CE 414: Prestressed Concrete
Lecture 18
Beam layout and partial prestress

Course Instructor: Saurav Barua

Assistant Professor, Department of Civil Engineering, DIU

Email: saurav.ce@diu.edu.bd

Phone: 01715334075

Contents

- Layout of pre-tensioned beam
- Layout of post-tensioned beam
- Limiting zone for c.g.s.
- Partial prestressing

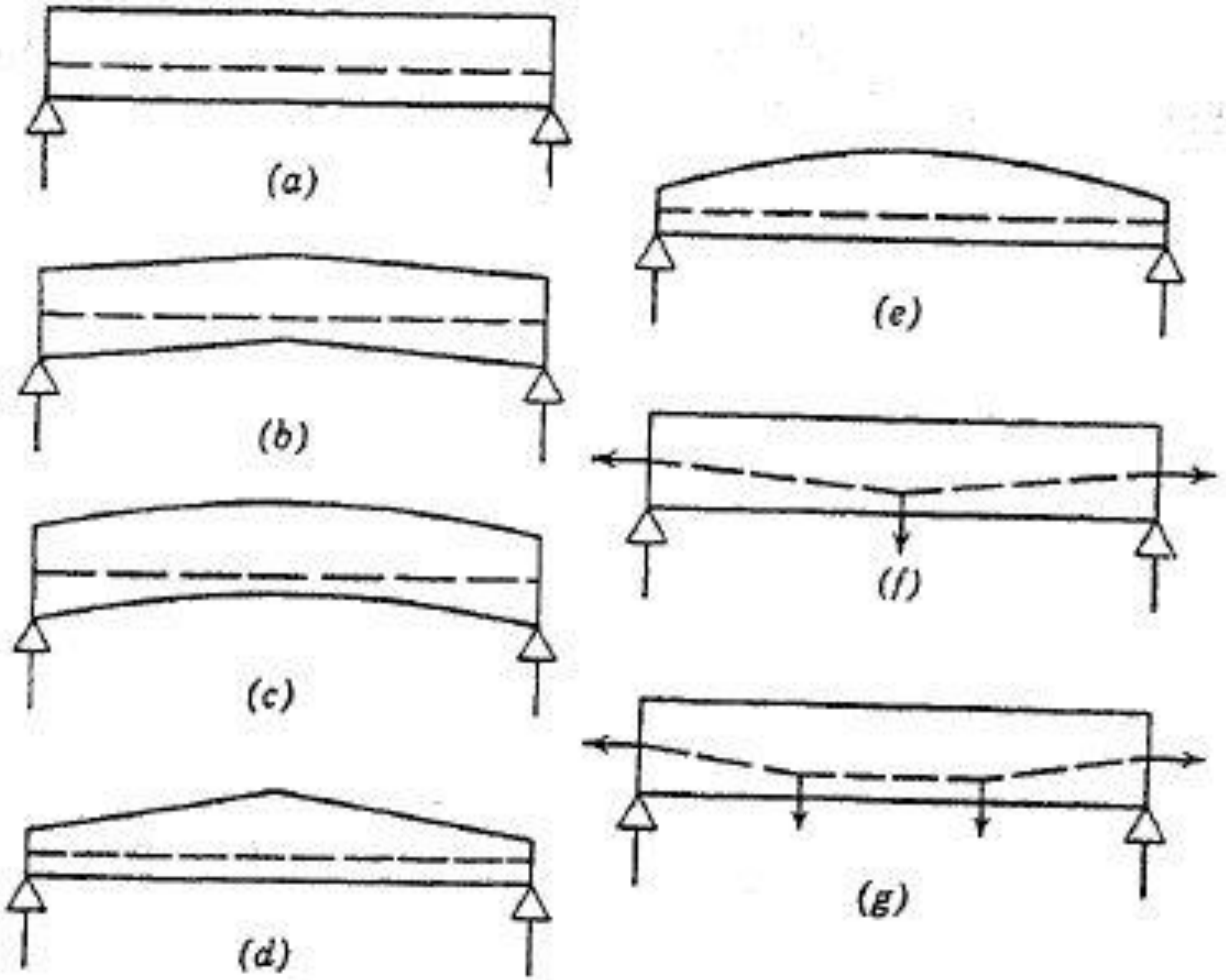


Fig. 8-7. Layouts for pretensioned beams.

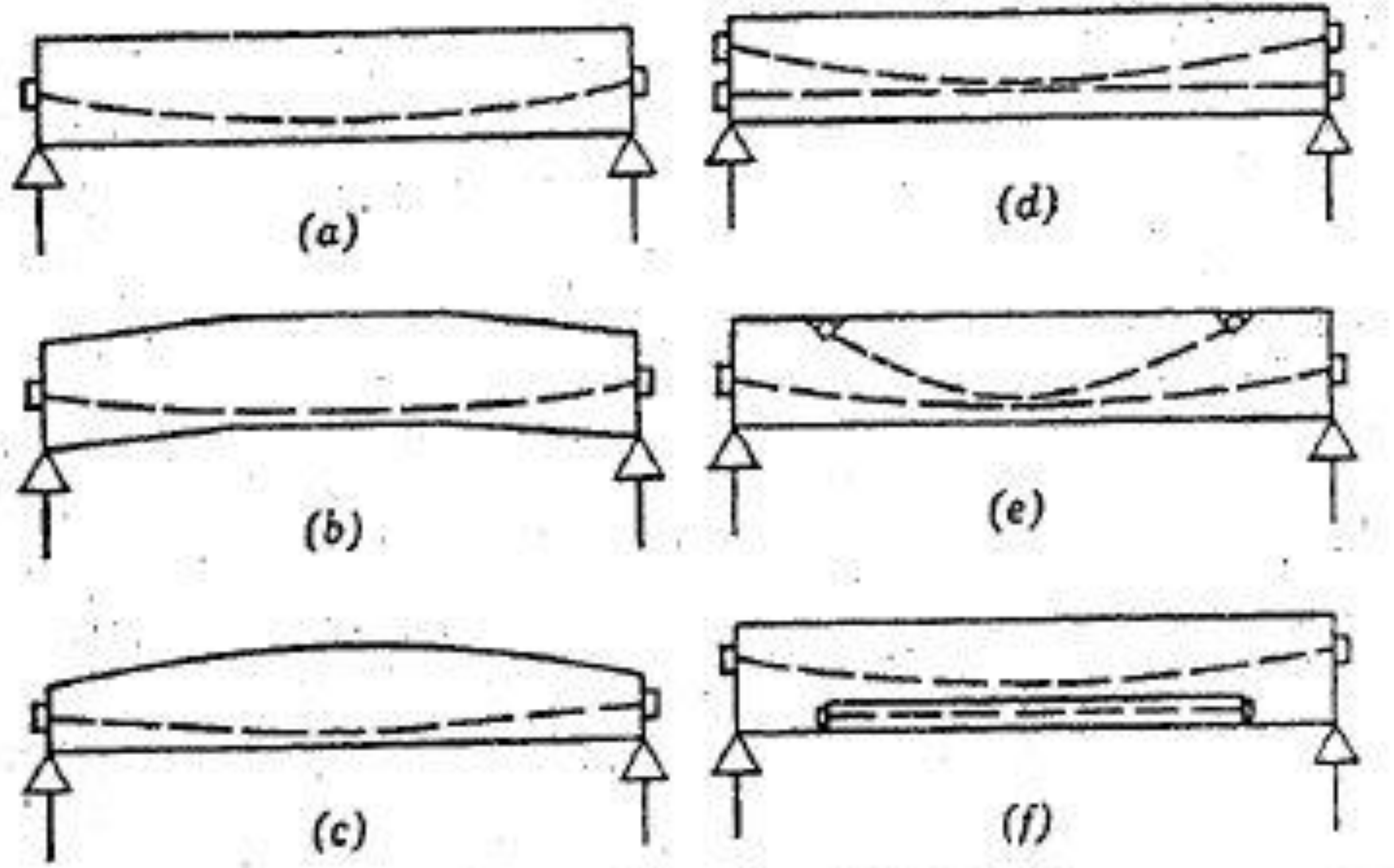
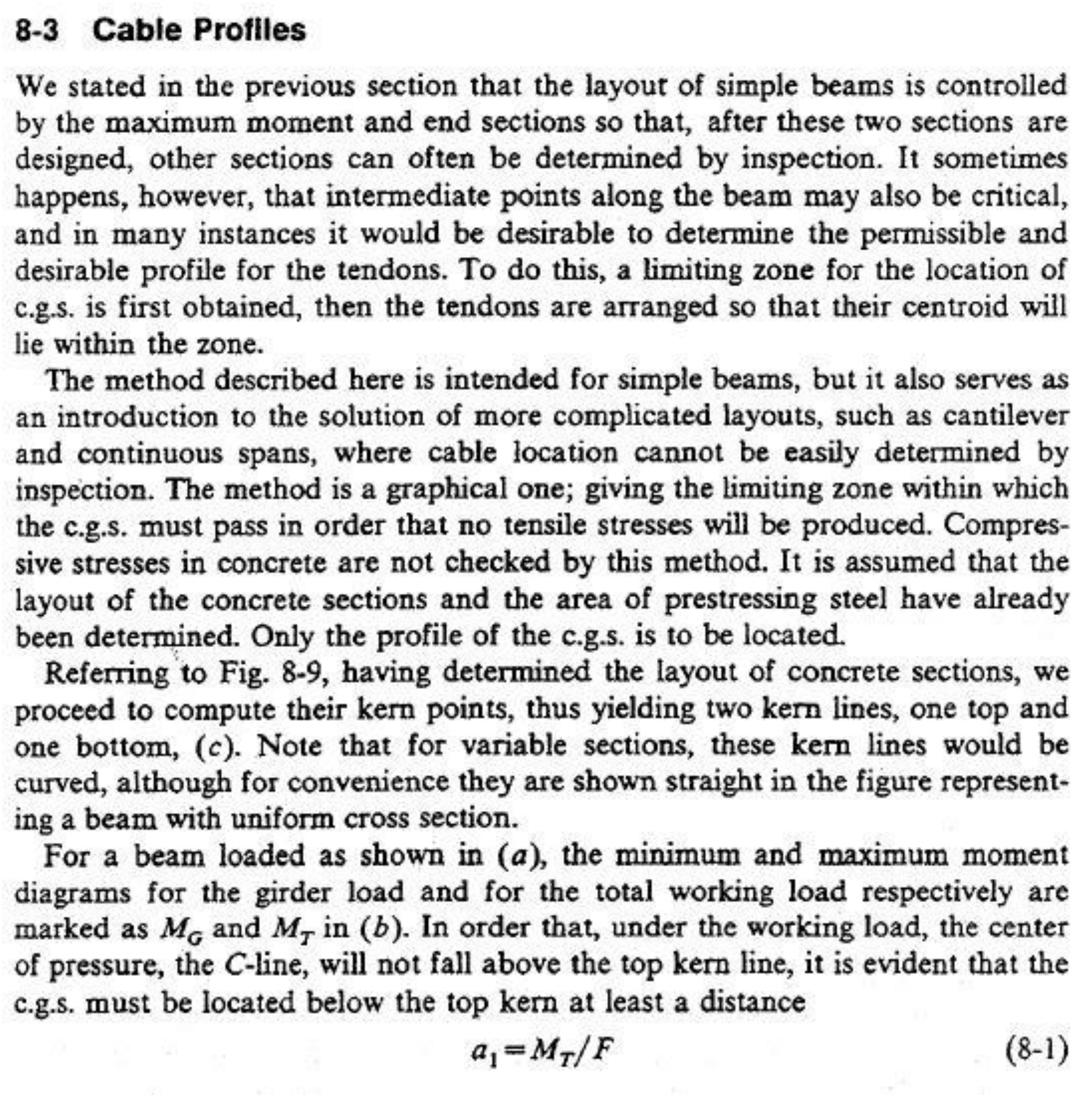


Fig. 8-8. Layouts for posttensioned beams.



8-3 Cable Profiles

We stated in the previous section that the layout of simple beams is controlled by the maximum moment and end sections so that, after these two sections are designed, other sections can often be determined by inspection. It sometimes happens, however, that intermediate points along the beam may also be critical, and in many instances it would be desirable to determine the permissible and desirable profile for the tendons. To do this, a limiting zone for the location of c.g.s. is first obtained, then the tendons are arranged so that their centroid will lie within the zone.

The method described here is intended for simple beams, but it also serves as an introduction to the solution of more complicated layouts, such as cantilever and continuous spans, where cable location cannot be easily determined by inspection. The method is a graphical one; giving the limiting zone within which the c.g.s. must pass in order that no tensile stresses will be produced. Compressive stresses in concrete are not checked by this method. It is assumed that the layout of the concrete sections and the area of prestressing steel have already been determined. Only the profile of the c.g.s. is to be located.

Referring to Fig. 8-9, having determined the layout of concrete sections, we proceed to compute their kern points, thus yielding two kern lines, one top and one bottom, (*c*). Note that for variable sections, these kern lines would be curved, although for convenience they are shown straight in the figure representing a beam with uniform cross section.

For a beam loaded as shown in (*a*), the minimum and maximum moment diagrams for the girder load and for the total working load respectively are marked as M_G and M_T in (*b*). In order that, under the working load, the center of pressure, the *C*-line, will not fall above the top kern line, it is evident that the c.g.s. must be located below the top kern at least a distance

$$a_1 = M_T/F \tag{8-1}$$

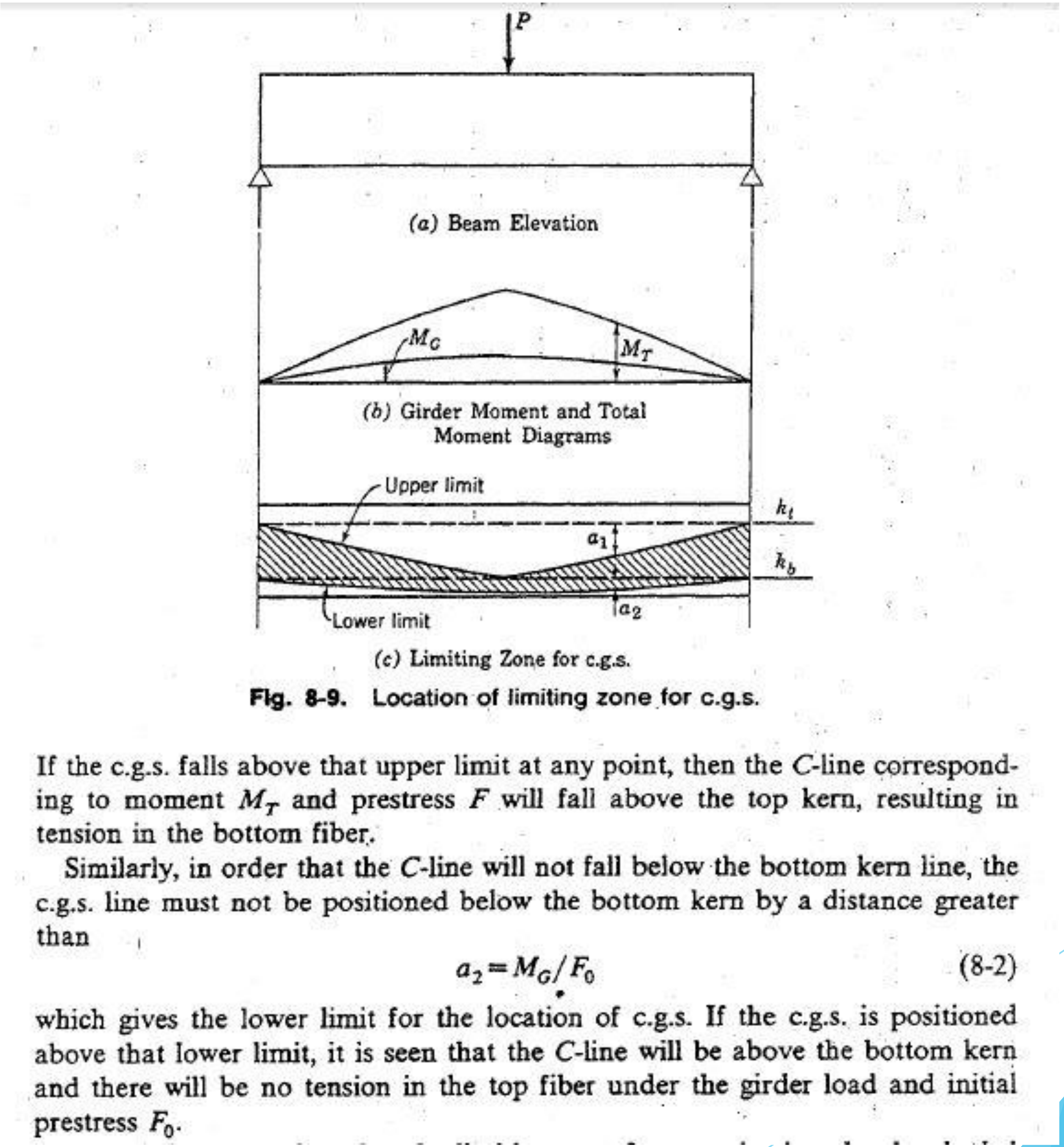


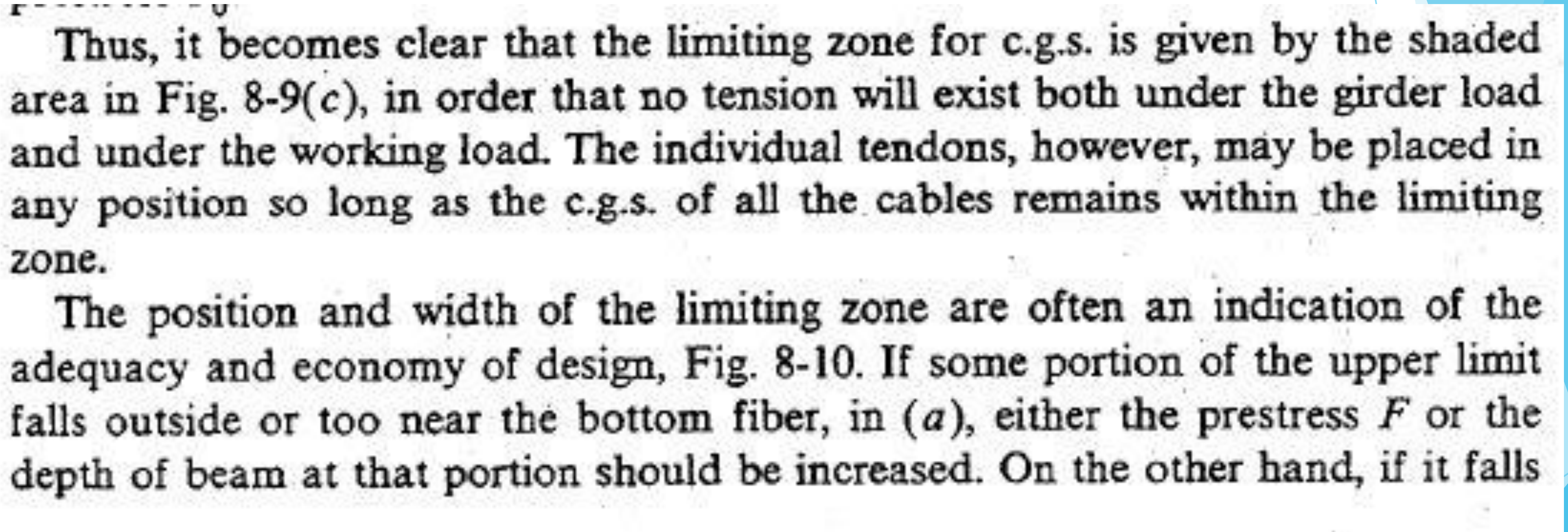
Fig. 8-9. Location of limiting zone for c.g.s.

If the c.g.s. falls above that upper limit at any point, then the *C*-line corresponding to moment M_T and prestress F will fall above the top kern, resulting in tension in the bottom fiber.

Similarly, in order that the *C*-line will not fall below the bottom kern line, the c.g.s. line must not be positioned below the bottom kern by a distance greater than

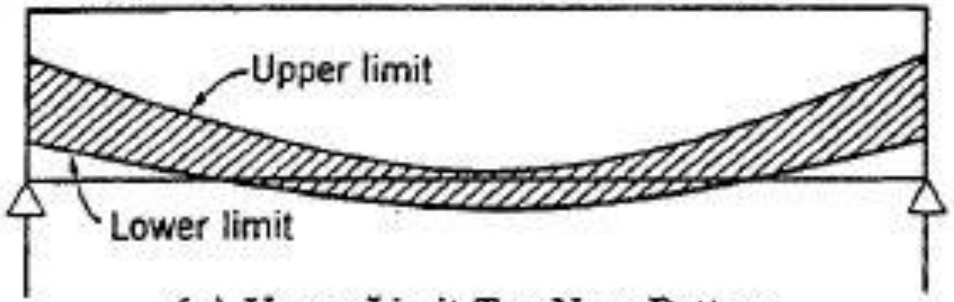
$$a_2 = M_G/F_0 \tag{8-2}$$

which gives the lower limit for the location of c.g.s. If the c.g.s. is positioned above that lower limit, it is seen that the *C*-line will be above the bottom kern and there will be no tension in the top fiber under the girder load and initial prestress F_0.

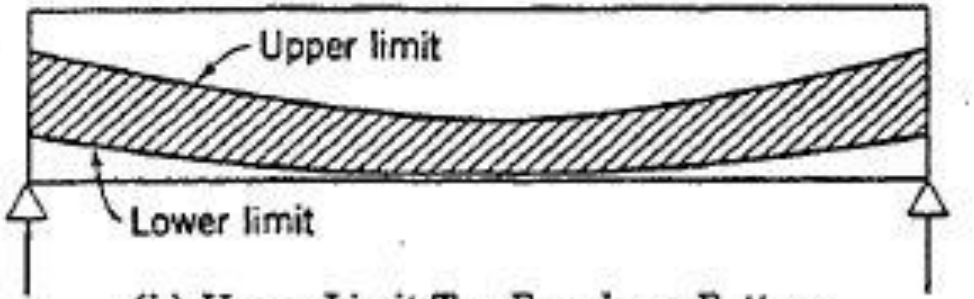


Thus, it becomes clear that the limiting zone for c.g.s. is given by the shaded area in Fig. 8-9(*c*), in order that no tension will exist both under the girder load and under the working load. The individual tendons, however, may be placed in any position so long as the c.g.s. of all the cables remains within the limiting zone.

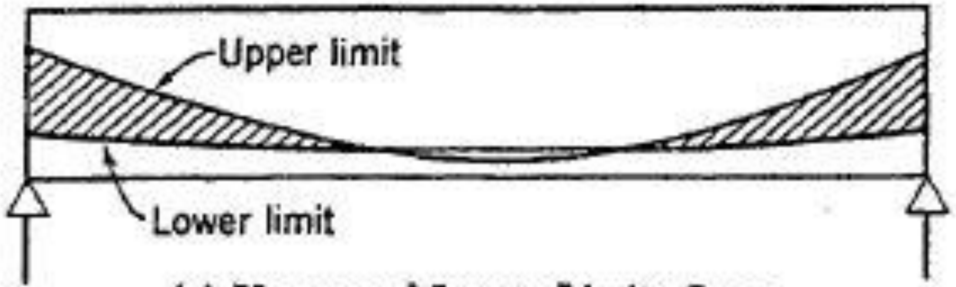
The position and width of the limiting zone are often an indication of the adequacy and economy of design, Fig. 8-10. If some portion of the upper limit falls outside or too near the bottom fiber, in (*a*), either the prestress *F* or the depth of beam at that portion should be increased. On the other hand, if it falls



(a) Upper Limit Too Near Bottom



(b) Upper Limit Too Far above Bottom



(c) Upper and Lower Limits Cross

Fig. 8-10. Undesirable positions for c.g.s. zone limits.

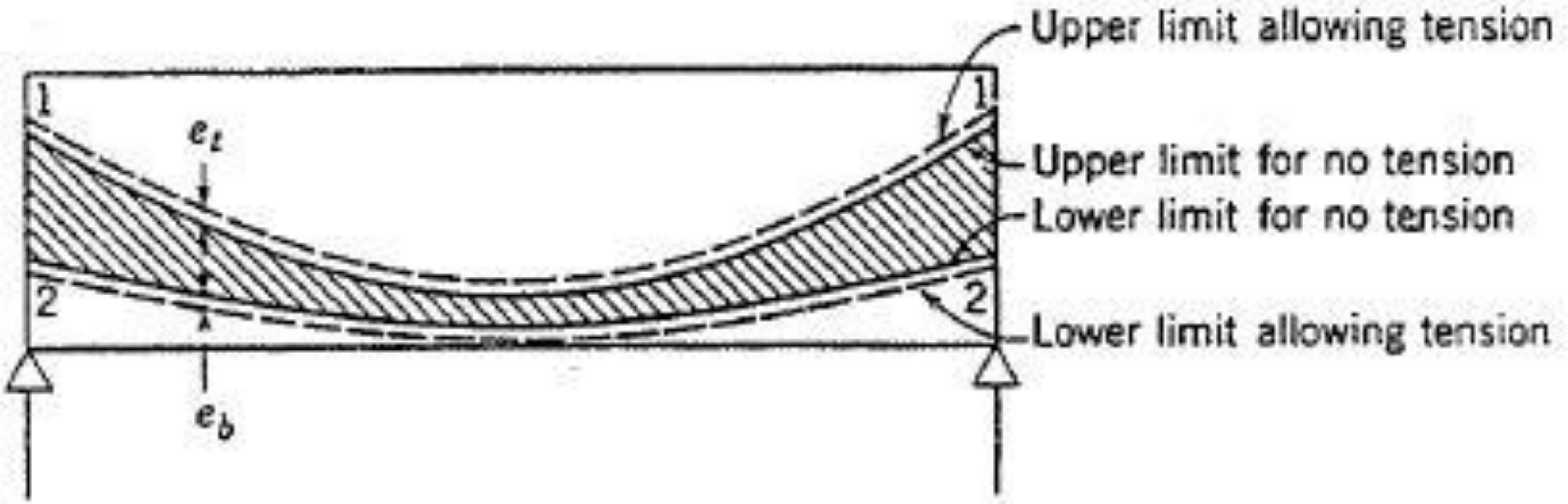
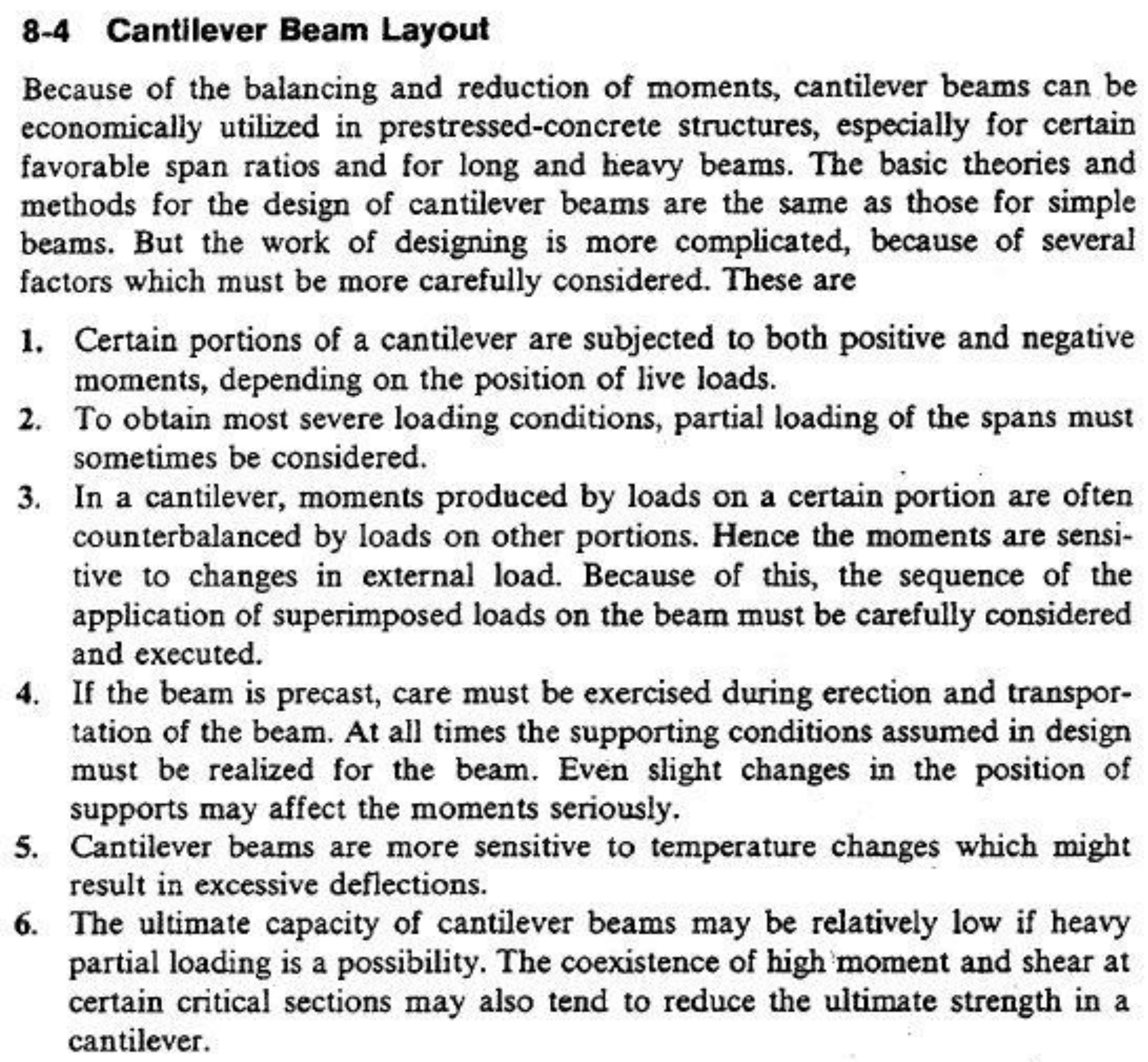


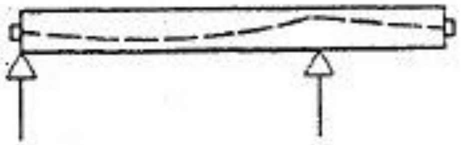
Fig. 8-12. Limiting zone for c.g.s. allowing tension in concrete.



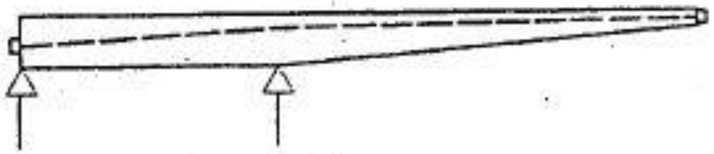
8-4 Cantilever Beam Layout

Because of the balancing and reduction of moments, cantilever beams can be economically utilized in prestressed-concrete structures, especially for certain favorable span ratios and for long and heavy beams. The basic theories and methods for the design of cantilever beams are the same as those for simple beams. But the work of designing is more complicated, because of several factors which must be more carefully considered. These are

1. Certain portions of a cantilever are subjected to both positive and negative moments, depending on the position of live loads.
2. To obtain most severe loading conditions, partial loading of the spans must sometimes be considered.
3. In a cantilever, moments produced by loads on a certain portion are often counterbalanced by loads on other portions. Hence the moments are sensitive to changes in external load. Because of this, the sequence of the application of superimposed loads on the beam must be carefully considered and executed.
4. If the beam is precast, care must be exercised during erection and transportation of the beam. At all times the supporting conditions assumed in design must be realized for the beam. Even slight changes in the position of supports may affect the moments seriously.
5. Cantilever beams are more sensitive to temperature changes which might result in excessive deflections.
6. The ultimate capacity of cantilever beams may be relatively low if heavy partial loading is a possibility. The coexistence of high moment and shear at certain critical sections may also tend to reduce the ultimate strength in a cantilever.



(a) Short Spans

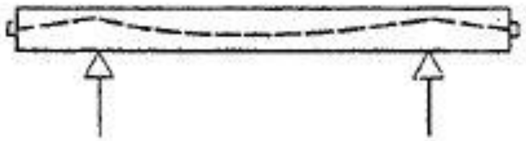


(b) Long Cantilevers

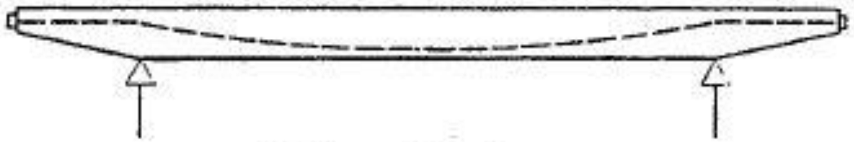
(c) Long Anchor Spans

(d) Straight Tendons

Fig. 8-14. Typical layouts for single cantilevers.

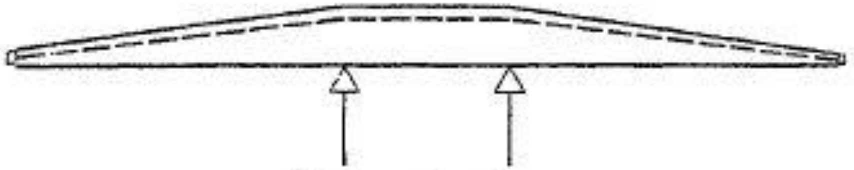


(a) Short Spans



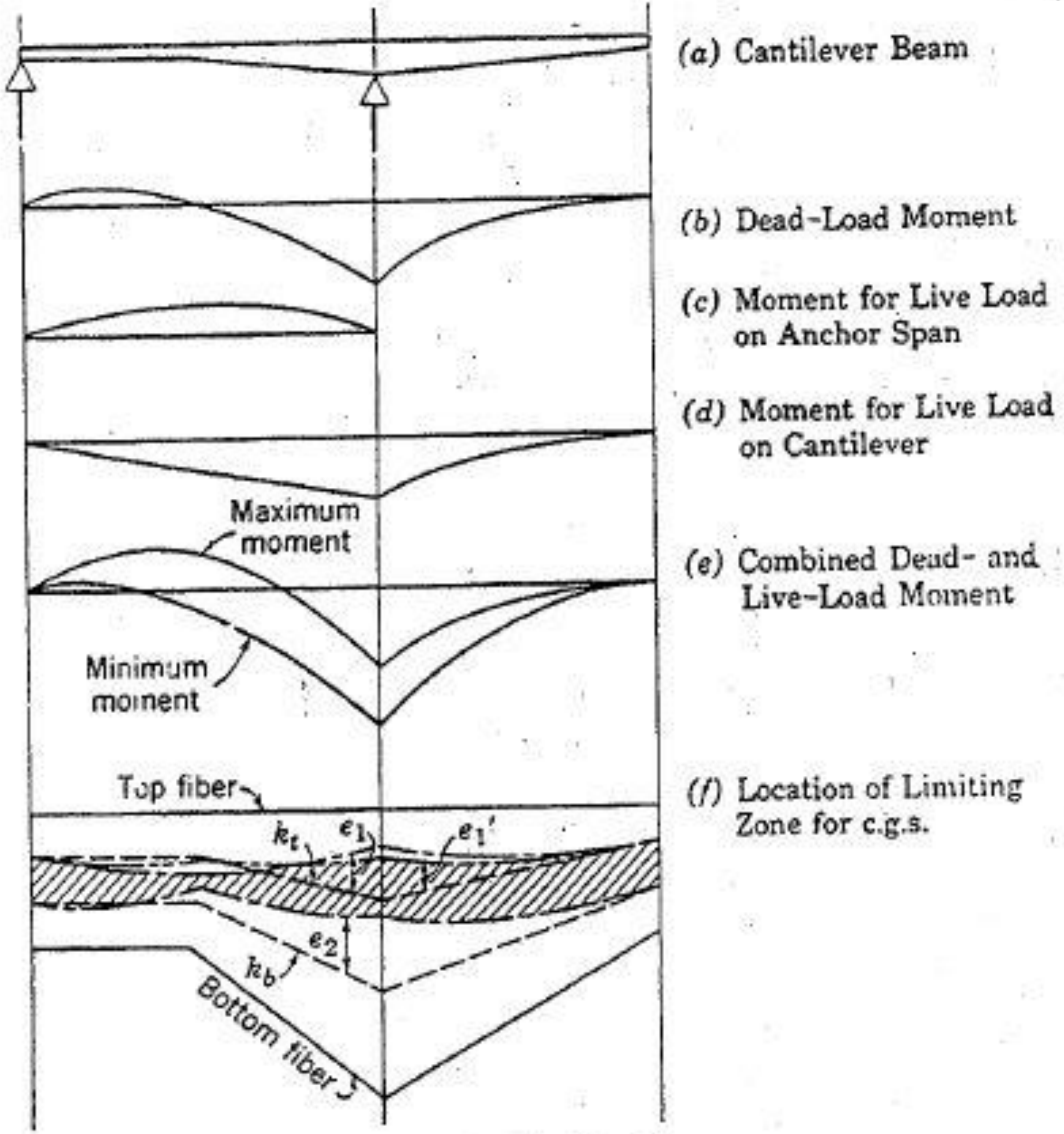
(b) Tapered Cantilevers

(c) Straight Tendons



(d) Long Cantilevers

Fig. 8-15. Typical layouts for double cantilevers.



(a) Cantilever Beam

(b) Dead-Load Moment

(c) Moment for Live Load on Anchor Span

(d) Moment for Live Load on Cantilever

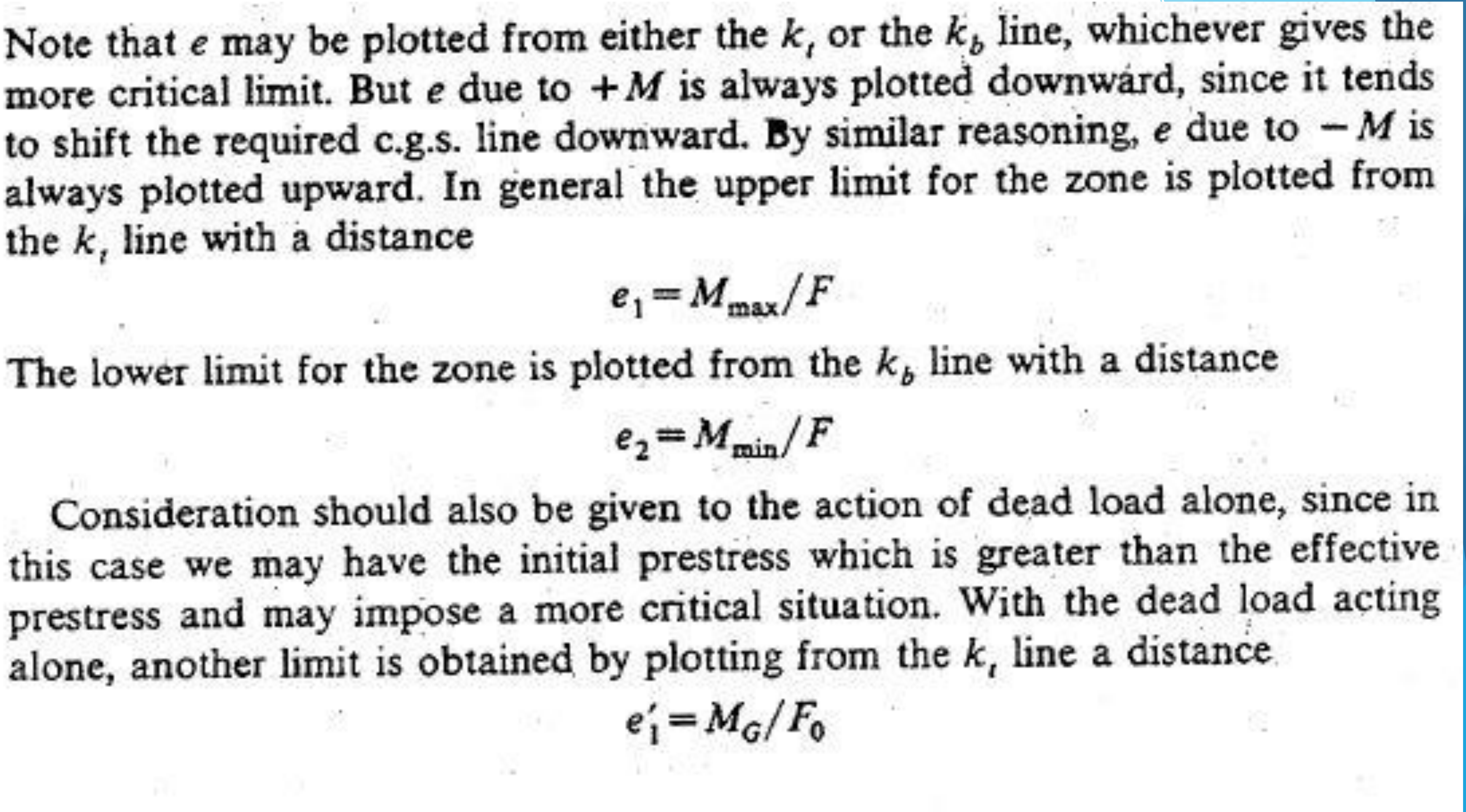
(e) Combined Dead- and Live-Load Moment

(f) Location of Limiting Zone for c.g.s.

Fig. 8-16. Graphical method for location c.g.s.

permissible eccentricity e, with

$$e = M/F$$



Note that e may be plotted from either the k_t or the k_b line, whichever gives the more critical limit. But e due to $+M$ is always plotted downward, since it tends to shift the required c.g.s. line downward. By similar reasoning, e due to $-M$ is always plotted upward. In general the upper limit for the zone is plotted from the k_t line with a distance

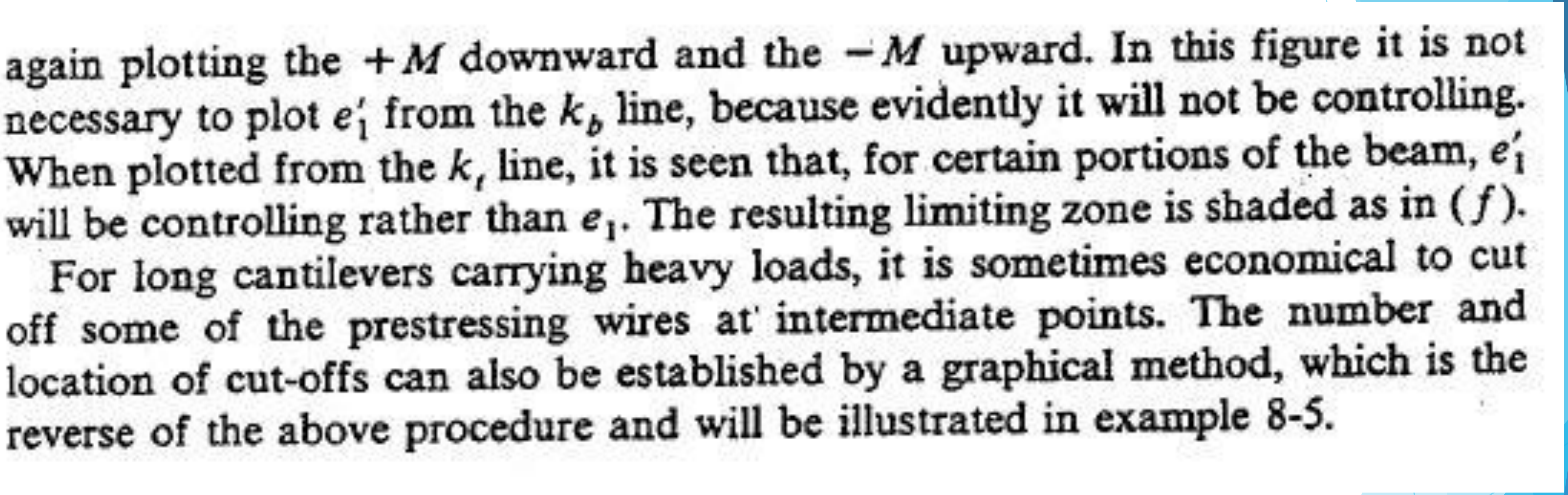
$$e_1 = M_{\max}/F$$

The lower limit for the zone is plotted from the k_b line with a distance

$$e_2 = M_{\min}/F$$

Consideration should also be given to the action of dead load alone, since in this case we may have the initial prestress which is greater than the effective prestress and may impose a more critical situation. With the dead load acting alone, another limit is obtained by plotting from the k_t line a distance

$$e_1' = M_G/F_0$$



again plotting the $+M$ downward and the $-M$ upward. In this figure it is not necessary to plot e_1' from the k_b line, because evidently it will not be controlling. When plotted from the k_t line, it is seen that, for certain portions of the beam, e_1' will be controlling rather than e_1. The resulting limiting zone is shaded as in (f).

For long cantilevers carrying heavy loads, it is sometimes economical to cut off some of the prestressing wires at intermediate points. The number and location of cut-offs can also be established by a graphical method, which is the reverse of the above procedure and will be illustrated in example 8-5.

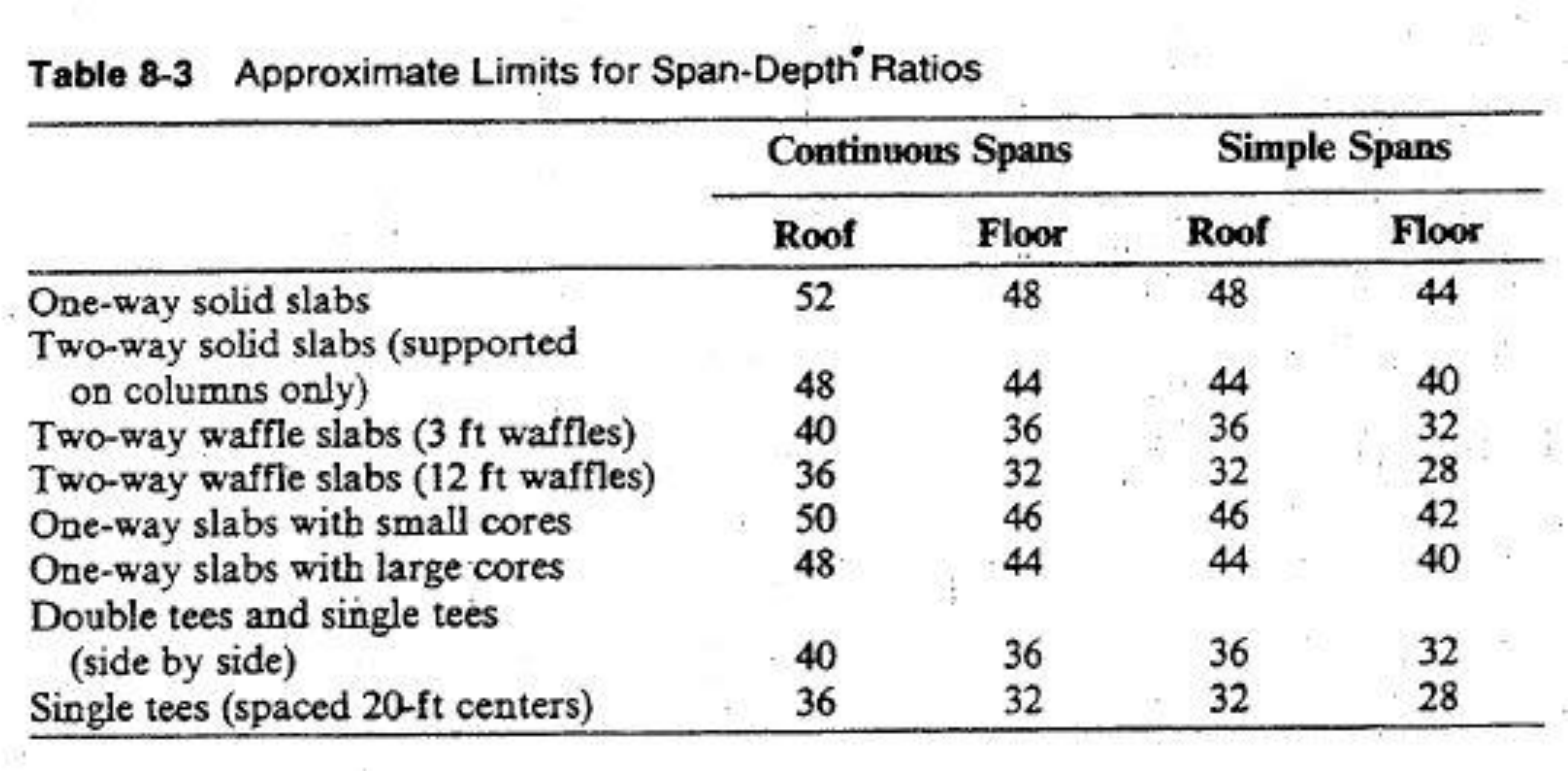


Table 8-3 Approximate Limits for Span-Depth Ratios

	Continuous Spans		Simple Spans	
	Roof	Floor	Roof	Floor
One-way solid slabs	52	48	48	44
Two-way solid slabs (supported on columns only)	48	44	44	40
Two-way waffle slabs (3 ft waffles)	40	36	36	32
Two-way waffle slabs (12 ft waffles)	36	32	32	28
One-way slabs with small cores	50	46	46	42
One-way slabs with large cores	48	44	44	40
Double tees and single tees (side by side)	40	36	36	32
Single tees (spaced 20-ft centers)	36	32	32	28

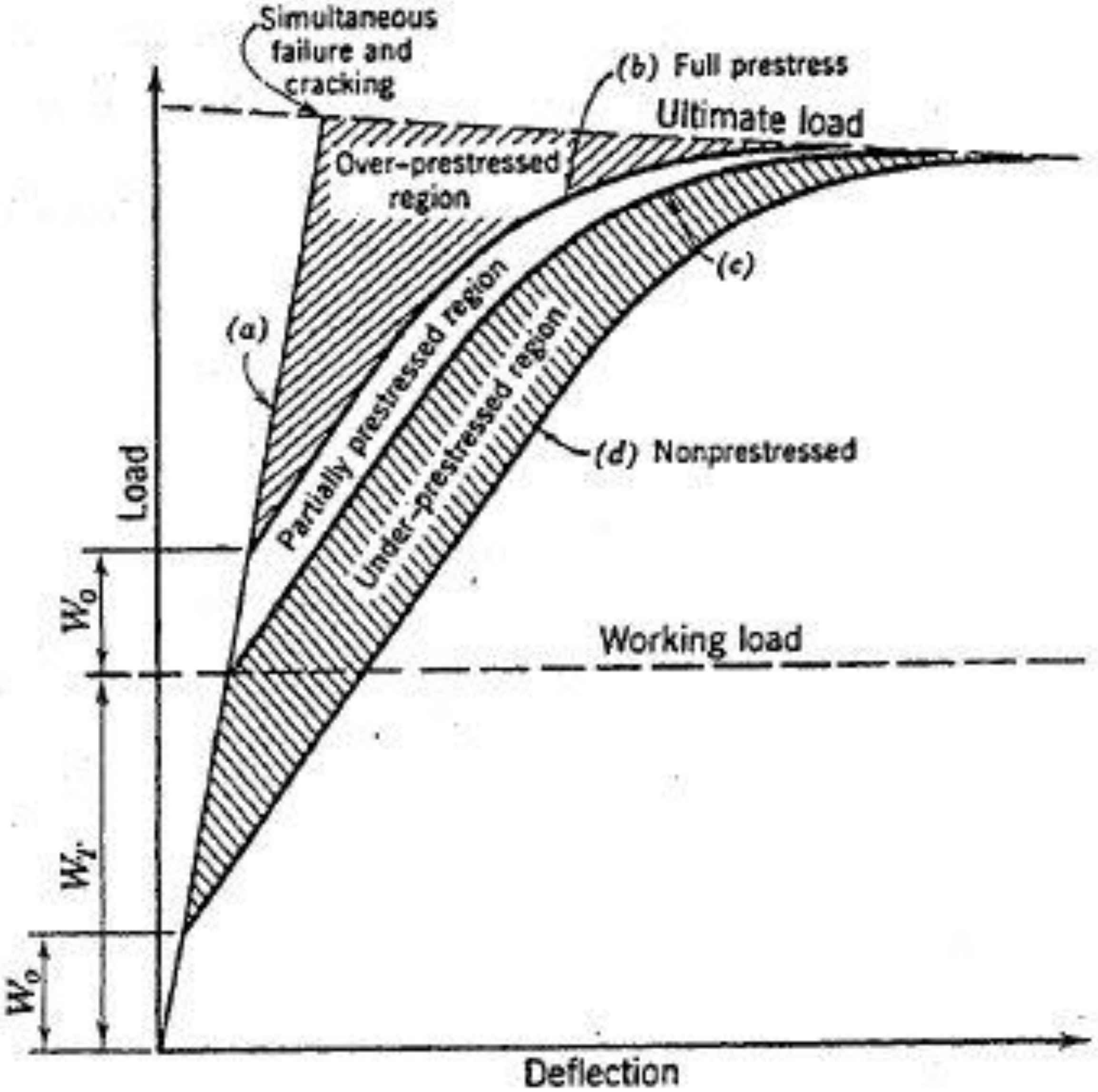
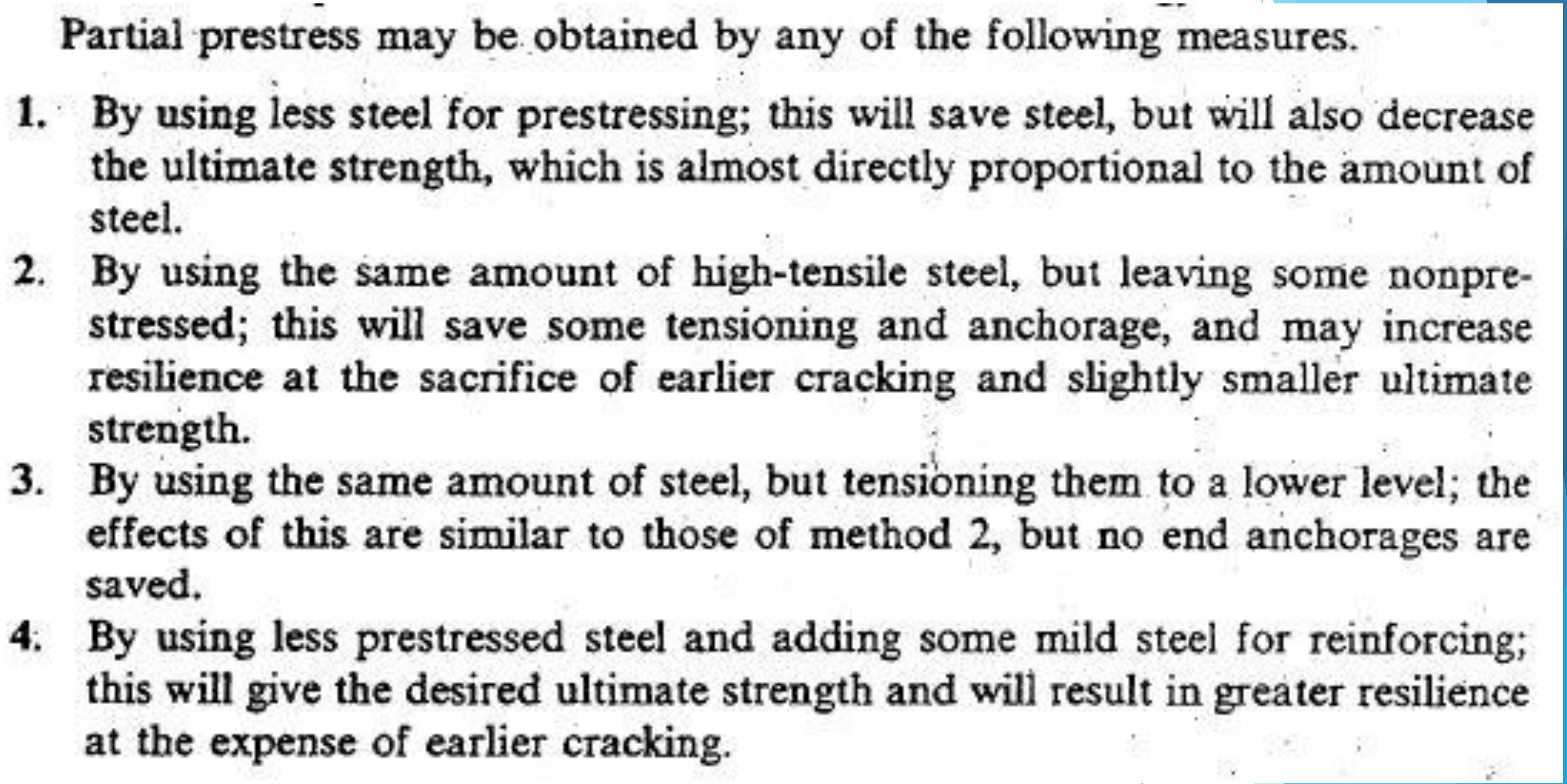
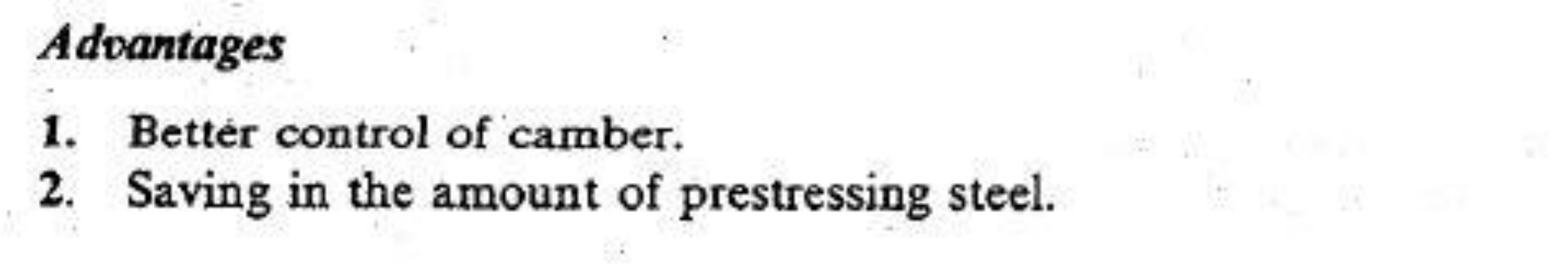


Fig. 9-2. Load-deflection curves for varying degrees of prestress (for underreinforced sections of bonded beams).



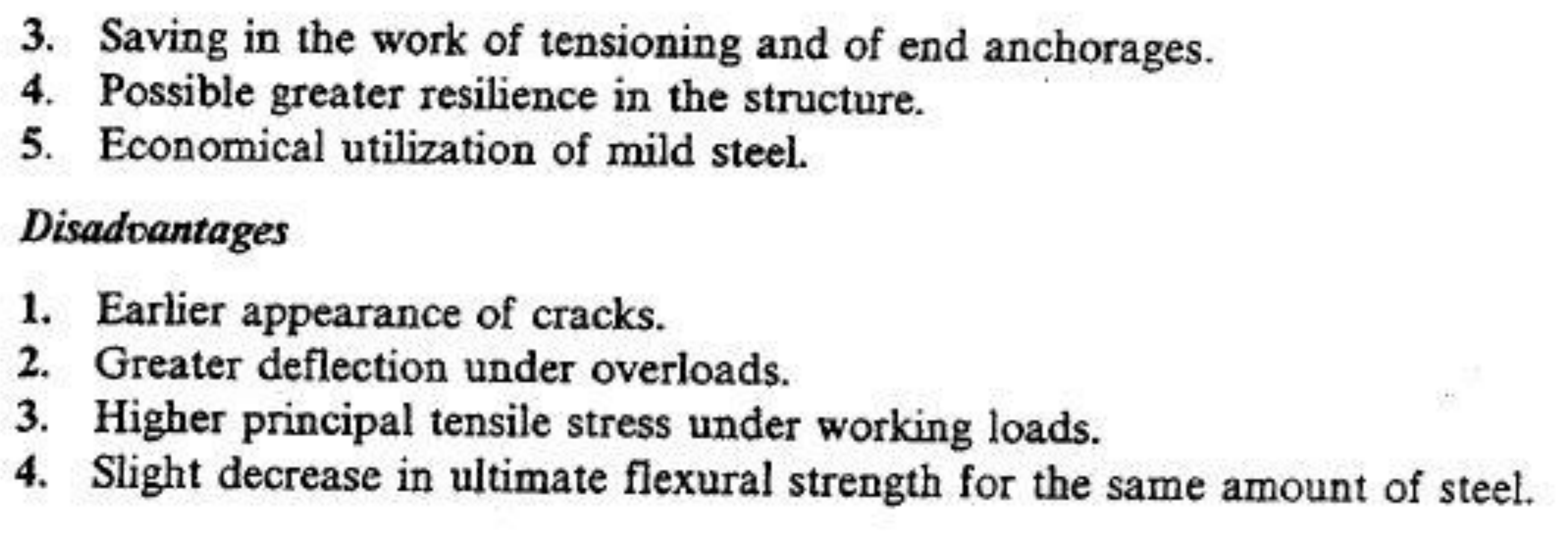
Partial prestress may be obtained by any of the following measures.

1. By using less steel for prestressing; this will save steel, but will also decrease the ultimate strength, which is almost directly proportional to the amount of steel.
2. By using the same amount of high-tensile steel, but leaving some nonprestressed; this will save some tensioning and anchorage, and may increase resilience at the sacrifice of earlier cracking and slightly smaller ultimate strength.
3. By using the same amount of steel, but tensioning them to a lower level; the effects of this are similar to those of method 2, but no end anchorages are saved.
4. By using less prestressed steel and adding some mild steel for reinforcing; this will give the desired ultimate strength and will result in greater resilience at the expense of earlier cracking.



Advantages

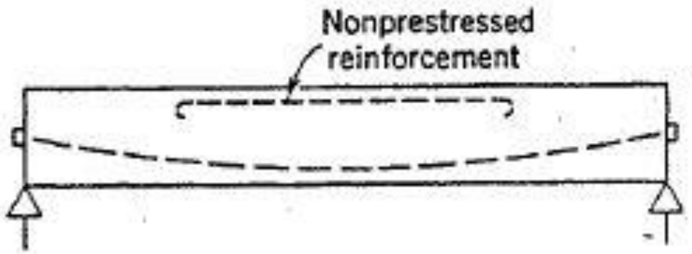
1. Better control of camber.
2. Saving in the amount of prestressing steel.



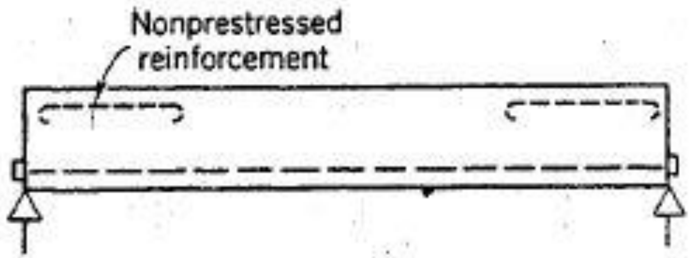
3. Saving in the work of tensioning and of end anchorages.
4. Possible greater resilience in the structure.
5. Economical utilization of mild steel.

Disadvantages

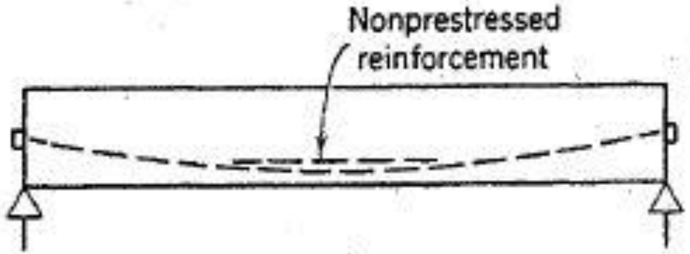
1. Earlier appearance of cracks.
2. Greater deflection under overloads.
3. Higher principal tensile stress under working loads.
4. Slight decrease in ultimate flexural strength for the same amount of steel.



(a) To Carry Tension Due to Prestress at Center of Span



(b) To Carry Tension Due to Prestress at Ends of Span



(c) To Carry Compression Due to Prestress

Fig. 9-3. Nonprestressed reinforcements to strengthen beam just after transfer of prestress.

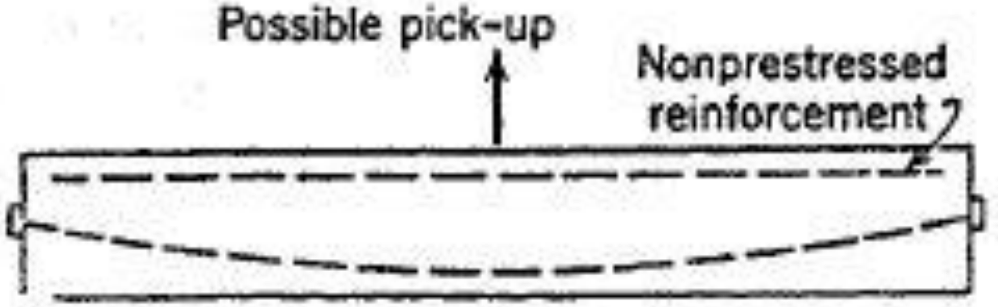
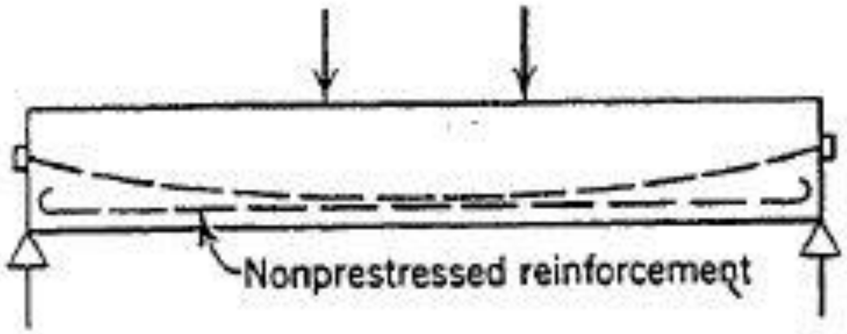
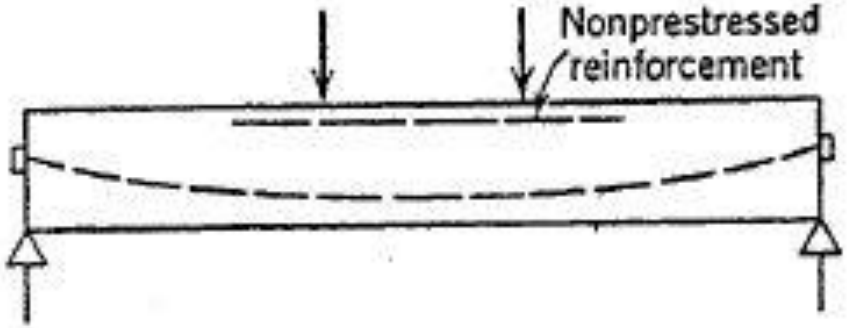


Fig. 9-4. Nonprestressed reinforcement to strengthen precast beam during handling and erection.



(a) To Distribute Cracks and Increase Ultimate Strength



(b) To Reinforce Compression in Concrete

Fig. 9-5. Nonprestressed reinforcements to reinforce beams under working and ultimate loads.

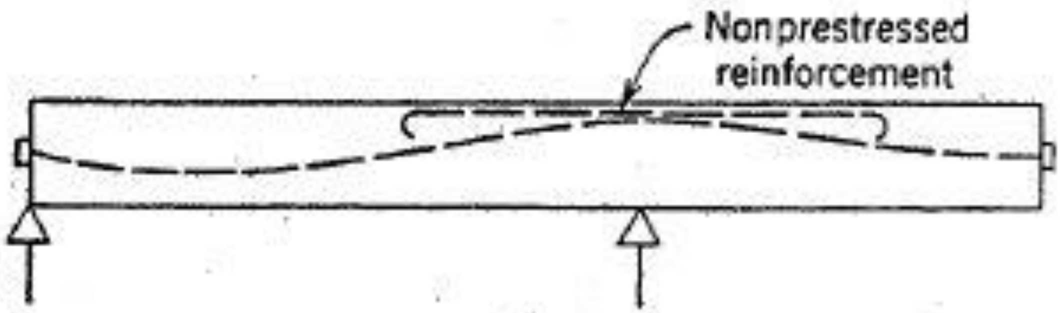


Fig. 9-6. Nonprestressed reinforcement to reinforce moment peaks in cantilevers.