VOUSSOIR ARCHES APPLIED TO STONE BRIDGES, TUNNELS, DOMES AND GROINED ARCHES

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649730520

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Edited by Trieste Publishing Pty Ltd.
Cover @ 2017

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Trieste

PREFACE.

THE following pages contain a discussion of the theory affecting the stability and strength of stone or brick arches, including bridges, culvert and tunnel arches, groined and cloistered arches, together with various styles of domes.

In the former treatise by the author, on *Voussoir Arches*, the theory of Dr. Scheffler (given in his German treatise on arches) for incompressible voussoirs was given, and applied to the experiments on arches, also to the case of a segmental stone bridge, the compressibility of the material being included in an empirical manner, which seemed to be justified in part from the consideration of the numerous experiments given.

In the present treatise the aim has been to make an advance in the theory, by considering the effect of the compressibility of the material in a theoretical manner. This has the effect of modifying the assumption that the principle of the least resistance applies, except at the limit of stability, which last was shown by the experiments. It is gratifying to note, however, that the present theory conducts to nearly the same solution for the arch eccentrically loaded as that proposed in the former volume, so that the conclusion reached in both cases is the same. The connection between voussoir and solid arches will be given subsequently in treating the latter subject.

In the sections relating to curves of pressure corresponding to the maximum and minimum of the thrust, and parts of the treatment of underground arches and domes, with certain examples, so far as they refer to an imaginary incompressible material, the writer is again indebted to Scheffler's "Theorie Der Gewölbe. In the treatment of spherical and conical domes, assistance has been derived in part from Prof. Eddy's "New Constructions in Graphical Statics." The aim throughout has been to carefully analyze hypotheses in the light of facts, and to present the subject in a simple manner, though not lacking in completeness; to which end the graphical method has been mostly employed.

THE AUTHOR.

VOUSSOIR ARCHES

APPLIED TO

STONE BRIDGES, TUNNELS, DOMES, ETC.

1. The following is a continuation of a paper èntitled "A Practical Theory of Voussoir Arches," which appeared in Van Nostrand's Magazine for October and November, 1874, and afterwards reprinted as No. 12 of *Van Nostrand's Science Series.*

In that treatise, the principles affecting the stability of arches, upon the hypothesis of incompressible voussoirs, were exposed and applied to the investigation of numerous experiments upon wooden arches, *at the limit of stability*, with which they were found to agree. A segmental stone viaduct was likewise examined: the theory for incompressible voussoirs being modified *empirically* for the elastic materials used in construction.

It was mentioned in the former treatise, that we shall hereafter designate as Part I, that if the effects of the elasticity, causing the deformation of the compressible arch were known, that the investigation of its stability for a statical load could be effected.

The attempt is made, in what follows, to throw some light upon this effect of the compressibility of the voussoirs; and the empiricism, before mentioned, will be criticized in the light of the deductions, as well as from a further consideration of the experiments themselves.

Afterwards, the precise part played by the spandrels will be pointed out and certain theories concerning them discussed. The subject of the theory of arches will then be extended to *underground arches*, *groined* and *cloistered arches*, and *domes*; and practical examples will be given, worked out in detail, to illustrate the investigation—as far as it can be made—of the stability and strength of such structures.

EFFECT OF THE ELASTICITY OF THE MATERIALS.

2. We shall introduce the present subject with some comments on the fourth experiment given in Part I. Fig. 1 represents one-half of a wooden gothic arch and pier of fourteen inches span; the depth of voussoirs being two inches, the horizontal width of pier, 1.9; its height, ten; and the uniform thickness of arch and pier, 3.65 inches. The contour curves of each half arch are described from the opposite springing points. The voussoirs were constructed of equal weight, the pier weighing 2.3 voussoirs. The inner edge of top of pier coincides with the intrados at the springing. With no weight on the crown the arch and pier stood, but fell with a slight jarring, such as a person walking across the room. Now, as the crown joint and joint 5 opened on the intradosal, and joint 3 on the extradosal side, even when the arch stood; the voussoirs bearing at the very edges opposite the opening; it is evident that the arch, at the moment