CE 414: Prestressed Concrete
Lecture 11
Flexural Design (Preliminary design)

Course Instructor: Saurav Barua

Assistant Professor, Department of Civil Engineering, DIU

Email: saurav.ce@diu.edu.bd

Phone: 01715334075

Contents

- Preliminary design
- Girder moment and total moment
- T- section design example
- I- section design example

6-1 Preliminary Design

Preliminary design of prestressed-concrete sections for flexure can be performed by a very simple procedure, based on a knowledge of the internal *C-T* couple acting in the section. In practice the depth *h* of the section is either given, known, or assumed, as is the total moment M_T on the section. Under the working load, the lever arm for the internal couple could vary between 30 to 80% of the overall height *h* and averages about 0.65*h*. Hence the required effective prestress *F* can be computed from the equation

$$F = T = \frac{M_T}{0.65h} \tag{6-1}$$

if we assume the lever arm to be 0.65*h*, Fig. 6-1. If the effective unit prestress is f_s for the steel, then the area of steel required is

$$A_{ps} = \frac{F}{f_{se}} = \frac{M_T}{0.65hf_{se}} \tag{6-2}$$

The total prestress $A_{ps}f_{se}$ is also the force C on the section. This force will produce an average unit stress on the concrete of

$$\frac{C}{A_c} = \frac{T}{A_c} = \frac{A_{ps}f_{se}}{A_c}$$

The top fiber stress, f_c, under working loads following ACI Code is $0.45f'_c$, Fig. 6-1. Table 1-2, Chapter 1, summarizes permissible stresses in steel and concrete for prestressed concrete members. For preliminary design, the average stress can be assumed to be about 50% of the maximum allowable stress f_c, under the working load. Hence,

$$\frac{A_{ps}f_{se}}{A_c} = 0.50f_c$$

$$A_c = \frac{A_{ps}f_{se}}{0.50f_c} \tag{6-3}$$

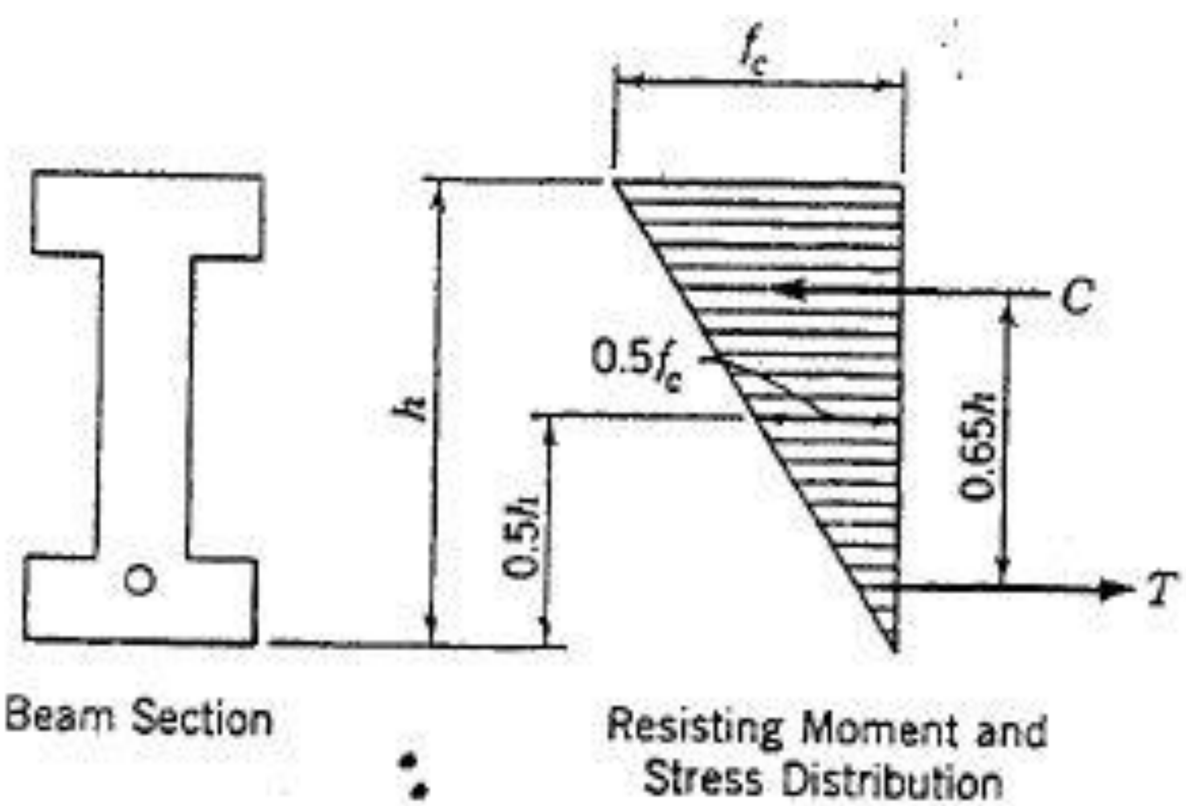

Fig. 6-1. **Preliminary design of a beam section.**

coefficients of 0.65 and 0.50. These coefficients vary widely, depending on the shape of the section. However, with experience and knowledge, they can be closely approximated for each particular section, and the preliminary design can be made rather accurately.

EXAMPLE 6-1

Make a preliminary design for section of a prestressed-concrete beam to resist a total moment of 320 k-ft (434 kN-m). The overall depth of the section is given as 36 in (914.4 mm). The effective prestress for steel is 125,000 psi (862 N/mm²), and allowable stress for concrete under working load is – 1600 psi (– 11.03 N/mm²).

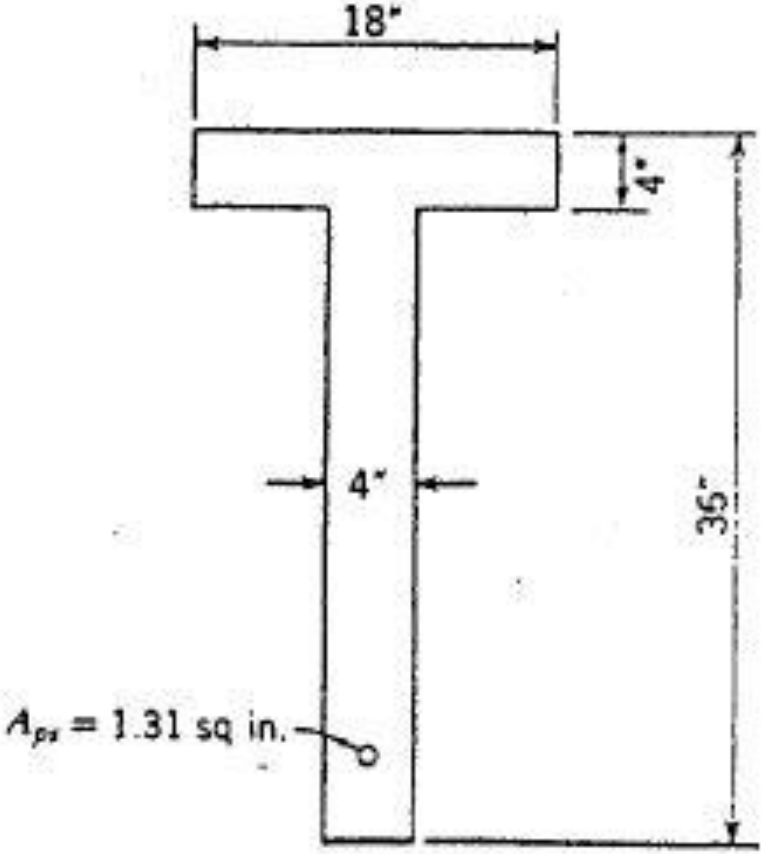

Fig. 6-2. Example 6-1.

Solution From equations 6-1, 6-2, and 6-3,

$$F = T = M_T/0.65h$$

$$= (320 \times 12)/(0.65 \times 36) = 164 \text{ k } (729.5 \text{ kN})$$

$$A_{ps} = F/f_{se} = 164/125 = 1.31 \text{ sq in } (845 \text{ mm}^2)$$

$$A_c = 164/(0.5 \times 1.60) = 205 \text{ sq in. } (132 \times 10^3 \text{ mm}^2)$$

Now a preliminary section can be sketched with a total concrete area of about 205 sq in. (132×10^3 mm^2), a height of 36 in. (914.4 mm), and a steel area of 1.31 sq in. (845 mm^2) Such a section is shown in Fig. 6-2. A T-section is chosen here because it is an economical shape when M_G/M_T ratio is large.

In estimating the depth of a prestressed section, an approximate rule is to use 70% of the corresponding depth for conventional reinforced-concrete construction. Some other empirical rules are also available. For example, the thickness of prestressed slabs may vary from $L/35$ for heavy loads to $L/55$ for light loads. The depth of beams of the usual proportions can be approximated by the following formula.

$$h = k\sqrt{M}$$

where h = depth of beam in inches
M = maximum bending moment in k-ft
k = a coefficient varying from 1.5 to 2.0

A more accurate preliminary design can be made if the girder moment M_G is known in addition to the total moment M_T. When M_G is much greater than 20 to 30% of M_T, the initial condition under M_G generally will not control the design, and the preliminary design needs be made only for M_T. When M_G is small relative to M_T, then the c.g.s. cannot be located too far outside the kern point, and the design is controlled by $M_L = M_T - M_G$. In this case, the resisting lever arm for M_L is given approximately by $k_t + k_b$, which averages about $0.50h$. Hence the total effective prestress required is

$$F = \frac{M_L}{0.50h} \tag{6-4}$$

When M_G/M_T is small, this equation should be used instead of equation 6-1. Equation 6-3 is still applicable.

EXAMPLE 6-2

Make a preliminary design for the beam section in example 6-1, with $M_T = 320$ k-ft, $M_G = 40$ k-ft, $h = 36$ in., $f_{se} = 125{,}000$ psi, and $f_c = -1600$ psi ($M_T = 434$ kN-m, $M_G = 54$ kN-m, $h = 914.4$ mm, $f_{se} = 862$ N/mm^2, and $f_c = -11.03$ N/mm^2).

Solution Since M_G is only 12% of M_T, it is not likely that the c.g.s. can be located much outside the kern. Hence it will be more nearly correct to apply equation 6-4. Thus,

$$M_L = M_T - M_G = 320 - 40$$
$$= 280 \text{ k-ft } (380 \text{ kN-m})$$
$$F = M_L / 0.50h = 280 \times 12 / (0.50 \times 36)$$
$$= 187 \text{ k } (832 \text{ kN})$$

Applying the first part of formula 6-2 and also formula 6-3, we have

$$A_{ps} = F / f_{se} = 187/125$$
$$= 1.50 \text{ sq in. } (968 \text{ mm}^2)$$
$$A_c = A_{ps} f_{se} / 0.50 f_c = 187/(0.50 \times 1.60)$$
$$= 234 \text{ sq in. } (151 \times 10^3 \text{ mm}^2)$$

Now a preliminary section can be sketched with a total concrete area of about 234 sq in. (151×10^3 mm^2), a height of 36 in. (914.4 mm), and a steel area of 1.50 sq in. (968 mm^2), as shown in Fig. 6-3. An I-section is chosen because it is a suitable form when the M_G/M_T ratio is small.

When it is not known whether M_T or M_L should govern the design, one convenient way is to apply both equations 6-1 and 6-4, and use the greater of the two values of F. For example, if $M_G = 80$ k-ft (108 kN-m) in example 6-1, we have, from equation 6-1,

$$F = M_T/0.65h$$

$$= (320 \times 12)/(0.65 \times 36)$$

$$= 164 \text{ k } (730 \text{ kN})$$

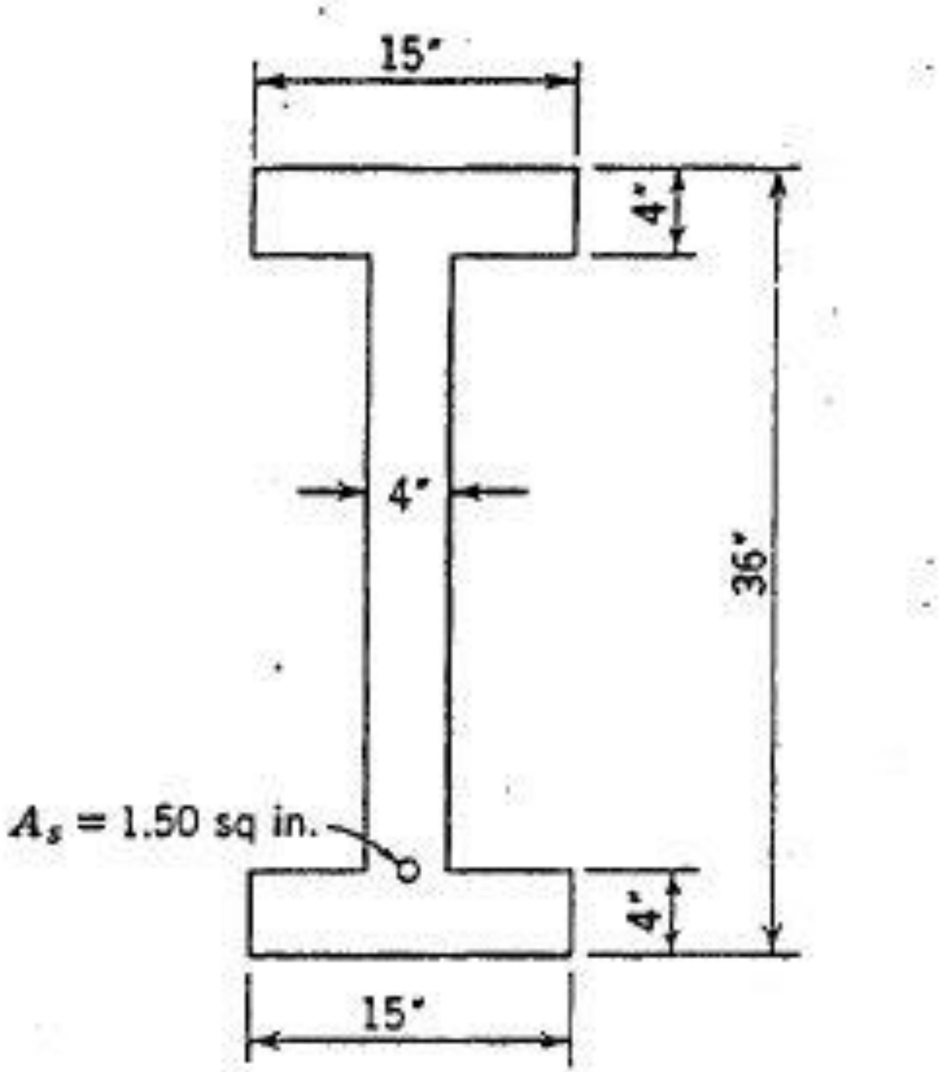

Fig. 6-3. Example 6-2.

From equation 6-4, we have

$$F = M_L / 0.50h$$
$$= [(320 - 80)12]/(0.50 \times 36)$$
$$= 160 \text{ k } (712 \text{ kN})$$

$F = 164$ k (730 kN) controls the design.