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DAM-RESERVOIR INTERACTION INCLUDING THE RESERVOIR BOTTOM EFFECTS IN TIME DOMAIN

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ABSTRACT

Dam-reservoir system subjected to a strong earthquake is likely to behave nonlinear mechanisms such as joint opening or water cavitation, even though the concrete material of dam remain elastic. Therefore, transient analysis of structures interacting with fluid and subjected to earthquake ground motion is necessary for realistic analysis. Estimating hydrodynamic pressures on concrete dams was originated first by Westergaard (1933). By assuming incompressible water, Zangar and Haefei (1952) and Zienkiewicz and Nath (1963) experimentally determined the hydrodynamic pressures on dams. Chopra (1968) reported the effect of water compressibility is significant for seismic response. Later, Saini et al. (1978); Chopra and Chakrabarti (1981); Hall and Chopra (1982), Fenves and Chopra (1985); Lotfi et al. (1987) studied this problem in frequency domain by using finite element method. Finite element time domain analyses were done by Sharan (1987), Tsai et al. (1990). In time domain formulations, researchers used a radiation boundary condition for far end or near end to consider radiating waves.

Another method is added mass approach and it was used by Kuo (1982). In this method, linear and nonlinear response of dam-reservoir interaction is approximated by adding a number of masses to dam equation.

Boundary element method type formulations were implemented by Humar and Jablonski (1988), Medina and Dominguez (1989) in frequency domain. Wept et al. (1988) and Antes and von Estorff (1987) used time domain boundary element formulations.

For linear analysis, frequency domain formulations are simpler but for nonlinear effect of structures it is necessary to develop time domain formulations. Added mass type of formulation can be used for linear and nonlinear analyses but it is not appropriate for cracking problems in the

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dam (Ghaemian and Ghobarah, 1998). Finite element method was used to discretize the fluid domain and far end was modeled by using radiation boundary conditions of Sommerfeld (1949). But, due to approximation made in transmitting boundary, it is necessary to use sufficient amount of elements in the analysis. This causes an increase in cost of time. Direct boundary element formulations may be preferred to reduce the number of unknowns, but for time domain analyses choose of time step, unsymmetrical matrices, presence of convolution integral and singularity of kernels in the formulations which requires large storage space and computing time for the calculation of the past time history are disadvantages of this method.

The absorption of pressure waves at the reservoir bottom is an important factor that may significantly affect the magnitude of the hydrodynamic force on the dam. Fenves and Chopra (1984) investigated the effects of sedimentary material deposited on the reservoir bottom. The study employed an approximate boundary condition to simulate energy absorption into the sediment. It was suggested that the sediment can play a significant role in modulating the response of concrete gravity dams. Lotfi and Tassoulas (1986) modeled the sediment as linearly viscoelastic, nearly incompressible solid. The analysis was based on the finite element method and used hyperelements in which all interactions were taken into account. Medina et al. (1990) carried out calculations using the boundary element method and obtained results similar to those of Lotfi and Tassoulas (1986). Cheng (1986) investigated the effects of poroelastic sediment on the hydrodynamic force on a rigid dam, seated on a half plane viscoelastic foundation. Bougacha and Tassoulas (1991) modeled the sediment material as a poroelastic continuum. The rigorous poroelastic model for the sediment material requires accurate information on the layer characteristics such as material grain size, porosity, degree of saturation and hydraulic conductivity. These details are not readily available for existing structures. Besides these, for compuational point of view, it requires enormous amount of computation.

In this study, dam and reservoir interaction under earthquake ground acceleration is modeled by using finite element method for dam and dual reciprocity boundary element method for reservoir domains (figure 1). For far end of fluid domain is truncated by implementing the Sommerfeld's boundary condition. Finally, for bottom absorption effects, a simple and one dimensional model is used to take into account the effects of sediments.

Keywords: Dam reservoir interaction, finite element method, dual reciprocity boundary element method, truncating boundary, hydrodynamic pressure, transient response of dam; reservoir bottom absorption

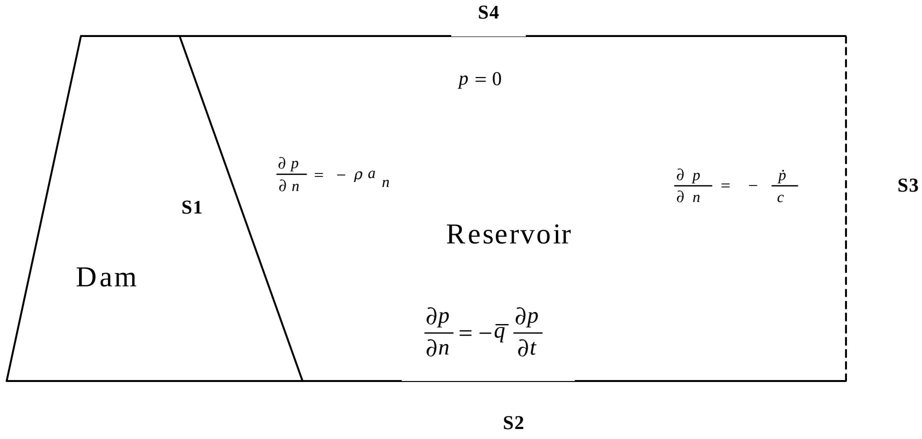

Figure 1. Dam and Reservoir

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