HYDRAULIC-FILL DAMS*

By Allen Hazen
Consulting Engineer, New York City

THE hydraulic-fill method of dam construction grew out of hydraulic mining. It was natural that a process conspicuously successful in mining on an enormous scale, and that moved material at very low unit costs, should find other applications.

The late James D. Schuyler and J. M. Howells were pioneers in the application of hydraulic methods to dam construction. Mr. Schuyler presented a paper to the American Society of Civil Engineers in 1906 setting forth in a most admirable way the peculiarities of the method and its application to actual dams.

The method is certain to have an important place in future dam construction. It has two fundamental advantages: First, in sorting out the fine particles and placing them in the centre of the dam, thus insuring complete watertightness; and second, in the use of power in place of muscle to the greatest extent, so that the labor cost and the animal cost of construction are reduced to a minimum.

It is sometimes possible to place material by the hydraulic process at much smaller cost than by any other method. On the other hand, several hydraulic dams have not proved to be stable. Failures, usually during construction, have caused great losses, and their occurrence has been discouraging.

There may have been more than one cause of failure, but one cause has certainly predominated. In the interior of the dams there have been masses of clay and other fine-grained material, that have not consolidated to the point of stability. Instead of forming an integral part of a solid dam, these have remained in almost liquid form, dividing the dams and tending to disrupt them. In this respect, hydraulic-fill dams are on a different basis from other earth dams. If the hydraulic method of dam construction is to be successfully used, this element of weakness must be eliminated.

There seem to be two promising ways of eliminating it. The first and most natural one is to increase the size of the dam until the solid parts forming the toes are amply strong to resist the full fluid pressure of the unstable core. The second consists in selecting material and handling it in a way to secure drainage and consolidation of the core, so that the whole dam will act as one solid mass.

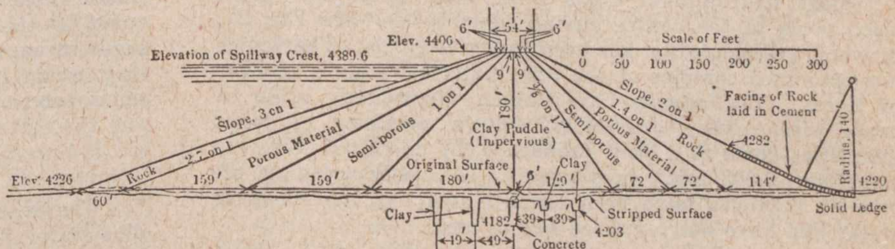
If core material can be fully drained and consolidated, there is no reason why a dam built by the hydraulic method on a section that is suitable for an earth dam built dry should not be safe. If drainage and consolidation of the core is not secured, however, safety can only be reached by making each toe large enough to stand the full pressure of the liquid core, and in that case, in order to be safe, a dam built by the hydraulic method must have flatter slopes and a larger section than is otherwise needed for an earth dam.

It is interesting to note that Clemens Herschel, in discussing Mr. Schuyler's paper in 1906, made the point that a larger section would be required for stability; Mr. Schuyler took exception to this, and stated that in his experience there was no reason for building a dam of greater dimensions because the material was placed in it by the hydraulic method.

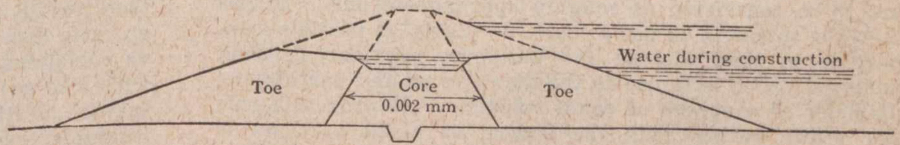
The advantages and economies of the hydraulic method are such that it will often be good business to use it, even though the required volume of the dam should be greater. If work can be built at half the cost per cubic yard, twice as many cubic yards can be placed for the same money.

The number of failures with the hydraulic-fill dams growing out of this fundamental condition of fluid cores and inadequate toes has been such as to make it clear that this condition of instability has not been recognized in the designs. Mr. Schuyler's excellent paper contains no discussion of this point. Looking at it from the standpoint of thirteen years afterward, it is easy to see how this condition could have been overlooked and to see, also, how some of the early failures were attributed to other causes.

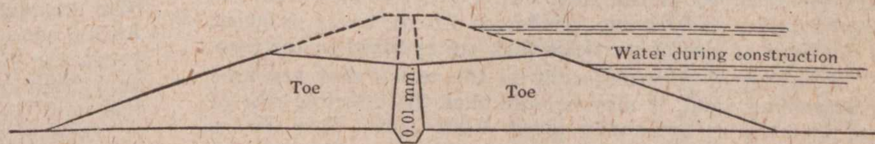
Now, however, enough experience has been gained so that a better analysis may be made. To insure success with future hydraulic dams, this analysis must be thorough. It is the writer's thought that it will be possible to make it in a way to secure as high a degree of safety in hydraulic-fill dams as is required, and is customary, in other engineering structures. It may be that we do not yet have all the necessary data; but, if not, the best way to find what is lacking is by using what we have.



CROSS-SECTION OF DAM NO. 2 AT NECAXA, MEXICO.
SHOWING
DIMENSIONS, CUT-OFF TRENCHES AND THEORETICAL DISTRIBUTION OF MATERIALS.
FIG. 1



TYPICAL SECTION OF HYDRAULIC FILL
DAM DURING CONSTRUCTION.
FIG. 2



ILLUSTRATING PROPOSED SECTION WITH
NARROW COARSE-GRAINED CORE.
FIG. 3

Character of Core Material

The first point to be considered is that, in many or perhaps, most hydraulic-fill dams, the core material is so fine in grain size that it is incapable of drainage. By that is meant that it is incapable of drainage within a reasonable length of time. The lower parts of the core do not become stable before the upper parts are placed upon them.

In general, all the material placed in hydraulic-fill dams may be divided into two classes, namely, toe material and core material. Mr. Schuyler presented a picture of materials divided into several classes, the coarsest being found at the outside and the finest in the middle (see Fig. 1). Practical experience does not show that the material is graded in quite that way. There is some grading in the toes and the average size of particles near points of delivery of material near the outer slopes is greater than away from those points and near the core; but, practically speaking, this gradation is not very important. Ordinarily, all the toe material is of coarse particles when first placed. Afterward, passage of silt-laden water from the operation

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