REINFORCED CONCRETE HOLLOW DAM OF BUTTRESS TYPE.

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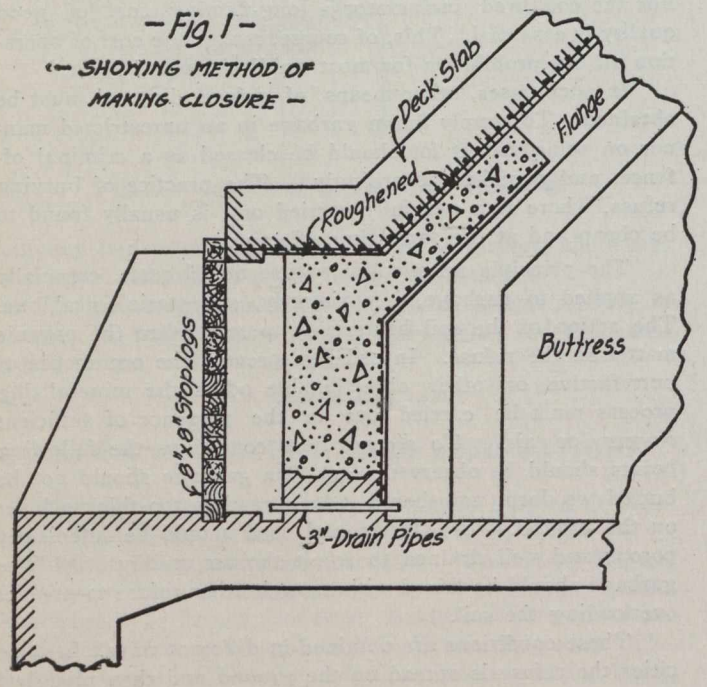
Concrete-steel is a relatively new material and the design of structures involving its use has not yet reached that state of standardization which exists, for example, in structural steel work. Certain tables and rules have been devised but in the details of design much is left to the ingenuity and practical skill of the designer. The nature of the material and its method of fabrication are almost entirely responsible for this. The manufacture of steel is carried out in a shop under ideal conditions for fabrication and inspection, and its erection is merely a matter of assembling and putting together the various units that go to make up the structure. Reinforced concrete, on the other hand, is manufactured in place, in the field, sometimes under far more ideal conditions, and by labor that is, for the most part, unskilled. Its supervision should always be in the hands of experienced and competent men. Unfortunately, this is not always the case and oftentimes the caliber of the construction organization will have considerable influence in determining the details of design.

-Fig. 1-



The forms, or molds, for the concrete exert even a greater influence. The cost of the forms is usually from one-half to two-thirds of the entire labor cost in a concrete structure, and very often economy of materials must be sacrificed to the simplification of the form work. As a general rule, all details should be made as simple as possible. Where the erection is to be beyond the control or supervision of the designer, great caution should be exercised in designing and delineating small but important details which may appear unimportant to the man in the field. The monolithic character of concrete will also introduce stresses due to continuity which may sometimes be used to advantage, but must always be provided for. Contraction and expansion must also be taken care of by the designer and not left to the ingenuity of the erector.

In this and the following papers, the notation, formulæ, unit stresses, etc., recommended by the Joint Committee on Reinforced Concrete will be mainly followed.*

* Proceedings, Am. Soc. C.E., February, 1913, p. 117.

Four or five types of hollow concrete dams have been developed, but the most widely used and the original form is the buttress type, which is here discussed. This form is patented by the Ambursen Hydraulic Construction Company, Limited, of Boston, Mass.

The first dam of this kind was built at Theresa, N.Y., in 1903, and was designed by Messrs. Ambursen and Sayles, of Watertown, N.Y. Since that time, over 75 dams have been built, varying in height up to 150 feet and in length up to 1,200 feet.

It is not the purpose of this paper to discuss at any length the merits of this type but a brief summary of its advantages seems desirable.

Compared with the regular gravity section of stone or cyclopean masonry we note that the latter is usually designed in such a way that the resultant pressure on the base acts at or near the down-stream edge of its middle third. Here the water pressure is turned downward by the weight of the masonry alone, and it is readily seen that an increase in head on such a dam will cause the resultant to pass outside the middle third, producing tension at the upper toe and finally overturning the structure if it does not fail in some other was before this occurs. In the hollow type the inclined slab causes the water pressure to be directed downward at all times, and the resultant pressure can be made to cut the base at any desired point by varying the design.

The facility with which the base pressure may be reduced in intensity by spreading the base, and made uniform over the base by correct proportioning is one of the marked advantages of this type of dam. In some cases, where the river bed is a hardpan or cemented gravel, overlying impermeable strata, the dam may be built directly on this material, because of this fact, and no deep foundations need be used. Extreme caution should be exercised in using this form of construction, however, and in general the buttresses should rest on rock or its equivalent, and the cut-off wall should extend to impermeable strata below all possible underflow.

The danger of ice thrust is also eliminated, as an ice jam would be forced up the inclined slab and its weight distributed over the structure, or, if the water were high enough, would be forced over the top of the dam.

While the hollow dam will, in general, cost less than a masonry structure of the gravity type, and while there are many places where the easy control of base pressure in the former makes it available because the cost of the latter would be prohibitive, no fixed cost relation can be given. Reinforced concrete work requires steel and lumber, the cost of which may, in some localities, be excessive, making a gravity dam more economical.

No actual failures have been recorded, but the oldest dam has been in service only 10 years. Cases have occurred in which the foundation has washed out under the dam, which has arched over the opening and remained practically intact. These serve to emphasize very forcibly the necessity of having the cut-off wall extend to a sufficient depth. It should also be remembered that the strength of the structure depends primarily on the imbedded steel, which must therefore be fully protected from rust. This can be done only by proper allowance for temperature cracks, by the use of expansion joints, and by using a concrete which will be essentially watertight.

Spillway.—Several types have been developed, depending on the head and on the foundation material. On ledge rock, a spillway section with a complete or part rollway is used when the fall exceeds 10 feet or thereabouts, depending on the quality of the rock surface and its ability to withstand the force of the falling water. On soft material, either a