Dynamic Behaviour of Sediment Deposits in Front of Concrete Gravity Dams

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Abstract

Analysis of dams is a complex problem due to the dam-reservoir-sediment interaction. An important factor in the design of dams in seismic regions is the effect of bottom sediment forces on the face of the dam as a result of earthquake ground motions. For an accurate analysis of resultant sediment forces on the dam, the sediment is represented in a fluid-filled porous solid on the basis of the Biot theory. In Biot formulation, the equations of motion of the soil mixture are coupled with the global mass balance equations to describe the realistic behavior of sediment. Because of irregular geometry, the sediment is generally treated as an assemblage of finite elements. The weighted residual standard Galerkin method with 8-node elements is used for developing finite element code. The analysis is carried out in time domain considering earthquake excitation. Newmark time integration scheme is developed to solve the time-discretized problem which is an unconditionally stable implicit method. Finally, the seismic behavior of sediment due to ground motion is investigated.

Keywords: Gravity dam, sediment, finite element, earthquake, interaction

1. INTRODUCTION

Current interest in geomechanics is focused on the transient phenomena occurring during earthquakes and consolidation. Since saturated soil consists of a portion of space occupied partly by a solid phase and partly by a void space filled with fluid, it must be treated as a two-phase porous medium. The mechanical behavior of the saturated sediment is governed mainly by the interaction of the solid skeleton with the fluid. However this interaction is particularly strong in dynamic problems, for example earthquakes. The dynamic response of fluid-saturated soil during earthquakes has been extensively studied in recent years. The investigation of wave motion in fluid-saturated porous media is attracting more attention because of its significance in a great number of practical engineering problems such as dynamic analysis of dams. A porous medium is an assemblage of the solid particles forming a skeleton whose voids are filled with fluid. The analysis of sediment requires a rigorous procedure that can properly characterize the interactions. The first continuum theory of porous media was developed by Biot and used to describe the behavior of soil saturated by a fluid [1, 2]. This theory was later generalized to determine the finite deformations of saturated porous media [3, 4].

At a later stage the mixture theory restricted by the volume fraction concept provided a new basis for such coupled phenomena. A survey of the historical development of the porous media theory and a discussion of inconsistencies implicit in the mixture theory has recently been given by Prevost [5]. Most of the problems of the two-phase behavior of a fluid-saturated porous soil can only be predicted quantitatively by elaborate numerical computation, which is possible today due to the development of powerful computers. Only a few analytical solutions are available. These analytical solutions have been used to verify the numerical results based on the same theory in a former investigation. Many investigations, based on different theories, are made in this field, for example by Prevost [6].

In this paper, the governing equations of motion of the soil mixture are coupled with the global mass balance equations and necessary assumptions are made to obtain the equivalent Biot’s equations from the general balance equations. The $\mathbf{u}_i - P - \mathbf{u}_j$ discretization formulation is used in the finite element spatial,