HYDRODYNAMIC PRESSURE ON DAMS

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Hydrodynamic pressure on rigid dam has been investigated by Westergaard (1933) and Chopra (1966). For a sinusoidal ground acceleration their approaches do not satisfy the initial condition of zero pressure.

The hydrodynamic pressure at the face of a dam at a depth y measured from bottom for a unit impulse, $p(y,t)$, is (1).

$$p(y,t) = \frac{4\gamma C}{\pi g}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{2n-1}\cos\lambda_n y \; J_0(\lambda_n C t) \qquad \ldots\ldots (1)$$

in which γ is the unit weight of water, C is the pressure wave velocity, g is gravitational acceleration, λ_n is $(2n-1)\pi/(2H)$ where H is the depth of water, J_0 is the bessel function of first kind and zeroth order. Using Eq. 1 for a ground acceleration $A_m t^m$ the hydrodynamic pressure can be expressed as:

$$p_m(y,t) = \frac{4\gamma C\, m!\, A_m}{\pi g}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{2n-1}\cos\lambda_n y\left[t^{m+1} + \sum_{r=1}^{\infty}\frac{(-1)^r\,\Pi(2r-1)}{r!\,(2r)!}\,\omega_n^{2r}\,\frac{t^{2r+m+2}}{(2r+m+2)!}\right] \qquad \ldots\ldots (2)$$

in which ω_n is $\lambda_n C$. Equation 2 can be used to obtain hydrodynamic pressure for ground accelerations expressible as a Taylor Series. For ground acceleration $A_p \cos pt$ the hydrodynamic pressure can be expressed as:

$$p_c(y,t) = \frac{4\gamma C A_p}{\pi g}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{2n-1}\cos\lambda_n y\left[C_0 \sin pt + \sum_{j=0}^{2m} C_{2j+1}\frac{(-1)^{j+1}(pt)^{2j+1}}{(2j+1)!}\right] \qquad \ldots\ldots (3)$$

and for the ground acceleration $A_p \sin pt$ the response is:

$$p_s(y,t) = \frac{4\gamma C A_p}{\pi g}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{2n-1}\cos\lambda_n y\left[-C_0 \cos pt + \sum_{j=0}^{2m} C_{2j}\frac{(-1)^{j+1}(pt)^{2j}}{(2j)!}\right] \qquad \ldots\ldots (4)$$

in which $C_j = \displaystyle\sum_{r=(j/2)^*}^{m}\frac{(2r)!}{(r!)^2\,p^{2r+1}}\left(\frac{\omega_n}{2}\right)^{2r}$

r is the nearest higher integer of $(j/2)^*$ and m is a large number.

It is seen that these expressions satisfy the initial condition of zero pressure. Ground accelerations can be expressed as a Fourier Series and equations 3 and 4 can be used to find hydrodynamic pressure.

REFERENCE

1. Chopra, Anil K., Hydrodynamic Pressure on Dams during Earthquake, Report no. 66-2, Structural Engg. Laboratory, University of California, Berkeley, April, 1966, p. 15.

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DISCUSSION

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The authors should state whether the Fourier Sine Series for any real earthquake converges fast for practical application of the equations proposed by them.

Assuming sinusoidal ground acceleration how the method proposed by the authors compares with the methods of Westergaard and Chopra.

Author's Closure

With regard to the question of Mr. Rao, we wish to state that for ground acceleration A_p Cos pt, the hydrodynamic pressure at the face of the dam as given by Chopra is

$$p_c(y,0) = -\frac{4A_p\gamma}{g\pi}\left[\sin pt\sum_{n=1}^{n_s-1}\frac{(-1)^{n-1}\cos\lambda_n y}{(2n-1)\sqrt{(p^2/c^2)-\lambda_n^2}} + \cos pt\sum_{n=n_s}^{\infty}\frac{(-1)^{n-1}\cos\lambda_n y}{(2n-1)\sqrt{\lambda_n^2-(p^2/c^2)}}\right]$$

which confirms with Westergaard's solution if $\lambda_1^2 > p^2/c^2$. The above expression does not satisfy the initial condition, $p_c(y,0) = 0$, whereas Eq. 3 of the paper satisfies the initial condition.

The ground acceleration contains a wide range of frequencies. For a better representation of accelerogram all the frequencies have to be considered. The convergence of Fourier sine series is therefore not very fast.