CE 414: Prestressed Concrete
Lecture 2
Prestressing

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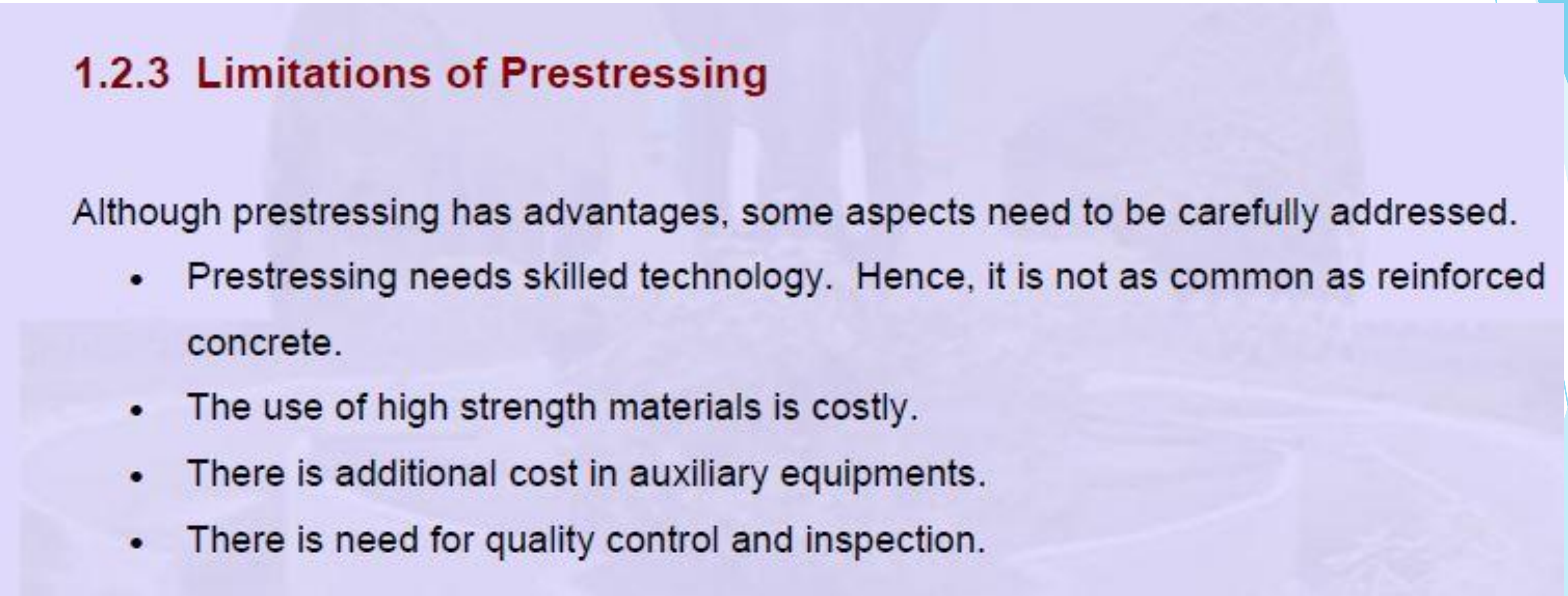
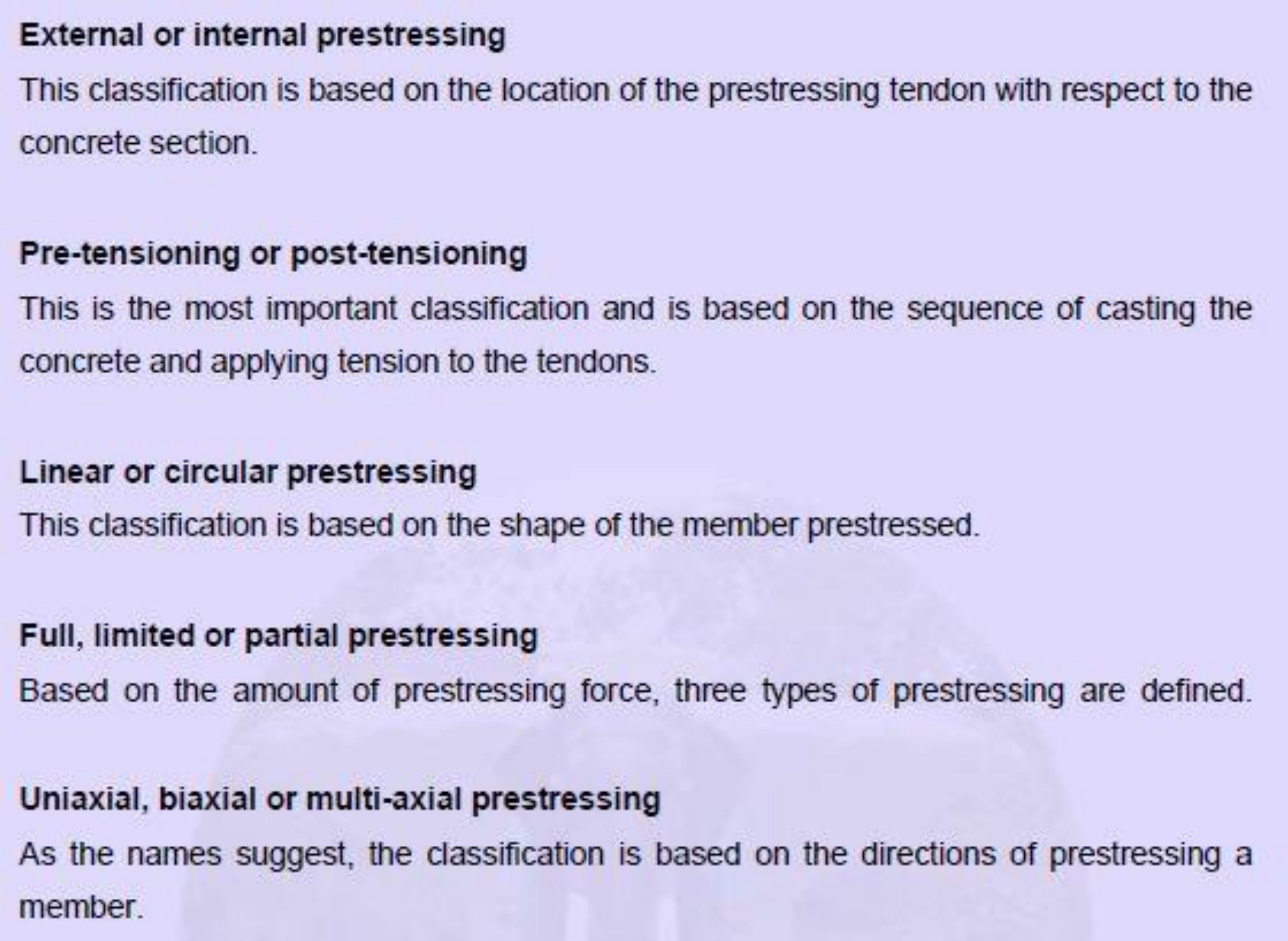


1.2.3 Limitations of Prestressing

Although prestressing has advantages, some aspects need to be carefully addressed.

- Prestressing needs skilled technology. Hence, it is not as common as reinforced concrete.
- The use of high strength materials is costly.
- There is additional cost in auxiliary equipments.
- There is need for quality control and inspection.



External or internal prestressing

This classification is based on the location of the prestressing tendon with respect to the concrete section.

Pre-tensioning or post-tensioning

This is the most important classification and is based on the sequence of casting the concrete and applying tension to the tendons.

Linear or circular prestressing

This classification is based on the shape of the member prestressed.

Full, limited or partial prestressing

Based on the amount of prestressing force, three types of prestressing are defined.

Uniaxial, biaxial or multi-axial prestressing

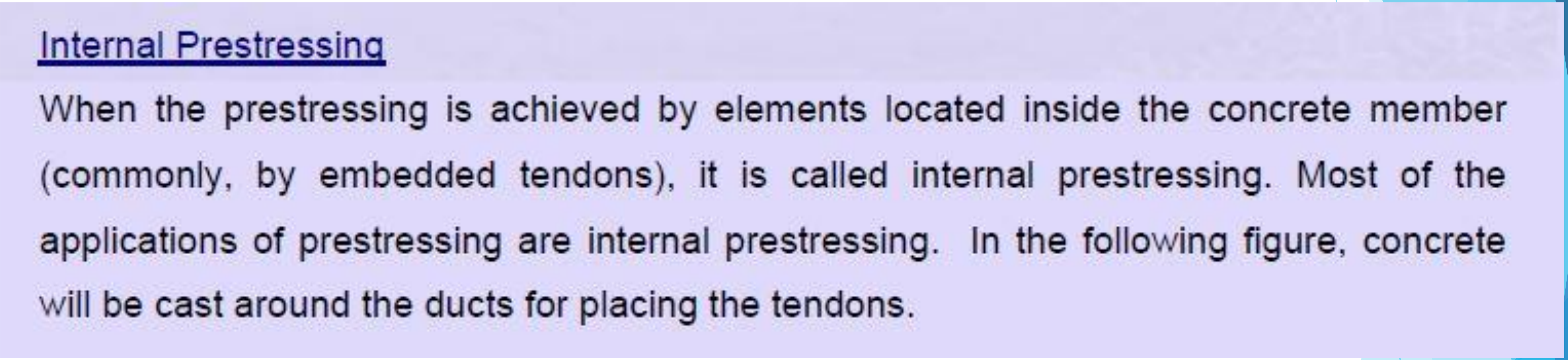
As the names suggest, the classification is based on the directions of prestressing a member.

External Prestressing

When the prestressing is achieved by elements located outside the concrete, it is called external prestressing. The tendons can lie outside the member (for example in I-girders or walls) or inside the hollow space of a box girder. This technique is adopted in bridges and strengthening of buildings. In the following figure, the box girder of a bridge is prestressed with tendons that lie outside the concrete.

Figure 1-2.2 External prestressing of a box girder

(Reference: VSL International Ltd.)



Internal Prestressing

When the prestressing is achieved by elements located inside the concrete member (commonly, by embedded tendons), it is called internal prestressing. Most of the applications of prestressing are internal prestressing. In the following figure, concrete will be cast around the ducts for placing the tendons.

Figure 1-2.3 Internal prestressing of a box girder

(Courtesy: Cochin Port Trust, Kerala)

Pre-tensioning or Post-tensioning

Pre-tensioning

The tension is applied to the tendons before casting of the concrete. The pre-compression is transmitted from steel to concrete through bond over the transmission length near the ends. The following figure shows manufactured pre-tensioned electric poles.

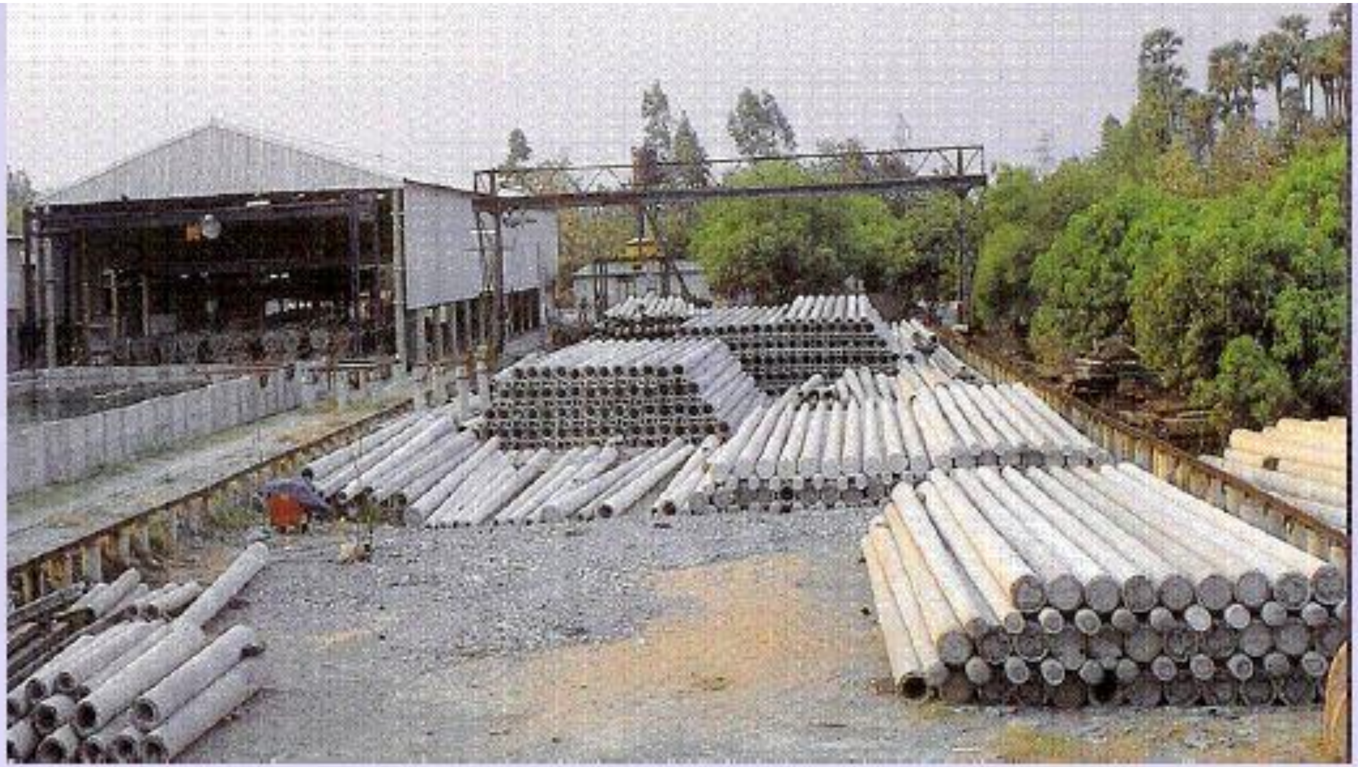
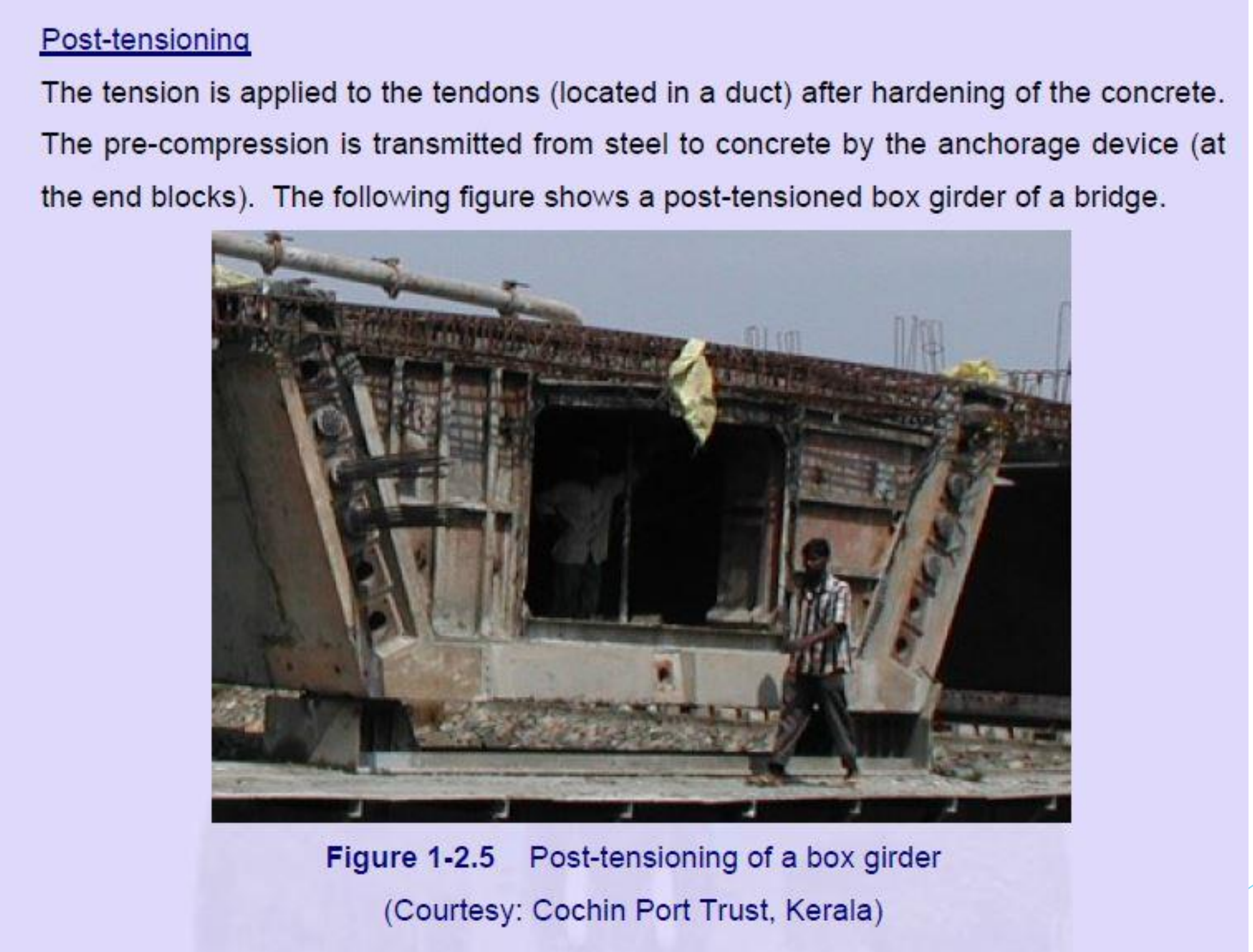


Figure 1-2.4 Pre-tensioned electric poles

(Courtesy: The Concrete Products and Construction Company, COPCO, Chennai)

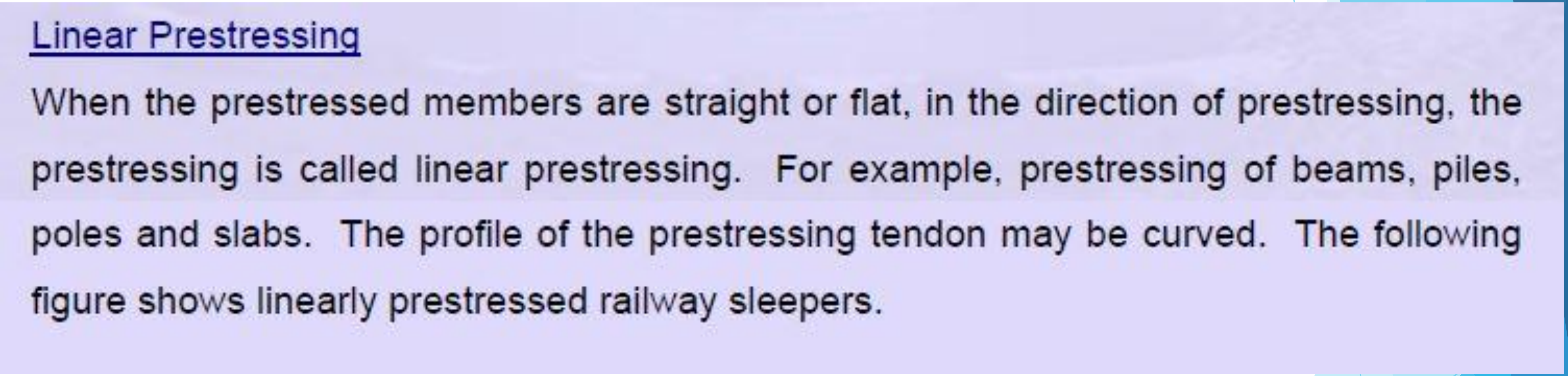


Post-tensioning

The tension is applied to the tendons (located in a duct) after hardening of the concrete. The pre-compression is transmitted from steel to concrete by the anchorage device (at the end blocks). The following figure shows a post-tensioned box girder of a bridge.

Figure 1-2.5 Post-tensioning of a box girder

(Courtesy: Cochin Port Trust, Kerala)

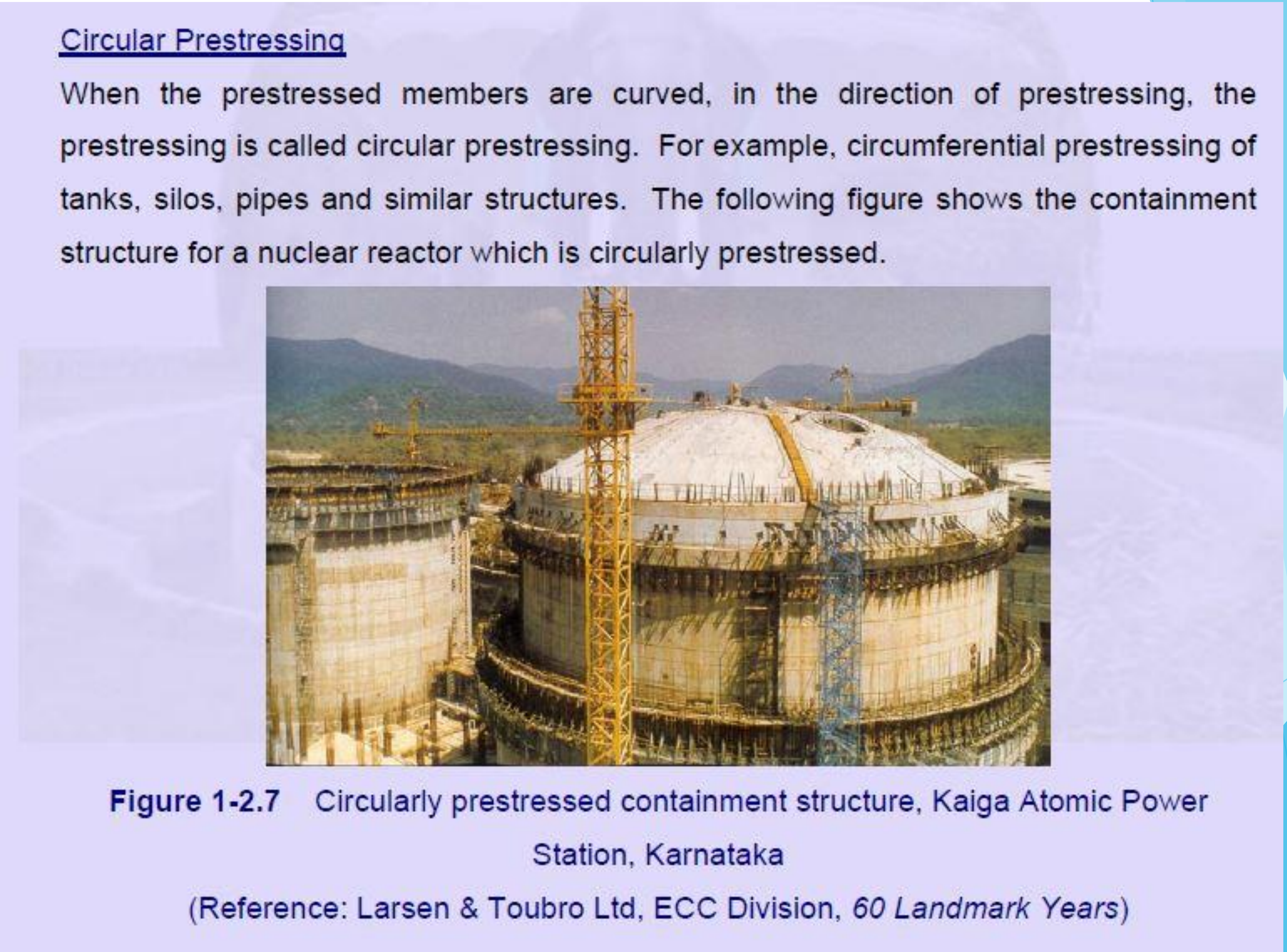


Linear Prestressing

When the prestressed members are straight or flat, in the direction of prestressing, the prestressing is called linear prestressing. For example, prestressing of beams, piles, poles and slabs. The profile of the prestressing tendon may be curved. The following figure shows linearly prestressed railway sleepers.

Figure 1-2.6 Linearly prestressed railway sleepers

(Courtesy: The Concrete Products and Construction Company, COPCO, Chennai)

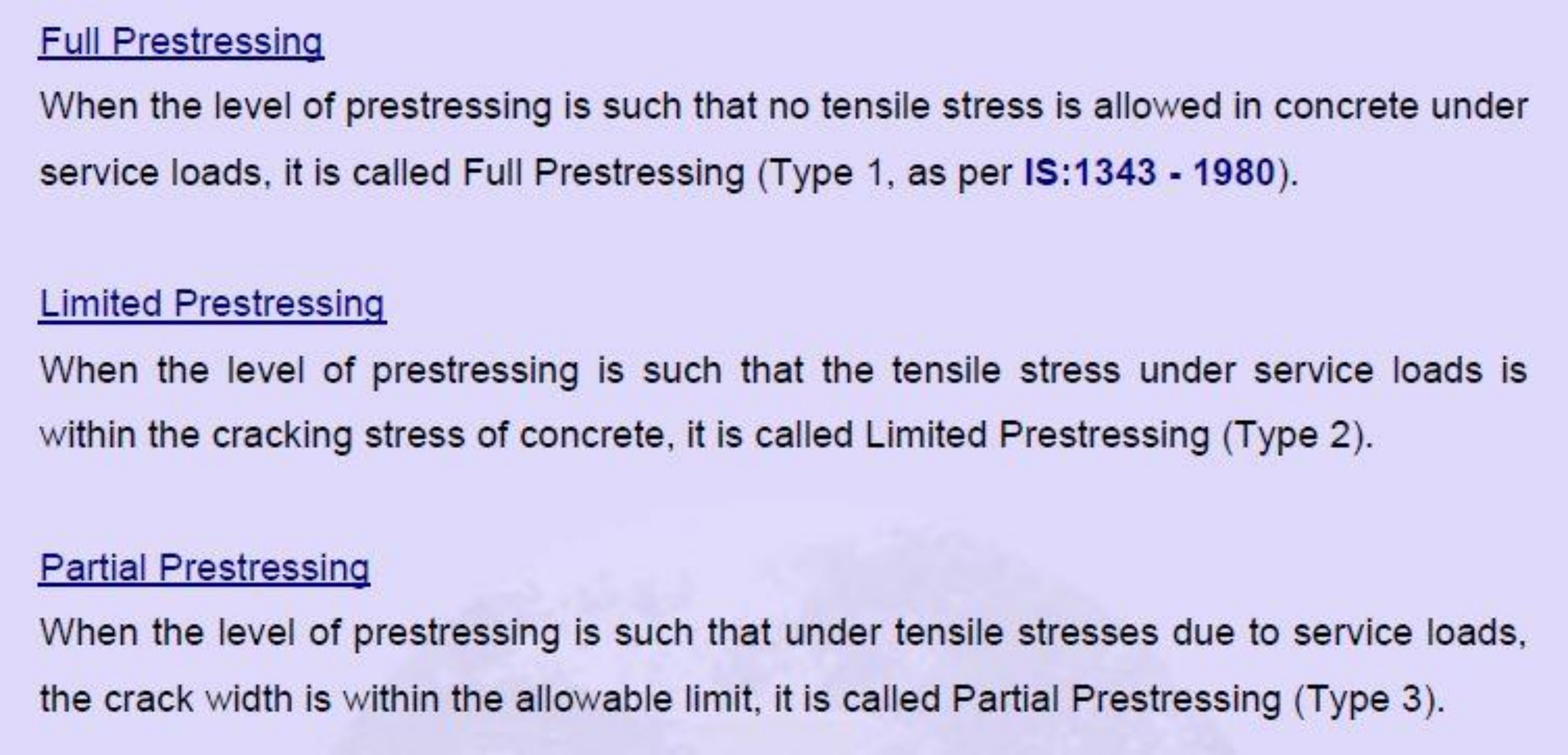


Circular Prestressing

When the prestressed members are curved, in the direction of prestressing, the prestressing is called circular prestressing. For example, circumferential prestressing of tanks, silos, pipes and similar structures. The following figure shows the containment structure for a nuclear reactor which is circularly prestressed.

Figure 1-2.7 Circularly prestressed containment structure, Kaiga Atomic Power Station, Karnataka

(Reference: Larsen & Toubro Ltd, ECC Division, *60 Landmark Years*)



Full Prestressing

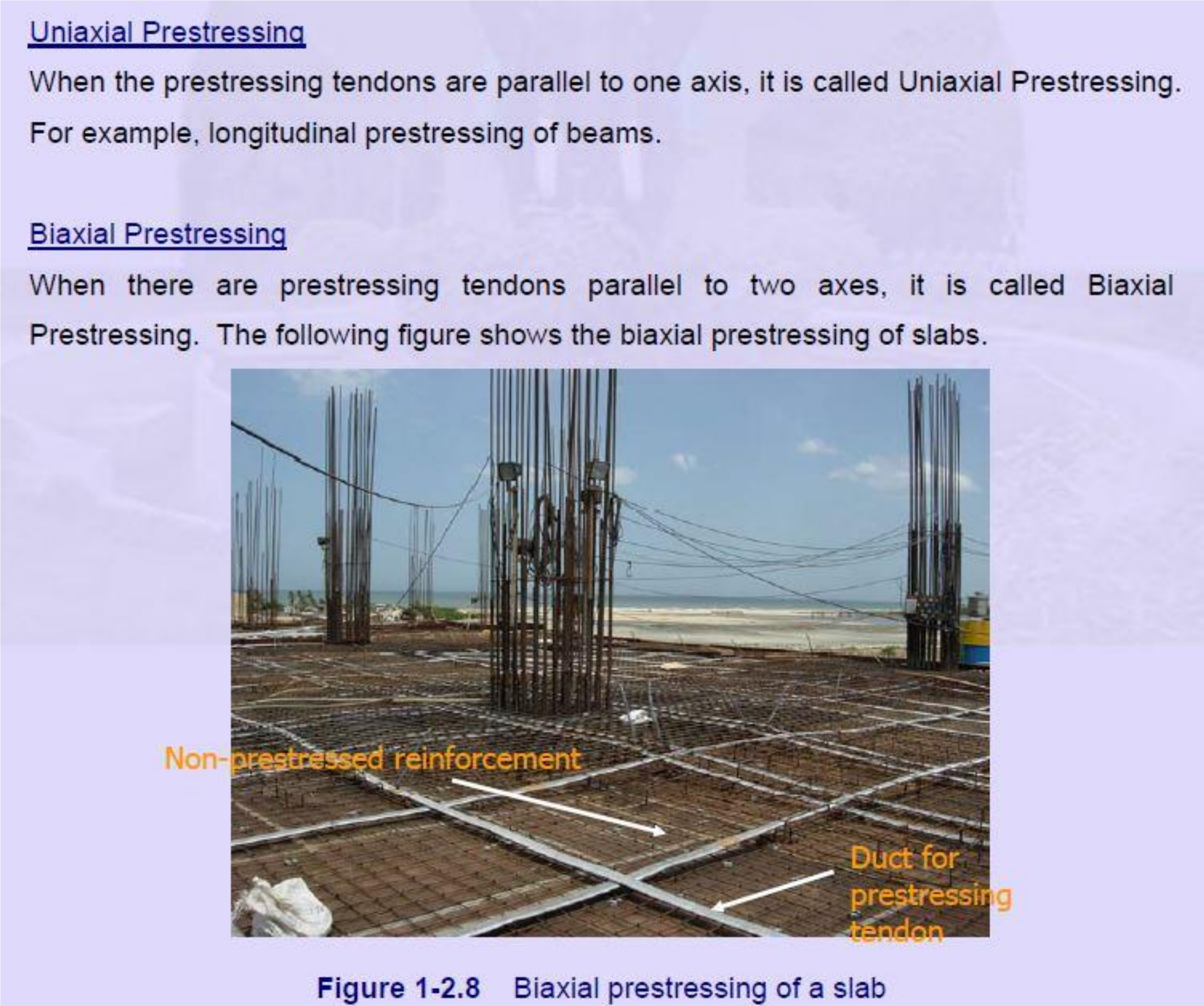
When the level of prestressing is such that no tensile stress is allowed in concrete under service loads, it is called Full Prestressing (Type 1, as per **IS:1343 - 1980**).

Limited Prestressing

When the level of prestressing is such that the tensile stress under service loads is within the cracking stress of concrete, it is called Limited Prestressing (Type 2).

Partial Prestressing

When the level of prestressing is such that under tensile stresses due to service loads, the crack width is within the allowable limit, it is called Partial Prestressing (Type 3).



Uniaxial Prestressing

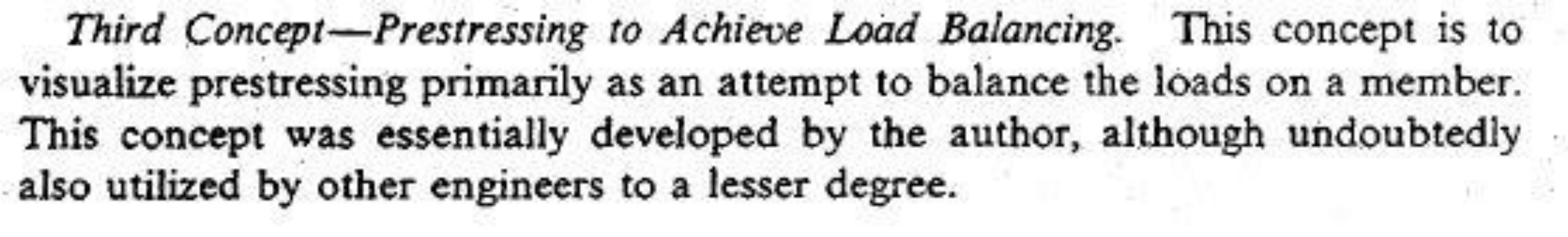
When the prestressing tendons are parallel to one axis, it is called Uniaxial Prestressing. For example, longitudinal prestressing of beams.

Biaxial Prestressing

When there are prestressing tendons parallel to two axes, it is called Biaxial Prestressing. The following figure shows the biaxial prestressing of slabs.

Figure 1-2.8 Biaxial prestressing of a slab

Third concept



Third Concept—Prestressing to Achieve Load Balancing. This concept is to visualize prestressing primarily as an attempt to balance the loads on a member. This concept was essentially developed by the author, although undoubtedly also utilized by other engineers to a lesser degree.

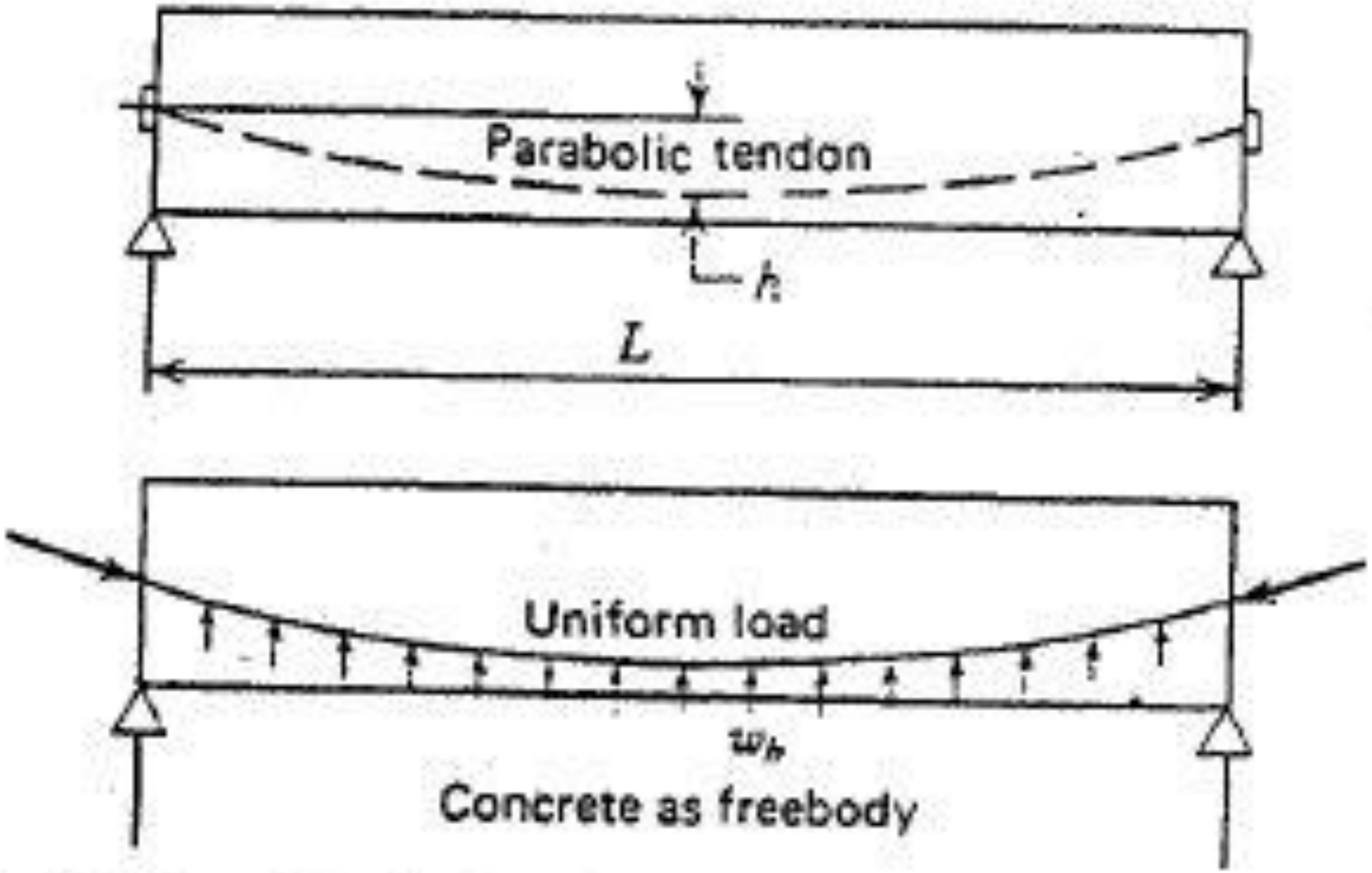
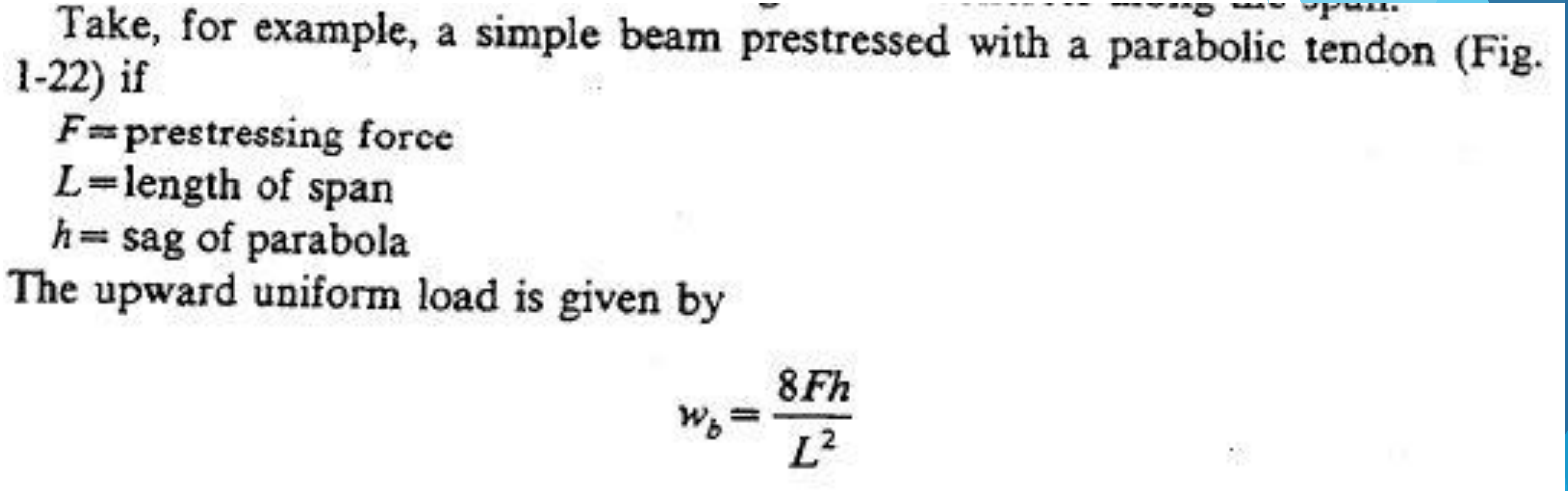


Fig. 1-22. Prestressed beam with parabolic tendon.



Take, for example, a simple beam prestressed with a parabolic tendon (Fig. 1-22) if

F = prestressing force
L = length of span
h = sag of parabola

The upward uniform load is given by

$$w_b = \frac{8Fh}{L^2}$$

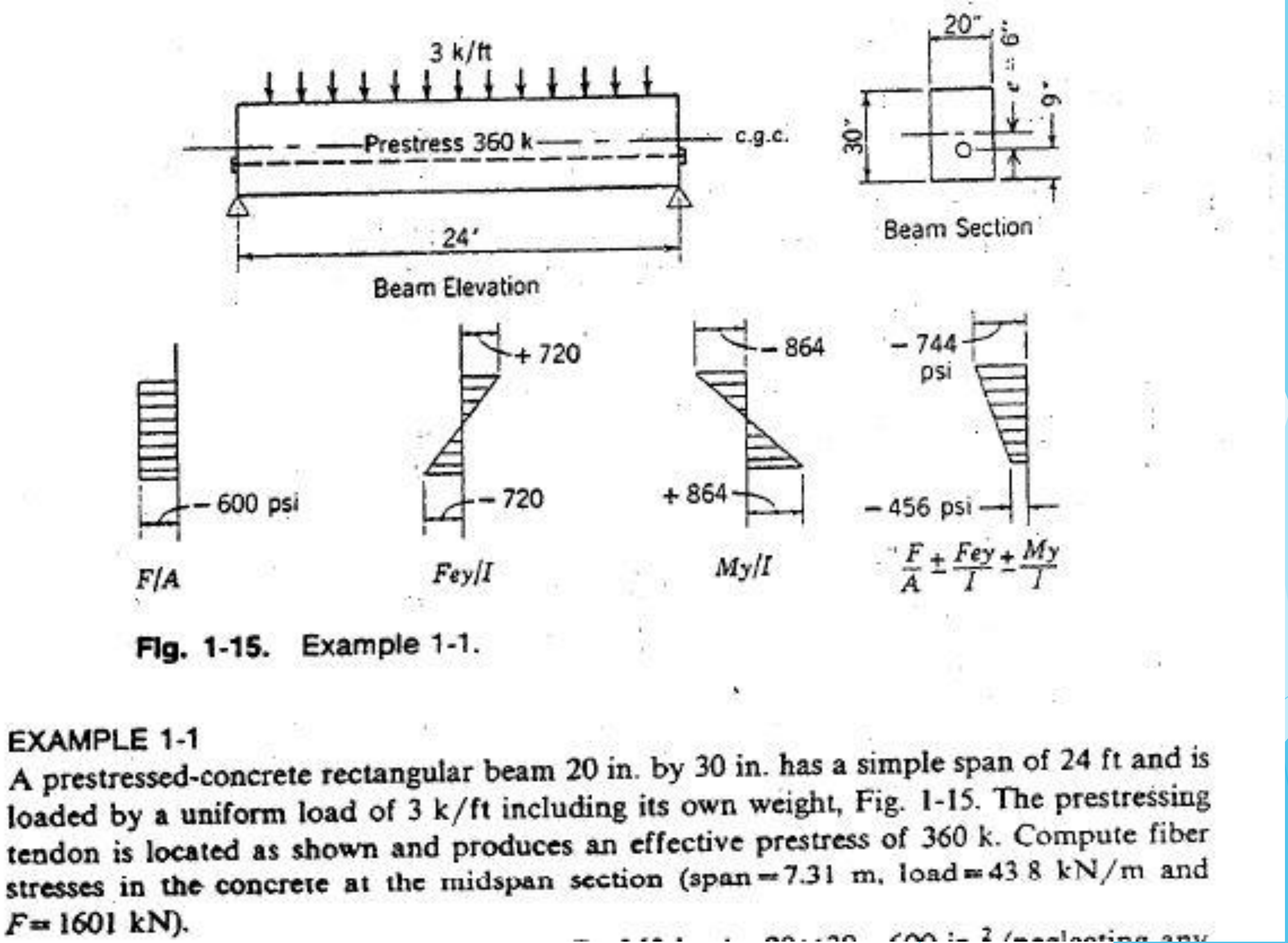
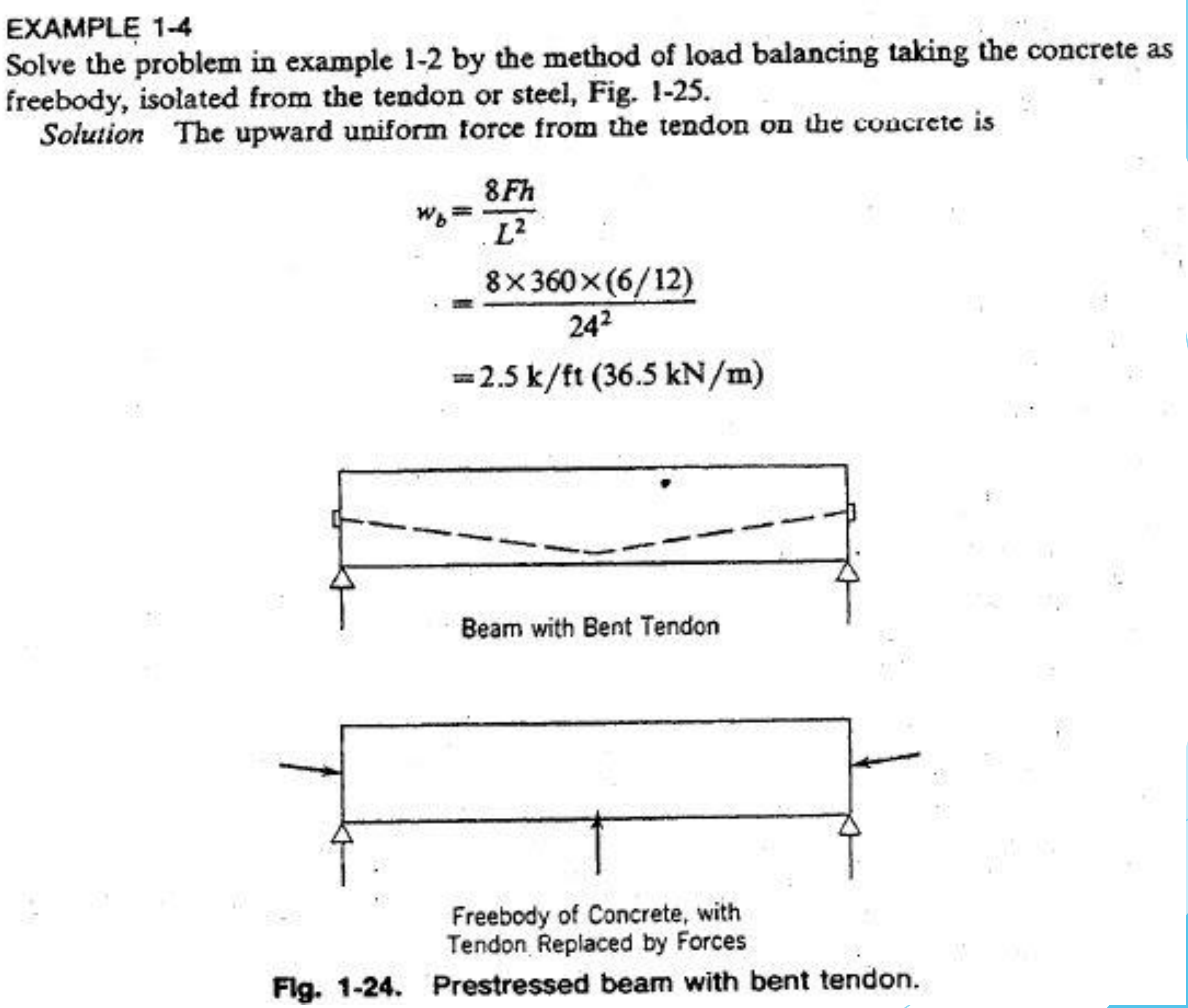


Fig. 1-15. Example 1-1.

EXAMPLE 1-1

A prestressed-concrete rectangular beam 20 in. by 30 in. has a simple span of 24 ft and is loaded by a uniform load of 3 k/ft including its own weight, Fig. 1-15. The prestressing tendon is located as shown and produces an effective prestress of 360 k. Compute fiber stresses in the concrete at the midspan section (span = 7.31 m, load = 43.8 kN/m and F = 1601 kN).



EXAMPLE 1-4

Solve the problem in example 1-2 by the method of load balancing taking the concrete as freebody, isolated from the tendon or steel, Fig. 1-25.

Solution The upward uniform force from the tendon on the concrete is

$$w_b = \frac{8Fh}{L^2}$$

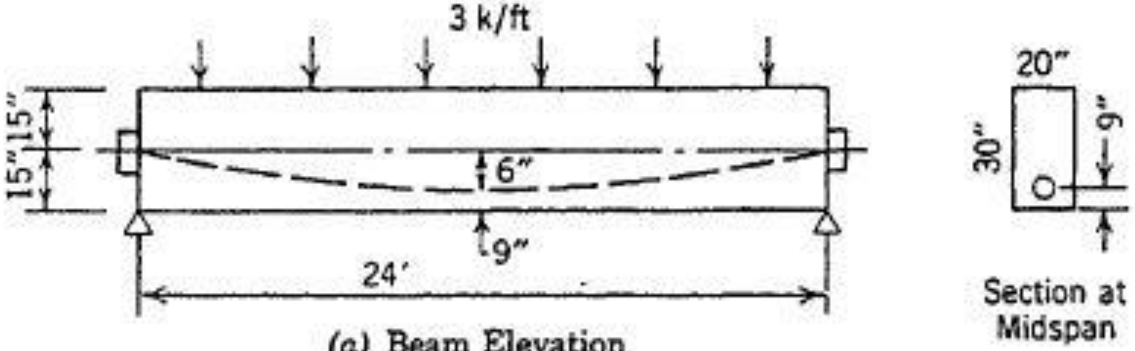
$$= \frac{8 \times 360 \times (6/12)}{24^2}$$

$$= 2.5\ \mathrm{k/ft}\ (36.5\ \mathrm{kN/m})$$

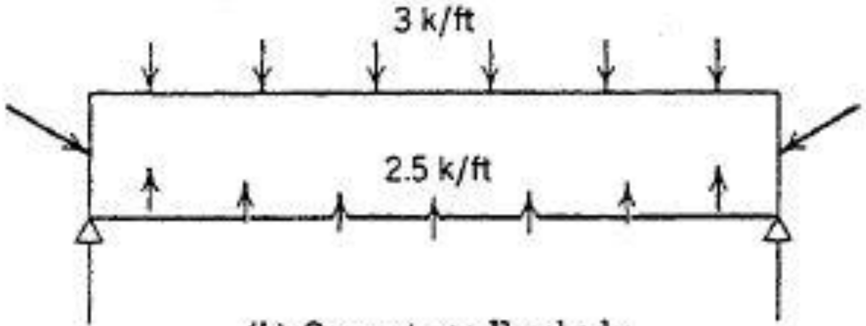
Beam with Bent Tendon

Freebody of Concrete, with
Tendon Replaced by Forces

Fig. 1-24. Prestressed beam with bent tendon.



(a) Beam Elevation



(b) Concrete as Freebody

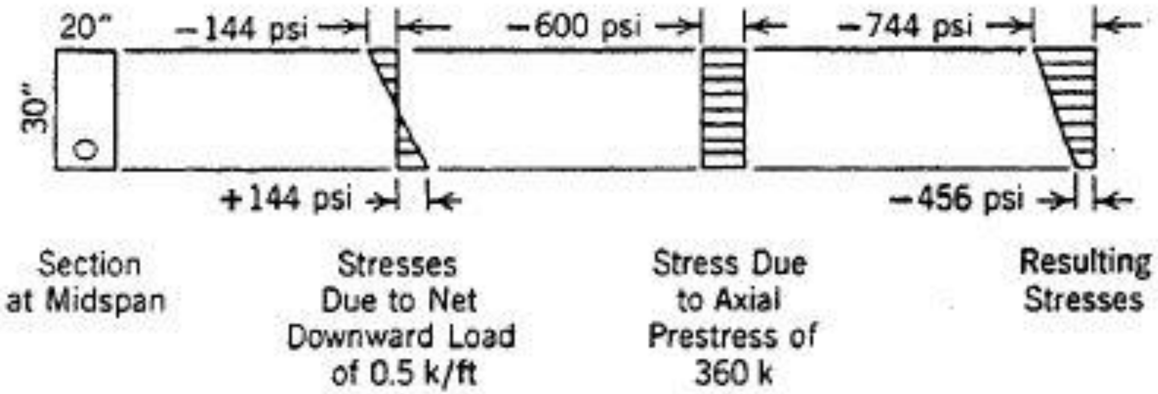
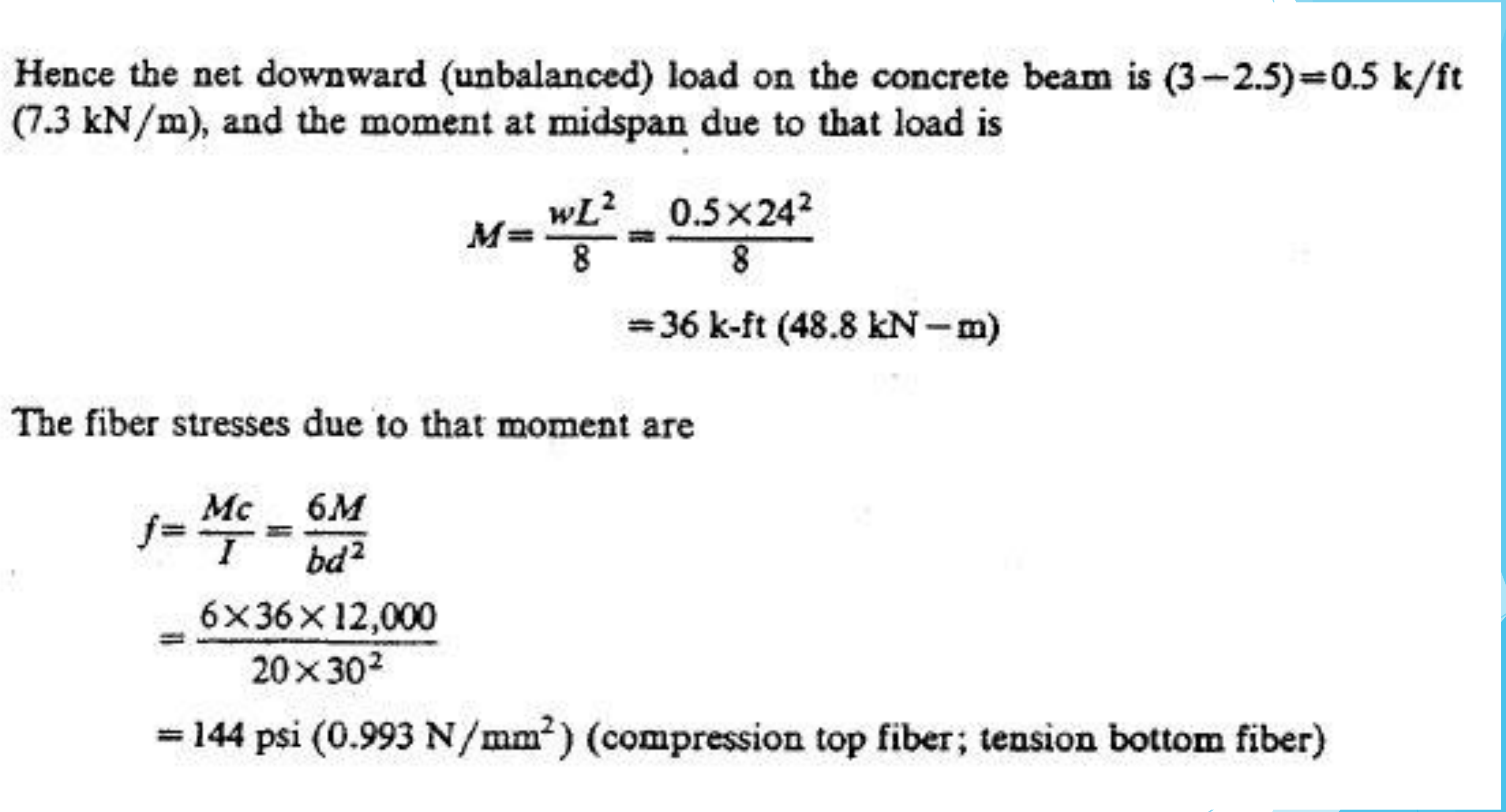


Fig. 1-25. Example 1-4.



Hence the net downward (unbalanced) load on the concrete beam is $(3-2.5)=0.5$ k/ft (7.3 kN/m), and the moment at midspan due to that load is

$$M=\frac{wL^2}{8}=\frac{0.5\times 24^2}{8}$$

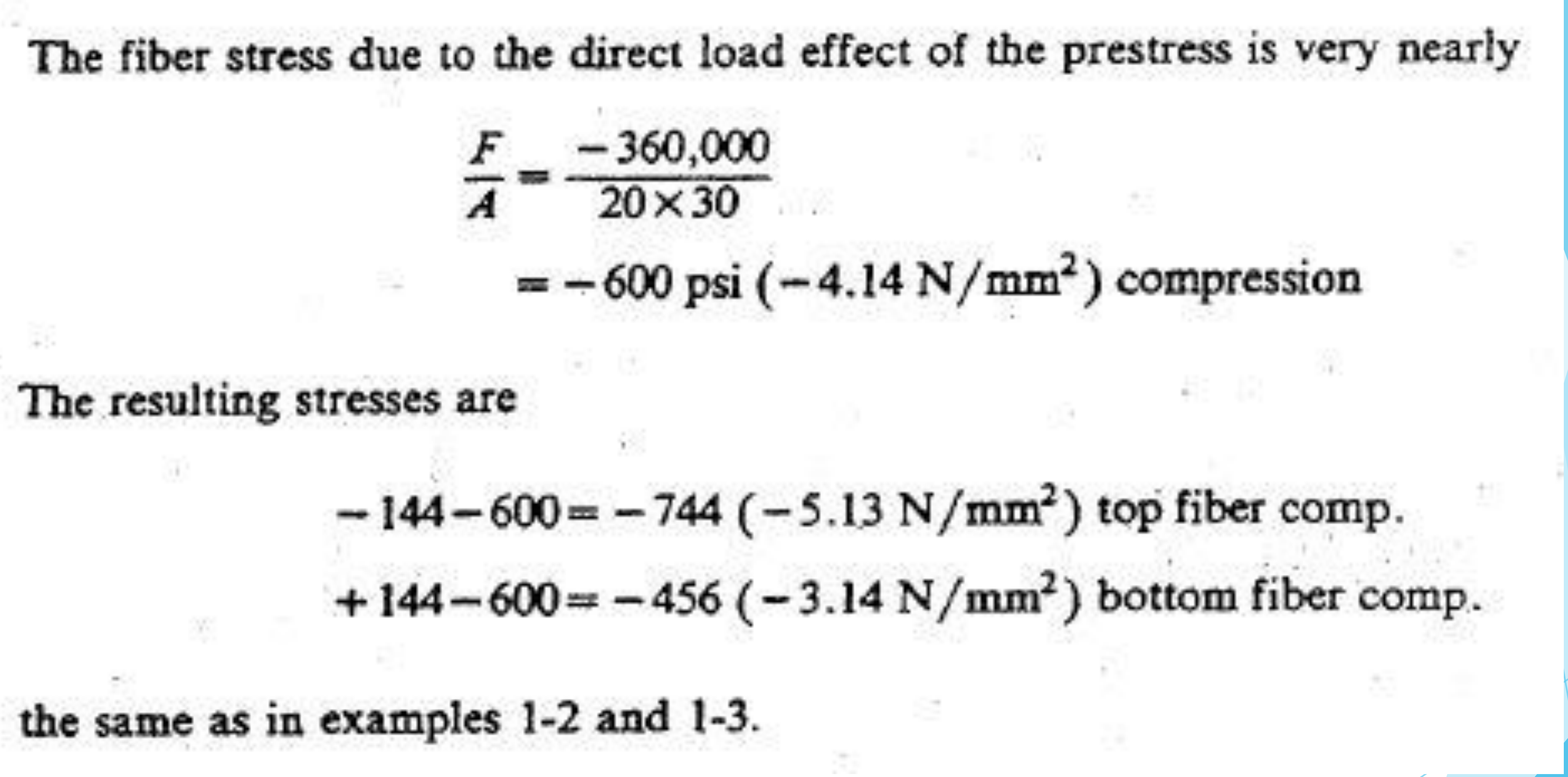
$$=36 \text{ k-ft } (48.8 \text{ kN}-\text{m})$$

The fiber stresses due to that moment are

$$f=\frac{Mc}{I}=\frac{6M}{bd^2}$$

$$=\frac{6\times 36\times 12{,}000}{20\times 30^2}$$

$$=144 \text{ psi } (0.993 \text{ N/mm}^2) \text{ (compression top fiber; tension bottom fiber)}$$



The fiber stress due to the direct load effect of the prestress is very nearly

$$\frac{F}{A} = \frac{-360{,}000}{20 \times 30}$$

$$= -600 \text{ psi } (-4.14 \text{ N/mm}^2) \text{ compression}$$

The resulting stresses are

$$-144 - 600 = -744 \ (-5.13 \text{ N/mm}^2) \text{ top fiber comp.}$$

$$+144 - 600 = -456 \ (-3.14 \text{ N/mm}^2) \text{ bottom fiber comp.}$$

the same as in examples 1-2 and 1-3.