TRUSSES
AND
ARCHES
GRAPHIC
METHOD
—
CENE

PART III.
ARCHES

6#8#178

JDávila 00"

Jenaro Dávila

Michigan 1899

$$\sum \frac{T}{p} \times \frac{l}{EA}$$

721

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.

BY

CHARLES E. GREENE, A.M.,

PROFESSOR OF CIVIL ENGINEERING, UNIVERSITY OF MICHIGAN.

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; STIFFENED SUSPENSION BRIDGES.

PART III.—ARCHES.

EIGHT FOLDING PLATES.

SECOND EDITION.

SECOND THOUSAND.

NEW YORK

JOHN WILEY & SONS

LONDON

CHAPMAN & HALL, LTD.

1897

Press of J. J. Little & Co.
New York, U. S. A.

PREFACE TO PART III.

THE curved lines of arches are pleasing to the eye, and may often be introduced with advantage in constructions. An arch may furnish, under some circumstances, a very economical way of spanning an opening; and arched ribs are employed in other cases, at conspicuous locations, where beauty of design is regarded, or where ample and uninterrupted space beneath a roof is desired. Stone arches have been built for many centuries; at the present time, wood, iron, and steel are also used as materials. If the principles which enable one to ascertain the forces acting in all parts of an arched structure are clearly understood, designs of this type will be more common than they now are; and it is with the desire to do what he can toward shedding some light upon this subject, as well as to give the ability to intelligently design an arch to those who are not familiar with the higher mathematics, that the author submits the following pages to the public.

Most persons experience difficulty in mastering the principles which govern the action of an arch, as they have hitherto been presented. Even one who has successfully worked through the mathematical theory, as he finds it in the text-books, may sometimes lose sight of the actual meaning of each step in the

process; so that there is a certain mystery about the application of the formulæ to a specific example, although one may feel confident that the results are reliable. To many constructors a treatise on the arch, as usually written, is a sealed book, and the whole subject is veiled in obscurity. Empirical rules, copying of existing examples, and guesswork have been the refuge of many. While such practice may answer for masonry structures, where the factor of safety as regards *strength* is very large, the introduction of iron skeleton structures, where the pieces occupy definite lines of force, and the sharp rivalry for economical disposition of the material, render a better practice desirable. It is hoped that the graphical method developed in the following pages will enable the reader to understand as clearly the effect of applied forces on an arch, as it has, through the explanations of Parts I. and II., enabled him to analyze trussed roofs and bridges.

From the *bending moment*, *direct thrust*, and *shear*, here obtained at successive sections of the arched rib, the stresses in the chords or flanges, and bracing or web, are derived as if the structure were a simple truss. In finding the resultant stresses in the pieces, the method of Part I. will sometimes be preferred to that of Part II. So far as possible, the formulæ of the text have been obtained by direct and easy ways; and, while it has been convenient to arrive at some of the definite results by the use of the calculus, such results have been obtained from the diagrams, and can in all cases be verified by the reader, for any specific example, by the most simple means.

After the subject is once mastered, the resulting formulæ and applications will, naturally, alone be referred to in working out designs: the author has therefore thought it best to place the results, &c., in direct connection with the explanatory

statements, and to have the analytical or mathematical demonstrations follow in smaller type. One who simply desires working-material may omit the matter printed in small type, without losing any of the facts, but must then take some statements for granted.

A distinctive notation for the figures, introduced in Parts I. and II., — capitals for structures and moment diagrams, small letters for the shear diagrams, and numerals for the stress diagrams, — has been generally adhered to. While an acquaintance with Parts I. and II. will aid the reader in understanding more readily the graphical constructions here given, it has been the aim of the author to enter sufficiently into detail to make this part intelligible by itself: hence a few explanations are repeated here.

It is believed that many things offered in these pages will be new to most readers. The work is almost entirely the result of independent investigation. A portion of the material was once printed in the "Engineering News," but it has been entirely revised since that time: over one-half of this part is now in type for the first time. The device of increasing the breadth of the parabolic rib, or the thickness of the flanges, from the crown to the springing, while the depth remains constant, — which device will be found in Rankine's "Civil Engineering," — enables the summation of ordinates to be made across the span, as for a beam, rendering the treatment simple. On the other hand, the depth and breadth of the circular rib are supposed to be constant, and the summation is made along the curve. Herein the treatment differs from that of some authors. It is shown that the direct thrust on a right section is not equal to the product of the horizontal thrust by the secant of the inclination of the rib at the section to the horizon, as some

writers assume, unless the equilibrium curve is parallel to the axis of the rib. Other points of difference in treatment and result will be found by readers who are familiar with the literature on this subject. The discussion, in Chapter VIII., of the action of the wind on an arched roof, will, it is hoped, be found timely and serviceable; the effect of change of temperature, and the change of form under stress (Chapter XI.), are often ignored by writers; an example of a stone arch of considerable magnitude is worked out in detail; the methods of stiffening suspension bridges are discussed and compared: on some of these points very little has heretofore been given.

C. E. G.

ANN ARBOR, MICH., July, 1879.

TABLE OF CONTENTS.

CHAPTER I.

GENERAL PRINCIPLES.