STRUCTURE

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Frontispiece National indoor gymnasium in Tokyo

STRUCTURE

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DEDICATION

To Olive Mary, my wife, who once again had to spend many long evenings on her own while this book was taking its course.

Preface

This is not just another contribution to the vast number of textbooks on the “Theory of Structures”. In these days, no single book can hope to cover the complexities of structural analysis and the almost endless number of structural possibilities. If it did make the attempt, it would be quite inadequate from the point of view of the specialist, while at best leaving the non-specialist with an incomplete picture of the problems encountered in structural engineering.

What matters to the architect and to anyone concerned with the construction of buildings — and what is not often realized by the structural engineer — is not so much the ability to calculate the sizes of structural members, but a clear understanding of their relation to one another, the contribution they make to the overall concept of a building, and the reasons behind their various shapes.

This understanding requires an appreciation of the laws of nature involved and the response of structures to them. The laws of nature have not changed, but what is in a constant process of change is our ability to interpret them and to comprehend the inherent properties of materials. So far as building is concerned, progress in this latter field is very slow.

This book attempts to show the fundamental laws governing structural behaviour. These can be reduced to one single concept; that of *Static Equilibrium*. This underlies all structural form, whether expressed in overall layout or in individual elements. It is a concept which applies quite irrespective of any particular material, the only differences arising being due to varying properties of elasticity and strength.

Because of this approach, the old division between “statics” (especially “graphic statics”) and “strength of materials” has been superseded.

In this book, calculations have nowhere been regarded as an end in themselves. Where they do occur, their purpose is merely to illustrate certain thought processes. Formulae are not regarded as magic codes, to be swotted up for examinations and soon forgotten, but as convenient shorthand descriptions of structural behaviour. On no occasion are they derived from purely mathematical reasoning. However, for the sake of completeness and out of fairness to the

reader, various appendices give examples of some fundamental computations for the design of basic structural members. These are based on SI notation and include a short conversion table.

In abstracting from the immense field of analysis the essentials of structural action, it is hoped that this book will make both the designer and constructor of buildings stress conscious and more aware of the meaning of structural form. The engineer may not find a great deal of new information, but being pre-occupied with the calculation of structures, he may find it helpful to have presented to him those aspects of theory which mainly control — or should control! — the design process.

In any case, it is hoped that what follows will help to bridge the gap between architect and engineer which unfortunately seems to widen rather than to become narrower. It may also be of help to the interested lay reader who wants to make himself familiar with the structural implications of the buildings of any period.

H. Werner Rosenthal
1972

Foreword

by

J. E. Gordon,

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Materials, elasticity and structures constitute a curiously underestimated and badly understood group of subjects. Failures of structures and of materials in artifacts are common and sometimes disastrous and it is obvious that to such people as engineers, architects and industrial designers the matter is of the first importance. Yet it is true that the majority of students find difficulty and indeed, experience an emotional resistance in understanding the problems of strength and deflection.

This resistance does not really arise because of any mathematical obscurity. For one thing, those who are good at mathematics are often just the people who have most trouble with elasticity and for another, as this book shows, much of the subject involves no more than the most elementary algebra and arithmetic. The central difficulty seems to consist of acquiring an imaginative feeling for the loads and stresses in structures. In my opinion, it is just at this level that the subject ought to be taught to the non-specialist.

In the past, there have been few books of this kind. The present volume will therefore be particularly welcome. It will be useful not only to architects but should also fill a gap in the teaching of engineers. It will also do no harm at all to people like furniture designers! All are concerned with structure. Or should be!

The subjective difficulty in apprehending the nature of structures is curious. Animals — birds, cats, squirrels, monkeys and so on — which perch or climb about in trees seldom break them. They seem to have some kind of instinct for the strength of structures which is absent in most human beings, even in so simple a matter as sitting in a chair.

Yet, as the author of this book remarks, our subjective appreciation of many architectural forms is based on considerations of elasticity. In early Doric architecture, the exaggerated entasis of the columns and the swelling of the echinoi suggest Poisson's ratio effects, conveying the idea that the columns are carrying a massive load. Here we have an exaggeration of the elastic effects not dissimilar to that employed by Shepherd when he made the roof-beams for the Hall of Churchill College excessively deep. In both cases there is the feeling either that the load is greater than it really is, or else the structure is more than capable of carrying it.

In the later Gothic forms, we get the reverse effect and we marvel that so slender a structure can safely carry such loads over the centuries although, in fact, the actual stresses are quite moderate.

Just as much Renaissance painting depended for its effect upon a deliberate distortion of perspective, so much architectural effect deliberately plays upon our structural feelings. But of course, one cannot break the rules until one knows what the rules are. My contacts with students in some of the schools of architecture suggest that far too many of them are content to remain ignorant of what keeps their buildings up. This minor problem is usually left to such banausic people as engineers, while architects pursue their lordly sociological objectives!

I do not believe that the duties of the engineers and the architect ought to be wholly separated. Indeed, as a naval architect, I am horrified at the idea of separating them at all. I would suggest to land architects that although we have of late acquired the habit of building ugly ships which not only lose money but quite frequently break in two, a study of H.M.S. *Victory*, of the *Cutty Sark* and of H.M.S. *Belfast* can teach many lessons in the art of combining appearance with function.

The aesthetic problem of buildings in which the structure is trivial (as it may be in small houses) or is concealed (as it is in most large modern buildings) does not seem to be within sight of solution. It is a depressing thought that probably more buildings have been erected and more ground covered with buildings during the last 30 years than in the whole of previous history. And that only a tiny proportion of all this immense effort can possibly cause our hearts to rise by even a single millimetre. Frankly, nearly all of this construction is beastly and nearly all of it is the fault of architects. It is probably high time that the public rose up and lynched them! Having said this, I have to confess that I do not know what the solution is! Clearly however, it is not to be found by ignoring structural considerations.

The problem of relating structural appearance to structural function is almost as old as architecture itself. Certainly it dates from the beginning of the 5th century B.C. But however much one may admire the architect Palladio, for instance, one cannot but agree with Dr Johnson that it is difficult to approve of an engaged column! Much of the difficulty must surely arise because the problem has generally been considered as exclusively an aesthetic one, argued from a position of massive structural ignorance or else from somewhat brash attitudes of crude functionalism. Mr Rosenthal's book makes an important contribution towards closing this gap.

May I end upon an unfashionable note? Some of the difficulty in apprehending the nature of elasticity arises from the sizes of the

figures which we handle in the arithmetic. Strains — and indeed deflections — are usually very small and often tiny fractions which are difficult to imagine. There is not much that we can do about this. By contrast, stresses and elastic moduli are in danger of being represented by very large arithmetical figures equally difficult to apprehend. This, however, we can do something about. If we speak of a stress of 10 tons per square inch we can easily imagine 10 tons operating on a square inch of material. Much the same sort of thing applies to kilograms per square centimetre. Ten tons per square inch is 154,800 kilonewtons per square metre. Trying to imagine 154,800,000 newtons operating in a square metre is like trying to believe six impossible things before breakfast! It can be done, but it is unnecessarily difficult!

J. E. Gordon

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