GRAPHICS FOR ENGINEERS, ARCHITECTS, AND BUILDERS: A MANUAL FOR DESIGNERS, AND A TEXT-BOOK FOR SCIENTIFIC SCHOOLS. TRUSSES AND ARCHES ANALYZED AND DISCUSSED BY GRAPHICAL METHODS, IN THREE PARTS

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649725601

Graphics for Engineers, Architects, and Builders: A Manual for Designers, and a Text-Book for Scientific Schools. Trusses and Arches Analyzed and Discussed by Graphical Methods, in Three Parts by Charles E. Greene

Edited by Trieste Publishing Pty Ltd.
Cover @ 2017

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TRUSSES AND ARCHES

ANALYZED AND DISCUSSED BY GRAPHICAL METHODS

BY

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IN THREE PARTS.

I.

ROOF-TRUSSES: DIAGRAMS FOR STEADY LOAD, SNOW, AND WIND.

II.

BRIDGE-TRUSSES: SINGLE, CONTINUOUS, AND DRAW SPANS; SINGLE AND MULTIPLE SYSTEMS; STRAIGHT AND INCLINED CHORDS.

III.

ARCHES, IN WOOD, IRON, AND STONE, FOR ROOFS, BRIDGES, AND WALL-OPENINGS; ARCHED RIBS AND BRACED ARCHES; STRESSES FROM WIND, AND CHANGE OF TEMPERATURE.

PART II.

BRIDGE-TRUSSES.

TEN FOLDING PLATES.

SECOND EDITION.

NEW YORK:

JOHN WILEY AND SONS,

15 ASTOR PLACE.

1884.

GENERAL PREFACE.

THERE is not the necessity which would have existed a few years ago to write a few words explanatory of graphical methods of analysis, and to urge their accuracy, convenience, and adaptability to all types of structure. If, however, some readers now glance at such subjects for the first time, it will be sufficient to point out, that, as forces may be represented by straight lines of definite magnitude and direction, the same operations which are performed by mathematical analysis may be more easily carried out by geometrical construction upon the drawing-board; and, as the whole system is founded upon the parallelogram of forces, the results deduced by a brief chain of reasoning are theoretically accurate, and only depend for their numerical exactness upon the scale of the diagrams, and the care with which they are drawn. Any draughtsman who gives the method a fair trial, and then takes the trouble to compare the results with those obtained by mathematical formulæ, will be surprised to see how closely the two agree. The difference is much less than can be taken account of in designing the proportions of the several parts of the structure. The simplest tools alone are needed, — drawing-board, T-square, triangles, and scale.

This work is intended for office use by any designer who may have occasion to prepare plans for a structure intended to support a load above any opening, — a roof, or bridge-truss, or an arch, — of any type, span, and distribution of load. It is also hoped that these three parts may be found serviceable as a text-book for engineering and architectural students, and may aid in clearing away some of the obscurity which is apt to surround certain parts of the subjects treated in the following pages, especially those of continuous bridges and arches. From his own experience as an engineer and as an instructor, the author has been led to go more into detail than an ordinary expansion of the methods would require, and in some cases to repeat what has been explained earlier; for he has found that both the practical man, taking up the subjects at intervals as required for use, and the student, finding so much that is new, need a certain amount of repetition to fix the principles clearly in mind. It will be found that students generally grasp readily, and evince a strong liking for, graphical methods. Mathematical and graphical analysis go well hand in hand, the latter aiding the student to more clearly apprehend the meaning of the former. Indeed, the mathematical formulæ may be, if desired, deduced directly from the diagrams. If sufficient time is allowed between the class-room exercises for the construction in the drawing-room of problems suggested by the text, the results accruing from this study will be most satisfactory.

Some special remarks in regard to subjects treated will be found prefacing the several parts.

C. E. G.

PREFACE TO PART II.

THE general method of analysis called "The Method by Area Moments," which is the foundation of the following pages, was first printed in 1874 in "Graphical Method for the Analysis of Bridge-Trusses," &c., having been discovered and taught by the author the year preceding. Part I., discussing roof-trusses, was founded upon what is known as Professor Clerk-Maxwell's method of drawing diagrams, and has little which is original, except the carrying-out of details. It is thought that Part II. will be found to contain much which is new, and, it is hoped, valuable. That this part is not a second edition, and simply a reprint, of the book above referred to, will be seen, when it is noticed that there is more than twice the amount of text, and sixty-three in place of fifteen illustrative figures. Chapter III. is devoted to an analysis of various types of trusses with horizontal chords having single systems of bracing, and is almost all new. The treatment of multiple systems of bracing, comprising Chapter IV., is entirely new. The construction for the bowstring girder, and the chapter on deflection of beams, are here introduced for the first time: partially continuous trusses and pivot-draws, with turn-table tipping or stable, have also been added.

As it is now four years since this method of area moments for the analysis of continuous girders was first given to the public by the author, and as no statement that such a method can be found in any other place has appeared, the author feels warranted in putting forth a claim for priority of discovery and originality. The attention of the reader is asked to the extreme simplicity and the generality of the formulæ here deduced for pier moments in continuous girders and draw-spans, and to the facility and brevity with which all the usual formulæ of the text-books, simple or intricate, for the slope and deflection of beams of one or more spans, are derived without the use of the integral calculus, as usually understood. These results have never been obtained, to our knowledge, in this way before. If the reader knows the position of the centre of gravity of a triangle, he need here accept nothing on faith. Following this investigation, it will be seen that the *Three Moment Theorem* in its special and general forms is deduced directly from the equation of *Area Moments* by simple substitution. The truth of all these formulæ is now for the first time made clear to the reader who has no knowledge of the higher mathematics. Indeed, it may not be amiss to state that all the propositions here advanced may be understood by one who possesses a very moderate knowledge of mathematics and mechanics.

The endeavor has been made to take nothing for granted: hence graphical proof has been offered in regard to the extent of load which produces maximum bending moment and maximum shear, in regard to the effect of inclination of chords on web-stresses, in regard to absence of stress in the braces of the parabolic girder, &c. Some minor points will be found to possess novelty: prominent among these is the construction for

web-stresses in the bowstring, parabolic truss, which will be found to be extremely simple in application. Whether the special constructions for trusses with multiple systems of bracing will be useful or not, depends upon the frequency with which they are needed: some of them are thought to be elegant; they are all short in construction. The method here set forth of drawing the line which limits the maximum shear ordinates in a single span truss, and which was given in the former edition without proof, is here shown by a mathematical demonstration to be theoretically exact.[1] A simple and convenient diagram for the effect of a locomotive, or a load of greater than average intensity, is inserted. Very many of the details are thought to be new, and a comparison is invited for accuracy and brevity between these constructions and those found in other books.

The author would also ask a candid comparison of his method of Area Moments with the German method, as a means of solving problems in continuous girders, believing that, for the small number of operations, and hence simplicity and accuracy, as well as comprehensiveness, it will be found at least equally convenient.

The attempt has been made, by the use of capitals for the lettering of the trusses, accented capitals for the moment diagrams, small letters for the shear diagrams, and numerals for the load line, &c., to render a reference to the several diagrams of each figure easy.

Part III., on arches of all types, is in an advanced stage of preparation, about one-half of it having been once already in

[1] This demonstration in its essential features, as here given, was the work of Mr. Charles A. Marshall, at the time a student in the University of Michigan.