1 - \frac{33.3 \times 51.2}{891}\right) - \frac{787 \times 10^2}{41410}$$

$$= -15.1\ MPa\ (C) < f_c = 18.6\ MPa \quad \text{O.K.}$$

$$f_b = \frac{-990}{2381}\left(1 + \frac{33.3\,(40.2)}{891}\right) - \frac{787 \times 10^2}{52766}$$

$$= 4.5\ MPa\ (T) < f_t = 6.4\ MPa\ (T) \quad \therefore \text{O.K.}$$

b) C-LINE METHOD:=

$P_e = 990\ KN$

$M_T = 787\ KN\text{-}m$

$$a = \frac{787}{990} = 0.795\ m$$

$$e' = a - e = 79.49 - 33.3 = 46.19\ cm.$$

$$f^t = \frac{-990\ KN}{2381\ cm^2}\left(1 + \frac{46.19 \times 51.2}{891}\right) \approx 15.1\ MPa\ (C)$$

$$f_b = \frac{-990\ KN}{2381\ cm^2}\left(1 - \frac{46.19 \times 40.2}{891}\right) = 4.5\ MPa\ (T)$$

c) LOAD BALANCING METHOD:=

$P' = P_e = 990\ KN$

$a = 33.3\ cm = e$

$$W_b = \frac{8P'.a}{l^2} = \frac{8(990) \times \frac{33.3}{100}}{(10.4)^2} = 24.38\ KN/m$$

$$W_{ub} = 52.6 + 5.6 - 24.38 = 33.82\ KN/m.$$

$$M_{ub} = \frac{W_{ub}.xl^2}{8} = \frac{33.82 \times (10.4)^2}{8} = 457.25\ KN\text{-}m$$

$$f^t = -\frac{P'}{A_c} - \frac{M_{4b}}{S^t} = -\frac{990}{2381} - \frac{457.25 \times 10^2}{41410} \approx 15.1\,MPa\,(C)$$

$$f_b = -\frac{P'}{A_c} + \frac{M_{4b}}{S_b} = \frac{-990}{2381} + \frac{457.25 \times 10^2}{52766} = 4.5\,MPa\,(T)$$

$$< f_t = 6.4\,MPa$$

$$\therefore \text{ok}$$

1.3 A simply supported pretensioned pretopped double T-beam for a floor has a span of 70 ft (21.3 m) and the geometrical dimensions shown in Figure P1.3. It is subjected to a gravity live-load intensity W_L = 480 plf (7 kN/m), and the prestressing tendon has an eccentricity at midspan of e_c = 19.96 in. (494 mm). Compute the concrete extreme fiber stresses in this beam at transfer and at service load, and verify whether they are within the permissible limits. Assume that all permissible stresses and materials used are the same as in example 1.1. The section properties are:

Section Properties
Untopped

A_c	=	1185 in.^{2}
I_g	=	109,621 in.^{4}
C_b	=	25.65 in.
C_t	=	8.35 in.
S_b	=	4274 in.^{3}
S^t	=	13,128 in.^{3}
W_D	=	1234 plf
		82 psf
V/S	=	2.45 in.

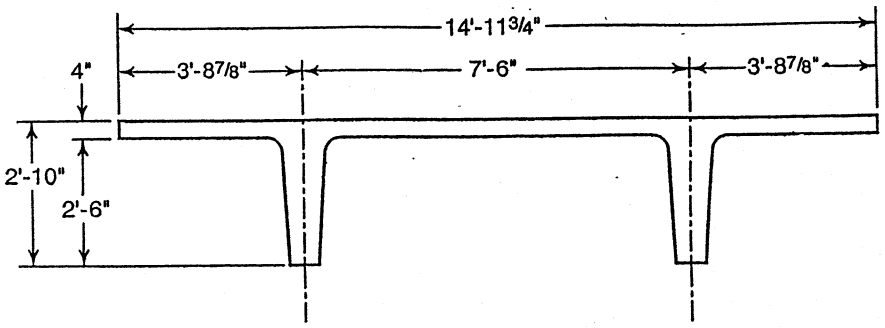


Figure P1.3.

Design the prestressing steel needed using ½-in.-dia stress-relieved seven-wire strands. Use the three methods of analysis discussed in this chapter in your solution.

SOLUTION:—

$l = 70$ ft

$W_L = 480$ lb/ft

$e_c = 19.96$ in

$f_c' = 6000$ psi

$f_c = 2700$ psi

$f_t = 12\sqrt{f_c'} = 930$ psi.

$f_{pu} = 270{,}000$ psi.

$f_{pi} = 189{,}000$ psi.

$f_{pe} = 145{,}000$ psi.

$A_c = 1185$ in^2

$I_g = 109{,}621$ in^4

$C_b = 25.65$ in

$C^t = 8.35$ in

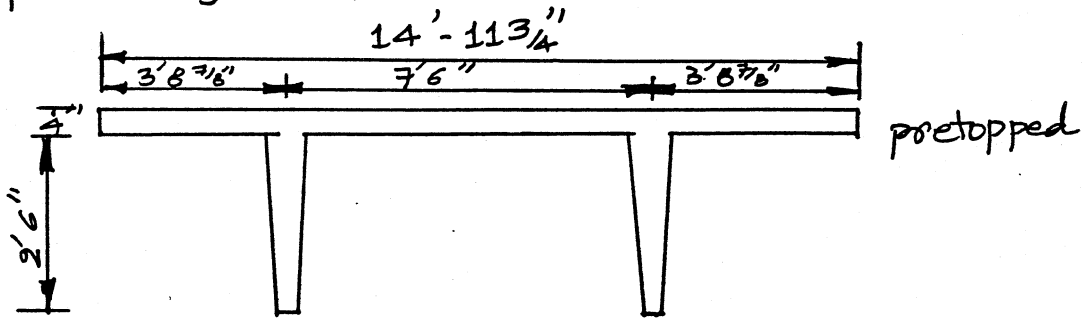
$r^2 = I/A = 92.5$ in^2

$S_b = 4274$ in^3

$S^t = 13{,}124$ in^3

$W_D = 1234$ lb/ft

$V/S = 2.45$ in



Assume $16-\frac{1}{2}$" dia seven wire tendons are used.

Initial Conditions @ Prestressing:

$A_{ps} = 16 \times 0.153 = 2.45 \text{ in}^2$

$P_i = A_{ps} \cdot f_{pi} = 2.45 \times 189{,}000 = 463{,}050 \text{ lb}.$

$P_e = A_{ps} \cdot f_{pe} = 2.45 \times 145{,}000 = 355{,}250 \text{ lb}.$

Midspan self-wt. D.L. moment

$$= \frac{wl^2}{8} = \frac{1234(70)^2}{8} \times 12 = 9{,}069{,}900 \text{ in-lb}$$

$$f^t = -\frac{P_i}{A_c}\left(1 - \frac{e \cdot c_t}{r^2}\right) - \frac{M_D}{S^t} = -\frac{463{,}050}{1185}\left(1 - \frac{19.96 \times 8.35}{92.5}\right) - \frac{9{,}069{,}900}{13{,}128}$$

$$= 313.31 - 690.88 = -377.57 \text{ psi (C)}$$

$$F_b = -\frac{463{,}050}{1{,}185}\left(1 + \frac{19.96 \times 25.65}{92.5}\right) + \frac{9{,}069{,}900}{4274}$$

$$= -431.4 \text{ psi (C)}$$

Assuming $f'_{ci} = 4800$ psi

$f_{ci} = 0.6 f'_{ci} = 2880$ psi.

then $-431.4 < -377.57 < f_{ci} = -2880$ psi

$\therefore$ o.k.

FINAL Condition @ Service Load:=

$$M_L = \frac{480(70)^2}{8} \times 12 = 3{,}528{,}000 \text{ in-lb}.$$

$$M_T = 3{,}528{,}000 + 9{,}069{,}900 = 12{,}597{,}900 \text{ in-lb}.$$