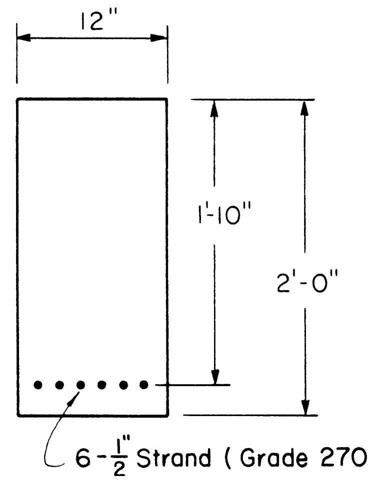
Example 24.3—Flexural Strength of Prestressed Member Using Approximate Value for f_{ps}

Calculate the nominal moment strength of the prestressed member shown.

f'_c = 5000 psi

f_{pu} = 270,000 psi (low-relaxation strands; $f_{py} = 0.90f_{pu}$)



Calculations and Discussion	Code Reference

1. Calculate stress in prestressed reinforcement at nominal strength using approximate value for f_{ps}. For a fully prestressed member, Eq. (18-3) reduces to:

$$f_{ps} = f_{pu}\left(1 - \frac{\gamma_p}{\beta_1}\rho_p\frac{f_{pu}}{f'_c}\right)$$ *Eq. (18-3)*

$$= 270\left(1 - \frac{0.28}{0.80} \times 0.00348 \times \frac{270}{5}\right) = 252 \text{ ksi}$$

where

$$\gamma_p = 0.28 \text{ for } \frac{f_{py}}{f_{pu}} = 0.90 \text{ for low-relaxation strand}$$

$$\beta_1 = 0.80 \text{ for } f'_c = 5000 \text{ psi}$$ *10.2.7.3*

$$\rho_p = \frac{A_{ps}}{bd_p} = \frac{6 \times 0.153}{12 \times 22} = 0.00348$$

2. Calculate nominal moment strength from Eqs. (9) and (10) of Part 24

Compute the depth of the compression block:

$$a = \frac{A_{ps}f_{ps}}{0.85bf'_c} = \frac{0.918 \times 252}{0.85 \times 12 \times 5} = 4.54 \text{ in.} \qquad \text{Eq. (10)}$$

$$M_n = A_{ps}f_{ps}\left(d_p - \frac{a}{2}\right) \qquad \text{Eq. (9)}$$

$$M_n = 0.918 \times 252\left(22 - \frac{4.54}{2}\right) = 4565 \text{ in-kips} = 380 \text{ ft-kips}$$

3. Check to see if tension controlled *10.3.4*

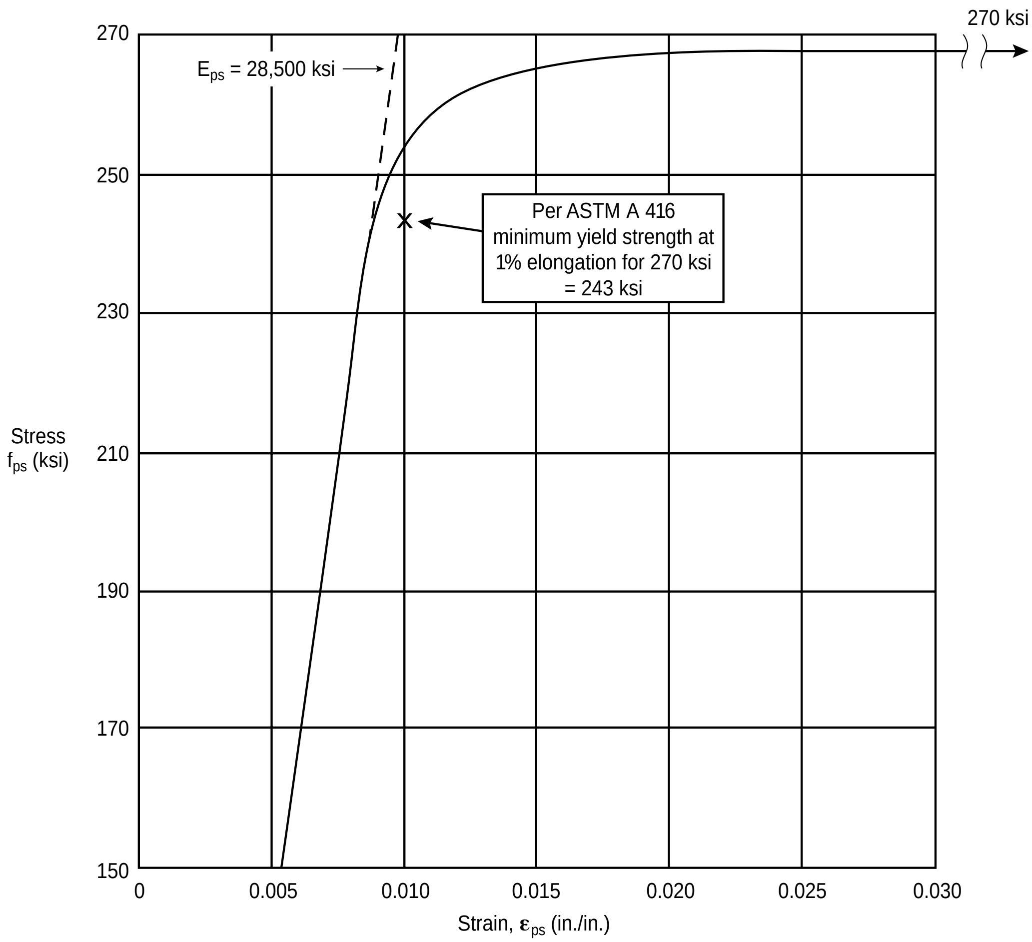
$$c/d_p = (a/\beta_1)/d_p = \left(\frac{4.54}{0.80}\right)/22$$

$c/d_p = 0.258 < 0.375$ *R9.3.2.2*

Tension controlled $\phi = 0.9$

Duct — A conduit (plain or corrugated) to accommodate prestressing steel for post-tensioned installation. Requirements for post-tensioning ducts are given in 18.17.

Sheathing — A material encasing prestressing steel to prevent bonding of the prestressing steel with the surrounding concrete, to provide corrosion protection, and to contain the corrosion inhibiting coating.



The above curve can be approximated by the following equations: $\varepsilon_{ps} \leq 0.0086$: $f_{ps} = 28{,}500\, \varepsilon_{ps}$ (ksi)

$\varepsilon_{ps} > 0.0086$: $f_{ps} = 270 - \dfrac{0.04}{\varepsilon_{ps} - 0.007}$ (ksi)

Figure 24-1 Stress-Strain Curve for Grade 270, Low Relaxation Strand(24.1)

18.2 GENERAL

The code specifies strength and serviceability requirements for all concrete members, prestressed or nonprestressed. This section requires that, for prestressed members, both strength and behavior at service conditions must be checked. All load stages that may be critical during the life of the structure, beginning with the transfer of the prestressing force to the member and including handling and transportation, must be considered.

This section also calls attention to several structural issues specific to prestressed concrete structures that must be considered in design:

18.2.3...Stress concentrations. See 18.13 for requirements for post-tensioned anchorages.

Example 24.4—Flexural Strength of Prestressed Member Based on Strain Compatibility

The rectangular beam section shown below is reinforced with a combination of prestressed and nonprestressed strands. Calculate the nominal moment strength using the strain compatibility (moment-curvature) method.

f'_c = 5000 psi

f_{pu} = 270,000 psi (low-relaxation strand; $f_{py} = 0.9f_{pu}$)

E_{ps} = 28,500 ksi

jacking stress = $0.74f_{pu}$

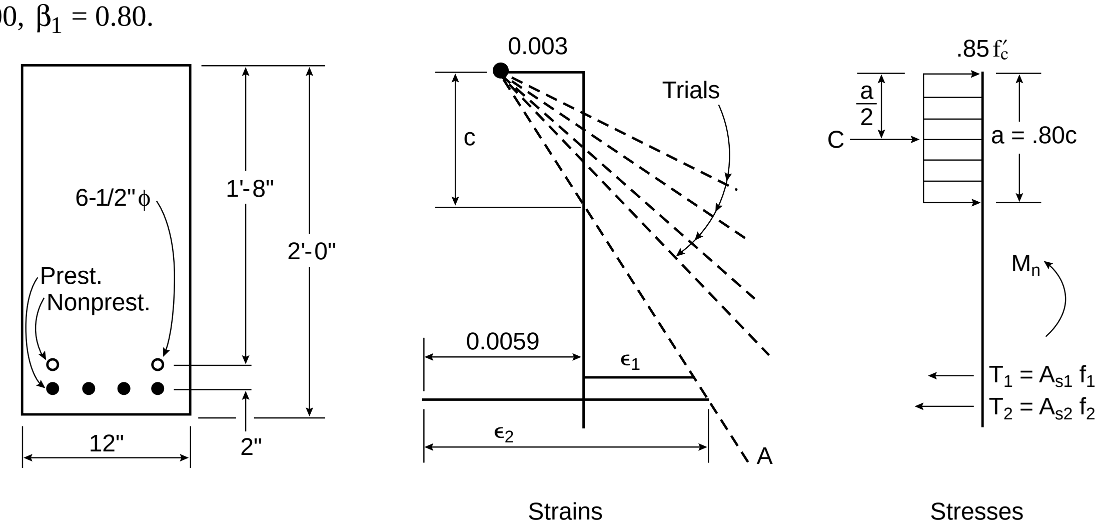
losses = 31.7 ksi (calculated by method of Ref. 24.4. See 18.6 — Loss of Prestress for procedure.)

Calculations and Discussion	Code Reference

1. Calculate effective strain in prestressing steel.

$$\varepsilon = (0.74f_{pu} - \text{losses})/E_{ps} = (0.74 \times 270 - 31.7)/28{,}500 = 0.0059$$

2. Draw strain diagram at nominal moment strength, defined by the maximum concrete compressive strain of 0.003 and an assumed distance to the neutral axis, c. For f'_c = 5000, $\beta_1 = 0.80$. *18.3.1*



3. Obtain equilibrium of horizontal forces.

The “strain line” drawn above from point 0 must be located to obtain equilibrium of horizontal forces:

$$C = T_1 + T_2$$

To compute T_1 and T_2, strains ε_1 and ε_2 are used with the stress-strain relation for the strand to determine the corresponding stresses f_1 and f_2. Equilibrium is obtained using the following iterative procedure:

a. assume c (location of neutral axis)

b. compute ε_1 and ε_2

c. obtain f_1 and f_2 from the equations in Fig. 24-1.

d. compute $a = \beta_1 c$

e. compute $C = 0.85 f'_c ab$

f. compute T_1 and T_2

g. check equilibrium using $C = T_1 + T_2$

h. if $C < T_1 + T_2$, increase c, or vice versa and return to step b of this procedure. Repeat until satisfactory convergence is achieved.

Estimate a neutral axis location for first trial. Estimate stressed strand at 260 ksi, unstressed strand at 200 ksi.

$T = \Sigma A_{ps} f_s = 0.306\ (200) + 0.612\ (260) = 220$ kips = C

$a = C/(0.85\ f'_c b) = 220/(0.85 \times 5 \times 12) = 4.32$ in.

$c = a/\beta_1 = 4.32/0.80 = 5.4$ in. Use c = 5.4 in. for first try

The following table summarizes the iterations required to solve this problem:

Trial No.	c in.	ε_1	ε_2	f_1 ksi	f_2 ksi	a in.	C kips	T_1 kips	T_2 kips	$T_1 + T_2$ kips
1	5.4	0.0081	0.0151	231	265	4.32	220	71	162	233
2 O.K.	5.6	0.0077	0.0147	220	265	4.48	228.5	67	162	229

4. Calculate nominal moment strength.

Using C = 228.5 kips, T_1 = 67 kips and T_2 = 162 kips, the nominal moment strength can be calculated as follows by taking moments about T_2:

$M_n = [((d_2 - a/2) \times C) - ((d_2 - d_1) \times T_1)]/12$

$= [(22 - (4.48/2)) \times 228.5 - (22 - 20) \times 67)]/12 = 365$ ft-kips