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Three-dimensional nonlinear seismic analysis of concrete faced rockfill dams subjected to scattered P, SV, and SH waves considering the dam–foundation interaction effects

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ABSTRACT

In this study, the nonlinear seismic analysis of a typical three-dimensional concrete faced rockfill dam is reported. Three components of the Loma Prieta (Gilroy 1 station) earthquake acceleration time history are used as input excitation. The dam under study is considered as if it were located in a prismatic canyon with a trapezoidal cross-section. A nonlinear model for the rockfill material is used, and contact elements with Coulomb friction law are utilized at the slab–rockfill interface. Vertical joints in the face slab are also considered in the finite element model. A substructure method, in which the unbounded soil is modelled by the scaled boundary finite element method (SBFEM), is used to obtain the scattered motion and interaction forces along the canyon. The dam is subjected to spatially variable P, SV, and SH waves, and the effect of dam–foundation interaction and the reservoir water effects are considered. The results are compared with the non-scattered input motion analysis. Results of the analyses indicate that due to applying the scattered motion to the canyon the response of the dam and concrete face slab significantly increases. The reservoir water pressure affects the tensile stresses induced in the face slab by reducing the uplift movement of the concrete panels.

Large horizontal axial forces are induced in the face slab due to out-of-phase and out-of-plane motions of the abutments. Although the normal movements of vertical joints are reduced due to the reservoir water confinement, the opening movements are still significant, and the local failure of construction joints is inevitable.

1. Introduction

The number of concrete faced rockfill (CFR) dams under design and construction is increasing in many parts of the world. Complete usage of local embankment materials, simple construction methods and short construction duration are some advantages of CFR dams. CFR dams are inherently safer than other types of dams, as the earthquake ground motion cannot lead to pore-water pressure buildup and strength reduction [29].

The performance of CFRDs under static loading conditions is well known, while static analysis of this type of dam can be carried out in a similar way to that of other types of earth and rockfill dams. Static design of CFR dams can be verified by available data from existing dams [20,18,24]. Seismic analysis of CFR dams in strong ground motion has been studied and published in the literature by various researchers [28,7,29,16,10,33,34,15,17,12]. The above studies indicate that the rockfill dam body is safe enough under strong earthquake conditions. However, damage can occur in the concrete slab due to the high axial forces and/or the repeated uplift and downfall of the slab on the dam body.

In addition, Bayraktar and Kartal [4] recently performed a series of 2D finite element analyses of Torul CFR dam considering dam–reservoir interaction. The horizontal component of 1992 Erizincan Earthquake was used in these analyses. The linear and nonlinear response of the dam in seismic excitation, and the effect of reservoir water were investigated. Bayraktar et al. [5] used the same model this time to study the effect of concrete slab–rockfill interface behaviour considering both friction and welded contacts. In the same direction, Kartal et al. [21] investigated the failure probability of the concrete slab on CFR dams with welded and friction contact under earthquake effects by the reliability analysis. They used the same model reported by Bayraktar et al. [4] considering the deconvolution of the free-field surface record to obtain the ground motion for the foundation base rock. In their study, the probability of failure of the most critical points in the concrete slab was obtained regarding various slab thicknesses.

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