The basic shape of an efficient pre-tensioned flexural member may be different from the most economical shape that can be found for a post-tensioned design. This is particularly true of moderate- and long-span members and somewhat complicates any generalization about which method is best under such conditions.

Post-tensioning is generally regarded as a method of making prestressed concrete at the job site, yet post-tensioned beams are often made in precasting plants and transported to the job site. Pre-tensioning is often thought of as a method of manufacturing that is limited to permanent precasting plants. Yet on very large projects where pre-tensioned elements are to be utilized, it is not uncommon for the general contractor to set up a temporary pre-tensioning plant at or near the job site. Each method of making prestressed concrete has particular theoretical and practical advantages and disadvantages, which will become more apparent after the principles are well understood. The final determination of the mode of prestressing that should be used on any particular project can only be made after careful consideration of the structural requirements and the economic factors that prevail for the particular project.

1-7 Linear vs Circular Prestressing

The subject of prestressed concrete is frequently divided into linear prestressing, which includes the prestressing of elongated structures or elements such as beams, bridges, slabs, piles, etc., and circular prestressing, which includes pipe, tanks, pressure vessels, and domes. There are no generally recognized criteria for the design and construction of circularly prestressed structures. The theory of such construction is relatively simple and is adequately covered in the literature (*see* Refs. 6 through 14). This book has been confined to the structural design and analysis of linear prestressed structures and the methods of prestressing used in this type of construction.

1-8 Application of Prestressed Concrete

Prestressed concrete, when properly designed and fabricated, can be virtually crack-free under normal service loads as well as under moderate overload. This is believed to be an advantage in a structure that is exposed to an especially corrosive atmosphere. Prestressed concrete efficiently utilizes high-strength concretes and steels and is economical even with long spans. Reinforced concrete flexural members cannot be designed to be crack-free, cannot efficiently utilize high-strength materials, and are not economical on long spans.

A number of other statements can be made in favor of prestressed concrete, but there are bona fide objections to the use of this material under specific conditions. An attempt is made to point out these criticisms in subsequent chapters. Among the more significant points to be kept in mind about this material are

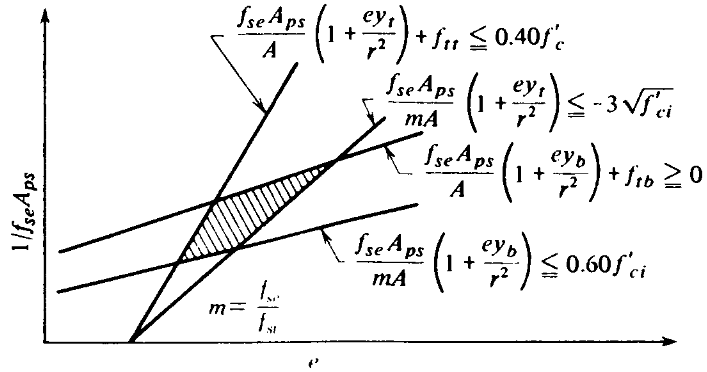

Fig. 7-5 Graphical solution of four equations in solving for the prestressing force and eccentricity.

It should be noted that f_{tb} is a negative stress and the negative sign is included in this symbol.

For an assumed concrete section and an assumed ratio between the effective steel stress and the initial steel stress $m = f_{se}/f_{si}$, the values of f_{tt} and f_{tb} can be computed and substituted in Eqs. 7-2 through 7-5, in which case, all of the terms that appear in the equations will be known or assumed, except the values of $f_{se}A_{ps}$ and e. Since a number of combinations of these terms will normally satisfy each of the four equations, the combinations that will satisfy all of the equations can be determined by plotting each of the four relationships, as shown in Fig. 7-5. The shaded area of Fig. 7-5 indicates the combinations of $f_{se}A_{ps}$ and e that satisfy the conditions of the allowable stresses for the assumed section.

Although the procedure of plotting a figure similar to that shown in Fig. 7-5, first suggested by Magnel (Ref. 1), will yield accurate results, it is obviously too cumbersome and time consuming to be used as a general design procedure. It does, however, illustrate the fact that there is frequently a combination of prestressing forces and eccentricities that will yield a satisfactory solution with a specific beam section.

7-4 Limitations of Sections Prestressed with Straight Tendons

It should be apparent that fully bonded, straight pretensioning tendons can only be used in prismatic beams in which the maximum flexural stress in the bottom fibers, due to the total load, does not exceed the arithmetic sum of either the allowable tensile stress and the final bottom fiber stress due to prestressing or the sum of the allowable tensile stress and the allowable compressive stress. If, for example the maximum stress in the bottom fiber due to the total external

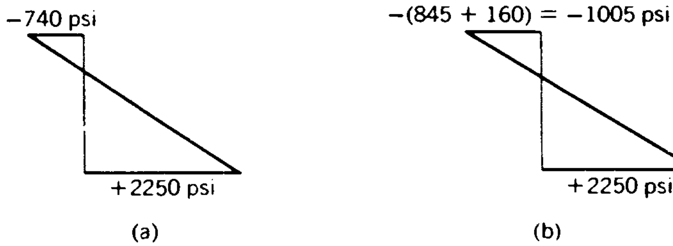

Fig. 7-13

nullified by the effective prestress. Non-prestressed reinforcement is not to be used and the top-fiber concrete stress due to initial prestressing plus dead load of the beam is to be limited to −190 psi. Assuming $f_{se}/f_{si} = 0.85$, the prestressing distribution shown in Fig. 7-13(b) limits the top fiber stress to the allowable value and exactly nullifies the total load stress in the bottom fiber. The bottom-fiber stress, due to the effective prestress, could be as high as $0.40\,f_c' + 695 = 2695$ psi. The most economical design will result from a prestressing force that can develop the required minimum effective prestress in the bottom fibers (+2250 psi), without exceeding the allowable, initial tensile stress in the top fibers, such as is shown in Fig. 7-13(b), if such a stress distribution can be obtained with a practical eccentricity.

For the distribution of stress shown in Fig. 7-13(b) the values of P and e are

$$\frac{P}{A} = 3255 \times \frac{24.7}{45.0} - 1005 = 782 \text{ psi}$$

$$P = 438 \text{ k}$$

$$e = \left(\frac{2250}{782} - 1\right)(-11.03) = -20.70 \text{ in.}$$

It is apparent that this is not a practical solution for this case, because the required eccentricity is greater than the distance from the center of gravity of the section to the bottom fibers (y_b); hence, if this solution were used, the center of gravity of the tendons would be below the bottom of the beam. Therefore, the distribution of stress due to the effective prestress must be revised in such a manner that the eccentricity is reduced.

Using the distribution of stress indicated in Fig. 7-13(a), the values of P and e are

$$\frac{P}{A} = 2990 \times \frac{24.7}{45.0} - 740 = 900 \text{ psi}$$

$$P = 504 \text{ k}$$

$$e = \left(\frac{2250}{900} - 1\right)(-11.03) = -16.5 \text{ in.}$$

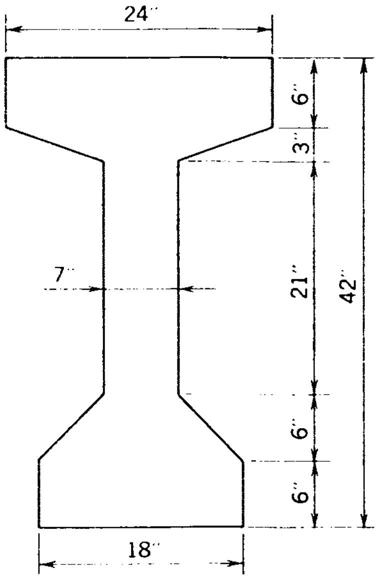

Fig. 7-18

The section is evaluated as follows:

Assume e = -22.1 in. + 4.5 in. = - 17.6 in.

$$P = \frac{1132 \times 12}{9.39 + 17.6} = 503 \text{ k}$$

	Top Fiber	*Bottom Fiber*
Stress due to M_D	+735 psi	-814 psi
Stresses due to M_{SL}	+1770 psi	- 1960 psi
	+2505 psi	-2774 psi
Stresses due to P	-665 psi	+2770 psi
Net stresses	+1840 psi	-4 psi

It should be noted that the prestressing force required in the final design is about 11% higher than the preliminary estimate and the concrete quantity is about 4% higher in the final design. These errors are the result of an error in the assumed value of $(e + r^2/y_b)$, which was assumed to be 0.70d and which is only 0.644d in the final design.

The initial stress in the bottom fiber should be checked. Assuming f_{se}/f_{si} = 0.85, the initial bottom-fiber stress is approximately +2445 psi, in which case, the value of f'_{ci} should be 4450 psi, if the initial compression is confined to 0.55 f'_{ci}, and 4100 psi and if the maximum allowable initial compression is 0.60 f'_{ci}.