CHAPTER 8

Tension, shear and bending moment

The 'internal forces' (tension, shear and bending moment) can vary from point to point in long narrow objects. Here we introduce the notion of graphing this variation and noting the features of these graphs. This graphing is a favorite chore of civil engineers.

In Section 5.4 starting on page 284 we defined *'internal forces'*, especially *tension* T, *shear* V, and *bending moment* M. A common issue in structural mechanics is keeping track of how these internal 'forces', and other more advanced internal force concepts (*e.g.,* stress), vary from point to point in a structure. Commonly this understanding comes from 'finite-element-method' programs①. However, there are a variety of important engineering problems for which the accurate and useful estimation of internal

① Part of the finite-element method is the division of an object into a grid; dividing the object of interest into 'finite elements'. Film and brochure makers are attracted to these grids, like a bee to a flower. So, even if you have never used one of these programs, you have seen signs of them, grids superposed on objects, in advertising, science, and science-fiction videos.

forces can be found using methods at the level of this book. These are problems where the structure of interest is long and narrow. For reasons like those discussed in the introductory paragraphs about trusses (*e.g.*, the discussion of 'swiss cheese' page 317), long narrow objects are surprisingly common in engineered objects as well as in biologically evolved designs. Despite the availability of computers for analysis of these, the elementary methods we will introduce here are useful because,

- For simple problems, they are easier than using a computer;
- The methods here help build understanding and intuition;
- The methods here can give formulas from which a design can be controlled more easily than by numerical parameter studies;
- For very narrow objects, the methods here are often more accurate than the computer solutions;
- To understand the vocabulary used in the output of the computer programs you need to appreciate the concepts associated with the methods here.

As for elementary truss analysis, the methods here are easily learned and pleasingly useful. For example, the formulas for bending moment in a simply-supported overhanging beam not only tell you the 'internal moment' for a given loading, but how to space joists in a floor or the wing supports on a human-powered hydrofoil. And the capstan formula isn't just a way to calculate cable tensions. It tells you how to make a simple modification to many bicycles to improve the performance of their brakes and derailleurs.