

Preface

The design of a wooden table has, traditionally, been in the hands of craftsmen. Fashion may cause changes in style, but the legs of the table, whatever their decorative shape, will have sufficiently robust dimensions that they will stand up to normal use – which may well include someone sitting or standing on the table top. There is no place for advanced mathematics in the design of such a table, although this will not necessarily deter scientists or engineers (and the distinction between the two professions is remarked in Chapter 1 of this book) from attempting to determine how the forces are carried from the table top to the ground. And in fact such an analysis will be useful if the traditional wooden material is replaced by say plastic or lightweight metal – the legs of the table may then have to be designed carefully if they are to carry their loads satisfactorily.

The design of the legs of the table may be taken as a simple but archetypal problem for the structural engineer – first, the forces to be carried by the legs must be calculated, and then the legs must be proportioned so that those forces are carried comfortably. It turns out that both these steps in design can be difficult. The four-legged table is, in technical jargon, hyperstatic; a table supported by three legs is easy to analyse, but the addition of a fourth leg greatly complicates the problem. The way in which the weight of a man, standing at a specified off-centre point on the table, is distributed to the four legs cannot be determined without a complex scheme of calculation. Such schemes of calculation form the subject matter of the *theory of structures* – the later step, the actual proportioning of the legs so that they are able to carry their loads, forms part of the science of *strength of materials*. The two steps cannot, in practice, always be separated.

There is, moreover, a complicating factor which may be appreciated by anyone who has dined outside a restaurant on a hot summer's night, with the portable table placed on the pavement. The table, annoyingly (both for the users and for the structural analyst), rocks. At any particular time a leg may be off the ground, and hence cannot be carrying any load – the other three legs must support the total weight of the table and its contents. Moreover, a passing waiter may nudge the table so that it takes up a new position, with a different leg off the ground. An attentive waiter will slice a wine cork lengthways on the slant to form two wedges, one of which may be put under an offending leg – that leg will then be supported not on hard pavement, but on a flexible footing. How, then, are the design values of the forces in the legs to be assigned, if any one of the legs may be carrying no load, or be supported rigidly or by a soft foundation?

The answer to this question is to be found in the application of the so-called plastic theory, which is discussed in Chapter 7, the final chapter of this book. Plastic theory was developed in this century, and it provides a way of designing a structure (like the four-legged table) whose precise state cannot be specified. All structures, except the very simplest, are of this kind and, in the past, designers have made calculations for conceptual models which ignore this inconvenient fact. As a result, those calculations lead to values – of stresses, for example – which cannot be observed in the real construction.

The seven sections of this book give accounts, in non-mathematical terms, of various aspects of structural theory. The presentation is roughly chronological, and, in a sense, forms a skeletal history of the subject. However, the objective is not to rake over the past but to illuminate the activity of the present-day structural engineer, and to show how a store of scientific information can be used creatively in design.

[No detailed bibliography is given. It is of interest that, for example, Euler solved the buckling problem in 1744, and this date is noted; only a dedicated scholar, however, will wish to consult the original Latin text. A full list of historical references may be found in J Heyman, *Structural Analysis: A Historical Approach*, Cambridge University Press, 1998; similarly *The Stone Skeleton*, Cambridge University Press, 1995 gives references for the masonry structure.]