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The effect of concrete slab–rockfill interface behavior on the earthquake performance of a CFR dam

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ABSTRACT

Earthquake response of the concrete slab is mostly depended upon its conjunction with rockfill. This study aims to reveal the effect of concrete slab–rockfill interface behavior on the earthquake performance of a concrete-faced rockfill dam considering friction contact and welded contact. Friction contact is provided by using interface elements with five numbers of shear stiffness values. 2D finite element model of Torul concrete-faced rockfill dam is used for this purpose. Linear and materially non-linear time-history analyses considering dam–reservoir interaction are performed using ANSYS. Reservoir water is modeled using fluid finite elements by the Lagrangian approach. The Drucker–Prager model is preferred for concrete slab and rockfill in non-linear analyses. Horizontal component of 1992 Erzincan earthquake with peak ground acceleration of 0.515*g* is used in analyses. The maximum and minimum displacements and principal stresses are shown by the height of the concrete slab and earthquake performance of the dam is investigated considering different joint conditions for empty and full reservoir cases. In addition, potential damage situations of concrete slab are evaluated.

1. Introduction

Concrete-faced rockfill (CFR) dams are considered to be safe under seismic excitations because of two following origins [1]. First, porewater development and strength descent do not occur because the entire CFR dam embankment is waterless during an earthquake. Second, CFR dams provide more stability with their whole rockfill mass than earth core rockfill (ECR) dams, since CFR dams do not permit water to penetrate inside the dam on the other hand only downstream rockfill mass of the ECR dams may resist for stability under seismic excitations.

CFR dams involve fluid–structure interaction problems. Hydrodynamic pressures resulted from earthquakes considerably affect dynamic response of dams. The hydrodynamic pressure effects on dynamic response of dams have been started to be researched in the 1930s [2–4]. Dynamic response of dam–reservoir systems using the Eulerian and the Lagrangian approaches has been investigated by many researchers [5–14]. In the last years, Bayraktar et al. [13–15] paid attention on hydrodynamic pressures on concrete slab of CFR dams.

Earthquake analysis of CFR dams subjected to strong ground motion was carried out and published in the literature by various researchers [1,13–22]. In addition, a new approach based on scaled boundary-finite element method was used to obtain scattered motion along a prismatic canyon with trapezoidal cross section [23]. The authors performed three-dimensional dynamic analysis of a typical CFR dam including dam-face slab–abutments interaction using scaled boundary-finite element method. Ghannad [24] performed numerical (finite element method) and analytical analyses of a CFR dam, which is located in a high seismicity region of Iran, and compared the results. The effect of non-linearity and time-dependent deformation on the separation of the concrete slab from the cushion layer was examined using contact analysis method [25]. Beyond these studies, there is limited research related to earthquake performance of CFR dams. Particularly, performance analysis of a CFR dam including dam–reservoir interaction and slippage–separation in concrete slab–rockfill interface is rarely seen in the literature.

Interface elements have a wide range of use to describe the interaction between different media [26–31]. Various researchers investigated discrete joints in non-linear analyses [32–38]. Interface elements were used to determine the effect of discontinuities on the response of circular tunnels established in layered geological media by Lee and Zaman [39]. The seismic response of rigid highway bridge abutments, retaining and founded on dry sand was examined considering sliding and debonding/recontact between the wall and the soil [40]. Toki et al. [41,42] used joint elements for dynamic analysis of soil–structure interaction systems to simulate time-dependent sliding and separation along the soil–structure interface. The interface behavior in reinforced

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