I-434 HYDRODYNAMIC PRESSURE GENERATED BY VERTICAL MOTION OF PROPAGATING EARTHQUAKE WAVE

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AIM OF THE STUDY

The hydrodynamic pressure phenomenon has been known and studied for half a century. But, upto now, most of the research was concentrated on horizontal earthquake component, and based on the assumption that earthquake wave reaches at any point of a reservoir simultaneously. The hydrodynamic pressure generated by vertical earthquake component, especially in propagating wave situation is still unsure. In this paper the numerical study is to be done with the Finite Difference Method (FDM) in order to get a better understanding on such problems.

METHOD OF ANALYSIS

Suppose that the vertical velocity of ground motion is $V_g(t)$. In the case of propagating wave, let it be supposed that the earthquake wave travels along the reservoir axis in a constant horizontal velocity U_e. (refer to Fig. 1). Here following three cases will be taken into account:

1. Propagating from dam toward upstream
2. Propagating from upstream toward dam
3. No propagating (uniform input)

In case 1, suppose that the earthquake wave reaches at dam site initially. The time when the wave reaches at point x_i should be later with a lapset of $t_i = x_i/U_e$. According to the relation between the velocity of water particle and the hydrodynamic pressure[1], following equation can be got:

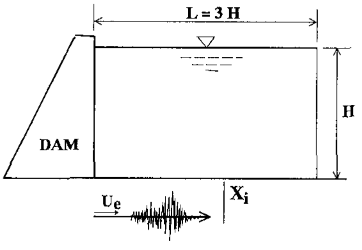

Fig.1 Analysis Model

$$\frac{\partial \Phi}{\partial t} - C_0\beta\left(\frac{\partial \Phi}{\partial n} - V_g(t - \frac{x_i}{U_e})\right) = 0 \qquad (1)$$

In case 2 the term in the above inner brackets will be $t + x_i/U_e$, and in case 3 there will be only t. The discussion on wave equation and other boundary conditions is omitted here.

For water bodies of various depthes, input EL-Centro, Olympia and Taft earthquake waves. The vertical maximum amplitude of ground acceleration is adjusted to 2/3 of the horizontal one.

RESULTS AND CONCLUSIONS

It was found that the propagating direction and velocity U_e have significant effects on the maximum value and distribution of hydrodynamic pressure. Fig. 2 and Fig. 3 show the general distribution of hydrodynamic pressure for the former two cases. In case 2, the maximum value certainly occurs on dam face. But in case 1 the maximum value usually occurs not on the dam face but on a transversal section apart from dam. Fig. 4 shows the effects of propagating velocity and direction on the maximum value of hydrodynamic pressure on the dam face. In case 1 the maximum value will increase monotonously as the propagating velocity gets higher and higher. When the velocity approaches infinite the maximum value will approximate to the value got in case 3. While in case 2 the situation will become more complicated. When the velocity is under a certain value (for ordinary reservoir the value usually is higher than the sound velocity in water) the maximum pressure will increase sharply as the velocity gets higher. But beyond the certain limitation the maximum value will decrease as the velocity increases. Samely as in the first case when the velocity approaches infinite the maximum value will approximate to the value got in case 3. From such observation we can think that the hydrodynamic pressure got in the case of uniform earthquake input is the extreme

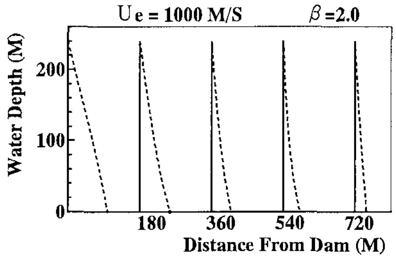

Fig.2 Propagating Toward Dam

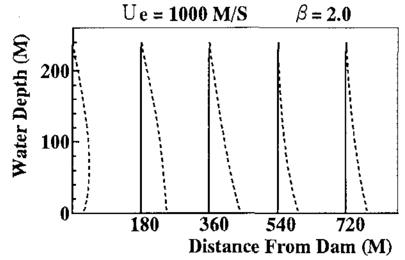

Fig.3 Propagating Apart Dam

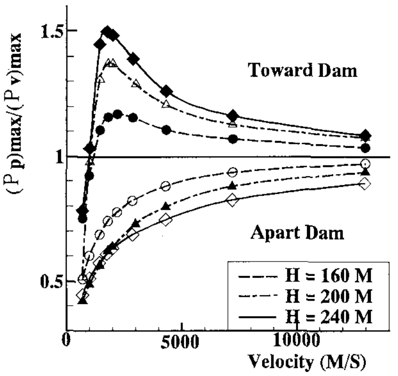

Fig.4 Effect of Wave Velocity

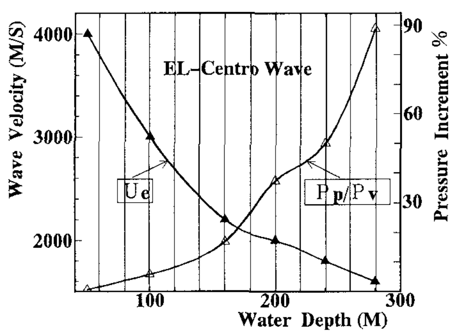

Fig.5 Analysis of Propagating Wave

case. In such extreme case, that is case 3, the maximum value is in a range from 40% (corresponding to deep water, 240 meters or more) to 85% (corresponding to shallow water, about 70 meters) of that got in the horizontal earthquake case. Corresponding to various water depthes, Fig. 5 shows the possible maximum increment and the velocity with which the maximum value occurs. It is clear that the possible maximum increment will increase and the corresponding velocity will decrease as the water gets deeper. When the depth is around 200 meters the two curves are concave-downward slightly. This may be due to that the dominating frequency of EL-Centro earthquake wave is near the resonant frequency of water body of a 200 meter depth.

From above studies following conclusions may be deduced:

1. The effects of the propagating velocity and direction of earthquake wave on hydrodynamic pressure are very significant. For the high dam design this factor should be taken into account, especially for the dams higher than 180 meters.

2. Vertical component of earthquake waves may generate hydrodynamic pressure greatly.

References

[1]. Hatano, T.: "An Examination on the Resonance of Hydrodynamic Pressure During Earthquakes Due to Elasticity of Water",*Trans. Japan Soc. Civil Engrs.*, 129, 1966