HIGH MASONRY DAM DESIGN

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PREFACE

It is the practice at Columbia University to require of the third-year students in the Department of Civil Engineering, the execution of the design of a masonry dam, and to aid them in this problem they have heretofore been furnished with "Notes on the Theory and Design of High Masonry Dams," prepared some years ago by Prof. Burr of the Department, and having for their basis the method as set forth by Mr. Edward Wegmann.

This procedure with which Wegmann is credited, and which was developed through the investigations undertaken in connection with the Aqueduct Commission of the city of New York, for the purpose of determining a correct cross-section for the Quaker Bridge dam, resulted in the first direct method for calculating the cross-section of such structures and is essentially a development of the Rankine theory.

The studies appeared first in the report made by Mr. A. Fteley to the chief engineer of the Aqueduct Commission of the city of New York, dated July 25, 1887, and later in Mr. Wegmann's treatise on "The Design and Construction of Dams."

Neither in the report nor in the treatise however, have the effects of uplift, due to water permeating the mass of masonry, and of ice thrust, acting at the surface of the water in the reservoir, been considered, and in consequence of this, objection might be legitimately raised that the series of equations determining the cross-section fails to account for these factors. Some difference of opinion may exist as to the relative importance of these considerations, but when a structure of great responsibility is projected, conservatism in design is essential.

The following presentation which aims to supply these omissions, has been prepared primarily that there may be had in convenient form a text, containing the general treatment and such consideration of these factors as more recent practice requires, together with a brief statement regarding the late investigations undertaken for the purpose of determining more accurately the variation of stress in masonry dams.

The formulæ relating to uplift, ice thrust, etc., were deduced by one of the authors and have been used in part in connection with the design of the large dams for the new water supply for the city of New York.

The computations for the design of a high masonry dam are appended to facilitate the ready comprehension and application of the formulæ.

It is hoped that the presentation may appeal to the practicing engineer as well as the student, and that there may be found therein enough to compensate him for the labor involved in its perusal.

C. E. M.
O. L. B.

COLUMBIA UNIVERSITY, 1910.

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THE method of analysis by which an economical cross-section of a high masonry dam may be most directly calculated, and the one which is most generally adopted in engineering practice, was first devised by Mr. Edward Wegmann through studies made in connection with the Aqueduct Commissioners of New York city, and it is that method which will be employed here, though it will receive some modification in certain particulars and be elaborated in certain others.

In determining the cross-section by the series of equations developed in that analysis, no account is taken of the condition of uplift due to water penetrating the mass of masonry, nor of the ice thrust acting horizontally at the surface of the water in the reservoir against the upstream face of the dam, though reference is made to it. Present practice requires however, that these two factors be considered where a structure of great responsibility is proposed, and in this respect at least, will the analysis be amplified.

While upward pressure in a masonry dam, either at the foundation or in joints higher up, should always be considered, the subject does not lend itself to a very exact treatment; in fact, it becomes necessary to make assumptions in regard to its presence and action which in the end depend principally upon the judgment of the engineer. It is not surprising therefore, that a wide range of opinion exists as to the method of dealing with this factor.

Such pressures may become effective from two causes: the percolation of water into small cracks either in the superstructure or the foundation, or by the presence of springs in the foundation itself.

In the best laid masonry it is undoubtedly true that small cracks exist into which the water gains entrance, but this should be guarded against as far as possible by the exercise of great care in the laying of the stone and the bonding of them, together with thorough inspection. "Temperature variations due to setting of concrete and also due to daily and seasonal changes, while inducing stresses that are indeterminate, thereby providing an argument for conservatism in design, in addition affect permeability to greater or less degree." Even in cyclopean masonry where no horizontal joints exist, except between the facing stones, the possibility of other small cracks being formed is always present, and therefore requires recognition here as well.

Where springs are found in the native rock of the foundation the effect of upward pressure from such a source must be overcome by a system of drains which shall lead the water below the downstream face of the dam. The difficulty here is from the possible formation of new springs as soon as the reservoir becomes filled, with which some connection will inevitably be formed, and thus cause an upward pressure due to the total hydrostatic head of the water back of the dam. It is evident therefore, that the foundation should be carefully examined and be specially prepared to receive the first course of masonry.

The method of allowing for upward pressure depends upon its properly assumed presence, and also upon some assumed law of variation. Present practice indicates that this may be considered as varying from a maximum at the heel to zero at the toe. But because it is hardly justified from experience with other dams to impose such severe conditions upon the masonry above, it is agreed to consider this pressure as acting over only a portion of the joint, or, in other words, to consider only a portion of the full hydrostatic head as acting at the upstream face of the joint under examination.

Although lack of exact data precludes the possibility of assigning a definite value to the force of expanding ice in its formation at the surface of a reservoir, yet it will be evident that a thrust from such a cause may greatly affect the dimensions of a profile, in cold climates especially. As this thrust is effective at the surface of the water, for a low structure it may become a very serious feature.

The studies involved in the determination of a cross-section demand an investigation along two general lines:

First, the direct calculation fixing the most economical cross-section under the imposed conditions, and

Second, studies in comparing cross-sections ranging between this one, which may be called the minimum, and one of an existing masonry dam, where the conditions