THE DESIGN OF CANAL DIVERSION WEIRS ON A SAND FOUNDATION.

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Sand is proverbially an unsuitable material on which to found a solid structure of any kind, but, when this structure in addition, acts as a dam in holding up water, nine persons out of ten would consider that its stability under such circumstances was absolutely impossible.

Such, however, is by no means the case and the object of this paper is to show the means adopted to insure the safety of structures such as river weirs, which are not only exposed to undermining by their foundation being washed out by subsoil percolation, but are also subject to the erosive action of the powerful currrent of a river in flood, which completely submerges the whole work. Not having its base resting on solid impervious material as clay or rock, the masonry of which the weir is composed is further subjected to the disability of loss of weight by displacement, which often amounts to one half of its weight in air.

When a dam of earth, as a reservoir embankment, is thrown across the sandy bed of a stream leakage will necessarily take place beneath the base of the dam. With a low level of water in the reservoir this leakage may be quite harmless, that is to say, the percolating water will not carry with it any particles of sand, when, however, the depth of the water in the reservoir, that is, the head acting on the base, is increased, the percolating undercurrent will likewise increase in volume and velocity and will eventually convey particles of sand along with it and so gradually undermine the dam.

The weight of the dam is naturally the same whatever be the depth of water impounded, and further sand is practically imcompressible, consequently the imposed load must be ruled out as a determining factor in this case. The real factor influencing the safety of the work is the length of the enforced percolation, or as it is technically termed the **creep** of the undercurrent, which is clearly identical with the base width of the earthen dam. This length of percolation must naturally be some multiple of the head of water acting on the work, and if we can only find out a safe value for this multiplying co-efficient, suitable to the particular sand under consideration, we shall be enabled to design any structure on a sand foundation with perfect confidence as regards its safety with reference to statical considerations.

An example of the successful construction of a dam on a sand foundation is that of the Amani Shah storage reservoir at Jeypore in India. This dam upholds a depth of over 30 ft. of water. It is built of sand and is founded on pure sand, but its base width is exceptionally great, being over 350 ft., i.e., 12 times the head. The silting up of the river bed, which occurred before the full flood level was reached, increased the effective value of the length of creep by over 100 feet, and thus enabled the work to stand an increased head of 44 feet in perfect safety. This dam is not water-tight and does not pretend to be so, but the visible leakage is unimportant.

The natural question will arise, if this is the case, why are the foundations of bridges over rivers, reservoirs, dams, etc., always carried down to solid rock or clay? The answer is that in these cases it is cheaper to do so. As we shall see later, the correct value of the requisite base width will be from 10 to 20 times the head, consequently in case of a dam 60 ft. high founded on sand, a base width of say $15 \times 60 = 900$ feet would be necessary for safety. Thus it would, as a rule, be more economical to adopt a deep foundation. As regards a river bridge, isolated piers of great depth are generally the only practicable and economical method of construction.

In large rivers the bed of sand is often of great depth, the piers of the Benares Railway Bridge over the Ganges River had to be sunk over a hundred and fifty feet through the sand before clay was met with, consequently for a continuous work, like a river weir, a deep foundation is an economic impossibility.

The definition of the term weir, in contradistinction to that of dam, implies that the river water falls over its crest, whereas in the case of a dam the surplus flood water is conveyed either through the body of the work, as in the case of the Assuan Dam in Egypt, or else its escape is provided for by a specially built waste weir distinct from the dam itself. Weirs built across rivers, with sand beds of great depth, are invariably, what is termed "diversion" weirs, that is to say, their function does not include that of the storage of water, but is limited to the diversion of a portion of the discharge of the river down a canal through an intake; a good example of this is the Calgary canal head in Alberta.

The function of a weir is to raise the water of the river when the latter is at a low level, in order to pass a sufficient supply down the canal. During flood time, or whenever the supply exceeds the demand, the crest is topped and the surplus water follows its course down the river. Owing to the sandy nature of the bed. which in part is carried along in suspension during floods, deposit takes place in rear of the weir almost to crest level, and in some cases even higher, so that during low water there is but a narrow channel from which supply can be drawn. This channel is artificially conserved by the adoption of weir scouring sluices in close proximity to the canal intake. As canals, when on sand, mostly take of at not more than 2 to 5 feet above river bed level, and their full supply depth seldom, if ever, exceeds 10 feet, it is clear that the height of these submerged diversion weirs will not be greater than 15 feet, the general average being 10 or 12 feet. On boulder or clay formations much greater heights are practicable.

A **dam** is subjected solely to hydrostatic pressure, but a **weir** on the other hand has also to withstand the dynamic scouring action of water. The design, however, is mainly influenced by hydrostatic considerations, for which alone precise rules can be framed, with however this proviso that the design of the work must also suit what may be termed the hydrodynamical side of the question.

The following facts may here be noted:

The hydostatic pressure on a weir is greatest when the head water stands exactly at crest level, the river bed being empty below, when this occurs the hydrodynamical forces are nil. Again, when the latter forces are a maximum, i.e., during full flood, the hydrostatical pressure on the weir foundation is at a minimum.

The hydrostatic problem, with water at rest, will first be considered as follows:

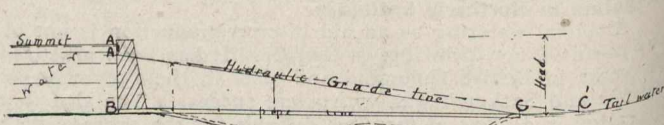

FIG 1

Figure 1 represents a pipe line BC, proceeding from the bottom of a reservoir of water. The original head H is the difference of levels between A, the summit level, and C, the tail water, it being presumed that the outlet at C is free and unrestricted. The line A, C drawn from a point near the summit level to C, is termed the hydraulic gradient, or grade line, and the hydrostatic pressures on the pipe at any point are measured by vertical ordinates drawn up to this line. The distance AA′ is the head due to the uniform velocity of the current in the pipe plus a further small quantity representing loss of head at entry.

This supposes the pipe to be straight or nearly so. If the pipe had vertical projections, and so was sensibly lengthened, the hydraulic gradient would not be A′C but A′C′; BC′ being the sinuous line of pipe stretched out straight.

Fig. 2 represents a simple section for a low masonry weir, built on river sand, supposed, as is usually the case, to be completely submerged during floods. Such a work must necessarily consist of a vertical wall of masonry, or any other material, whose function is to uphold the water, connected

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