The Canadian Engineer

A Weekly Paper for Civil Engineers and Contractors

Effect of Water Uplift on Overturning of Dams

Theory Advanced That Water Pressure Acting Upward Replaces Portion of Foundation Reaction and That Its Overturning Effect Is Annulled by Counter Moment Produced by "Remaining Foundation Reaction"—Effect of Uplift Upon Sliding

By ERWIN MAERKER

Formerly Structural Engineer, Toronto Power Co.

THE method usually followed by engineers engaged in the design of dams (and other structures resisting water pressure), is to add the upward water pressure under a dam to the reaction of the foundation against the base of the dam, causing an additional overturning moment. The writer cannot agree with this theory, and he regards uplift as a force replacing part of the foundation reaction instead of adding to the foundation reaction.

It is not within the scope of this article to determine the amount and distribution of the uplift; that is, whether pressure due to the full head should be allowed at the heel of the dam, or a fraction thereof, or whether the pressure should diminish uniformly to zero at the toe of the dam, or vary according to a parabolic law or otherwise; but the article treats with the effect of the uplift assumed to act on the base of the dam.

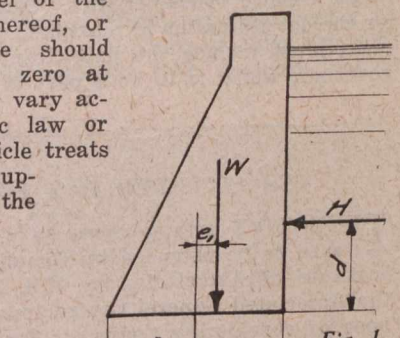


Fig. 1

Assume a block of masonry 20 ft. in height, with base dimensions of 1 by 15 ft., resting on its foundation. With a unit weight of masonry of 150 lbs. per cu. ft., the foundation reaction will be $20 \times 150 = 3{,}000$ lbs. per sq. ft.

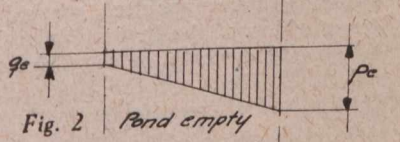


Fig. 2 Pond empty

For the sake of simplicity we will confine ourselves to vertical forces only, and omit horizontal water pressure, without in the least affecting the principle. Assume further a uniform upward water pressure of 1,000 lbs. per sq. ft., corresponding to a head of 16 ft., to act with equal intensity on the base of the block of masonry. Since the weight of the block of masonry produces a downward pressure of 3,000 lbs. per sq. ft. and the upward water pressure is only capable of exerting 1,000 lbs. per sq. ft., it is evident that the foundation reaction still in contact with the base of the block, must exert 2,000 lbs. per sq. ft. By increasing the uplift to 3,000 lbs. per sq. ft., the block will be entirely sustained by the interposed film of water between base of block and its foundation, and the block will be floating.

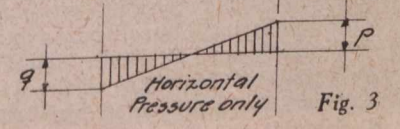


Fig. 3

Fig 5 shows the uplift varying uniformly from 1,000 lbs. per sq. ft. at one extremity of the base to zero at the other extremity. The common error made is to regard the uplift as producing an overturning moment on the block, but the fact that the remaining foundation reaction is also producing an overturning moment counter to the moment of the uplift, is completely lost sight of. The two moments annul each other, and their total upward pressure is 3,000 lbs. per sq. ft., the upward water pressure substituting itself in place of the foundation reaction.

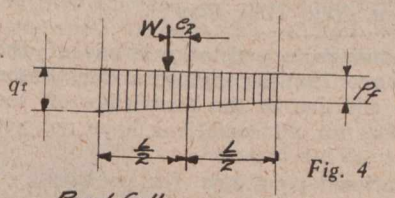
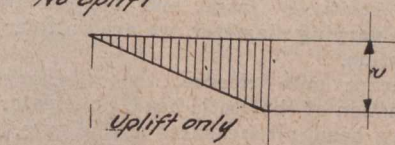


Fig. 4

Pond full, No uplift



Uplift only

Fig. 5

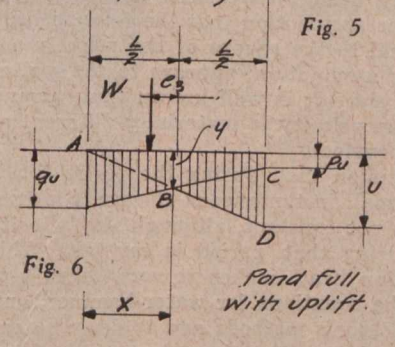


Fig. 6 Pond full with uplift

How the uplift can be regarded as producing an overturning moment, and at the same time the counter-moment of the foundation reaction be wilfully neglected, is beyond the writer's comprehension. It is a case of mechanics, pure and simple.

Lamar Lyndon, in his first volume on "Hydro - Electric Power," speaking of this added overturning moment, writes:—

"How such a weird fancy could have ever obtained the importance of a standard engineering rule of design, is beyond the writer to understand, being contrary to every law of physics, mechanics and common sense."

In case the uplift exceeds the foundation reaction at the heel of the dam, there will be an excess pressure acting upward, and it is this excess pressure only which will have to be considered as producing an overturning moment. The following equations will make this clear:—

Let W = Weight of dam per foot of length.
H = Horizontal water pressure.
L = Length of base.
d = Distance of H above base of dam.
e_1, e_2, e_3 = Eccentricity.
p = Pressure at heel of dam.