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EXPERIMENTAL BUILDING SCIENCE

VOLUME TWO

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BEING AN INTRODUCTION TO MECHANICS AND ITS APPLICATION IN THE DESIGN AND ERECTION OF BUILDINGS

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PREFACE

To the student of building construction, the most fascinating pages in the history of industrial and scientific development are those which tell of the growth of the science of Mechanics, of the invention and the production on a large scale of mild steel and of Portland cement, and of the extended use of this knowledge and of these materials in the design and erection of modern buildings in steel and in reinforced concrete.*

It is a remarkable fact, however, that the knowledge and experience so gained has not as yet had any substantial effect upon the older methods of building construction, which are still to a large extent conditioned by traditional usage, rather than by conformity to the more scientific methods adopted in some of the newer forms of construction. In addition, as recent experience has shown, the introduction of new building materials and of new methods of construction have not always brought those immediate benefits which might have been expected. This has no doubt in part been due to the fact that, while it has been relatively easy to oust the older, traditional and less well-advertised methods of building construction, it has proved to be much more difficult to establish—even in these times of rapid change and re-adjustment—a common tradition of design and technique in the new materials, and to replace the large bodies of technical and craft skill which have thus been rendered ineffective. It is largely because of this fact that, in spite of the progress which has been made, the difficulties and responsibilities of the architect, the builder and the structural specialist are probably greater to-day than they have ever been in modern times.

The results of such an experience suggest that the most solid and lasting achievements in the development of building practice will not be found in the exclusive use of any one material—a method which usually results in a wasteful technique, when the new material is used in details for which it is not suited—but in the skilful use of all those materials which, either by the test of

* For a more detailed statement see J. Leask Manson, "Factors in the Development of Structural Practice," *The Structural Engineer*, March, 1926.

time or by the more rapid scientific tests of the laboratory, have proved themselves to be worthy of adoption and retention. Such a solution, however, will hardly be possible until there is a more widespread acquaintance with the chief properties of each material and with the general principles upon which their use in construction is based.

Apart from problems concerning the architectural form and style of buildings and the decorative use of materials—problems which would obviously be out of place in any volume included in this series—the design and construction of any building should, if it be carried out on rational lines, be the outcome of a knowledge of the external forces to be resisted, of the internal stresses resulting therefrom, and of the mechanical properties and the permanence of the materials to be employed. In the main, any consideration of the lasting powers or permanence of building materials must depend upon the application of the principles of Physics and Chemistry. The structural use and the strength of building materials can, however, be largely determined by the application of the principles of Mechanics, and it has therefore appeared to the authors that, under the general title of *Experimental Building Science*, and following the first volume (which dealt with the application of general elementary science to building work), a volume might well be devoted to the development of the more elementary and relevant sections of Mechanics, including Elasticity and the Strength of Materials, and to the application of this knowledge to well-known forms of building construction, the manner of treatment being such as to make it of value not only to the young student of both general and specialised construction, but also to the more mature reader who, for practical purposes, desires a straightforward and not too academic treatment of these topics.

The volume has been divided into three main sections. While the contents of each section are described in the opening paragraph in each case, reference may be made here to the general plan which has been adopted and to certain features which the authors hope will prove to be of special interest to the readers.

Section I deals with the general principles governing the equilibrium of systems of forces and with the applications of these

principles to the analysis of the forces acting in framed structures. When using some of the more recently introduced types of hoisting and erecting plant, the modern builder is faced with some interesting problems in stability, and the opportunity has been taken to utilise these problems to form an interesting and elementary introduction to the consideration of systems of forces which act in more than one plane. In this particular form the latter portion of this work is believed to be new; the authors hope that it will prove to be instructive and of practical value.

Section II is mainly devoted to the development of the ordinary theory of bending. In building up this important subject very careful attention has been given to the order in which the theory is developed. Thus the forces acting in a loaded beam are first considered as separate forces, apart from the strains and stresses set up in the material of the beam; fundamental relations are thus established in a simple manner before the full theory is introduced. Similarly the somewhat complex relations between shear stress and bending stress in beams are dealt with immediately after an elementary consideration of complementary shear stresses. This order of treatment, which is reasonably logical, should somewhat reduce the difficulties sometimes experienced by the student in dealing with this subject for the first time.

In **Section III** the principles developed in the two preceding sections are applied to modern forms of building construction. While no attempt has been made to give exhaustive details of construction or to elaborate the technique of testing, the information included should be sufficient to render the treatment complete and effective, and many references have been included to more advanced text-books for those who desire to pursue their studies further and in greater detail. The principles of construction in steel and in reinforced concrete, and especially the theory of column design, have thus only been developed far enough to be of service to the young student and to the general reader, but the treatment is such as to prepare the way for a more specialised study in any particular direction at a later stage should it be desired. In order to show how the older methods of construction may be modified to conform to more scientific methods of design, the subjects of Masonry and of Timber Construction have been

dealt with in greater detail than is usual except in works specially devoted to these methods of construction.

This volume assumes that the reader possesses a knowledge of the elementary principles of Mechanics (such, e.g., as are outlined in Chaps. VI and VII in Vol. I).

While there has been no intention of shirking the difficulties proper to the development of the subject, difficulties of a purely mathematical nature have been omitted where they add little to the elucidation of the subject. In cases where the more advanced methods of mathematical reasoning may be used with advantage by readers who are familiar with them, they have been included as alternative methods.

While graphical methods have been freely used throughout the volume, the authors lean to the view that arithmetical and algebraic methods of solution should be utilised in the first attempts since, as experience shows, a sounder knowledge of the principles involved can be obtained in this way. For this reason many worked Examples have been included.

All important statements of principles and all important formulae and expressions are, for ease of reference, *numbered consecutively through each chapter* (the former in large and the latter in small Roman numerals). The authors are of the opinion, however, that the memorising of these expressions and formulae will usually be of much less value than the possession of a clear conception of the arguments which lead up to the final results embodied in these expressions.

While the volume can be read and understood by a reader who is unable to conduct the experiments which are described in the text, the greatest profit will be derived if, as has been suggested herein by the authors, all important statements are either introduced or checked by experiment. In order to facilitate such treatment special experiments have been devised so that the total number of essential experiments may be kept as small as possible.

Except for the experienced practitioner and the advanced student, experimental work will be the main channel by which the student gains a practical and organised body of knowledge and experience of the nature of the various materials, and also of the departures which in practical construction are made from the ideal

conditions assumed in developing the subject-matter of this volume. Similarly it is important that, as with the growth of his industrial experience he is able gradually to reduce his dependence upon the conduct of laboratory experiments, the student should come to look upon full-sized constructional work as an extension of the simpler methods of the laboratory, and seek to analyse along similar lines the knowledge and experience so gained.

In the absence of a generally accepted standard notation the authors have adopted a scheme (see Appendix II) which is simple and reasonably in accordance with good practice at the present time.

The authors desire to express their thanks to the Governors of the Manchester Municipal College of Technology for facilities which have enabled them to carry out experimental work and for the use of the testing laboratories; their thanks are also due to the following firms for permission to use certain blocks and photographs: Messrs G. Cussons, Ltd., Manchester; Mr A. Macklow Smith, Westminster; and to the British Engineering Standards Association for permission to publish the tables printed in Appendix I.

J. L. M.
F. E. D.

July 1929

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