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Seismic behaviors of earth-core and concrete-faced rock-fill dams by dynamic centrifuge tests

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ABSTRACT

The investigation on the seismic behavior of dams becomes crucial but is limited to lack of experimental or field data. This paper aims to experimentally simulate two major dam types of earth-core rock-fill dam and concrete-faced rock-fill dam by dynamic centrifuge tests to investigate the seismic response of the dam. A series of staged centrifuge tests was performed by applying real earthquake records from 0.05 to 0.5*g*. The distributions of amplification ratio differed depending on the magnitude of earthquake loading and the zoning condition. The amplification ratio at the crest increased in the bedrock acceleration that exceeds 0.3*g* and strongly influenced by the loosening behavior of the upper part. The residual settlements and horizontal displacement at the dam crest were small. Shallow surface sliding was dominant failure. The maximum tensile stress on the face slab by dynamic loading occurred at a height of around 4/5 near the upstream water level. Finally, two-dimensional numerical simulations were performed in an effort to simulate the centrifuge models. The centrifuge tests and numerical analysis obtained mostly comparable results, thus confirming that centrifuge modeling reasonably simulates the seismic behavior of dams.

1. Introduction

Over the past few decades, large number of ECRDs (earth-core rock-fill dams) and CFRDs (concrete-faced rock-fill dams) have been constructed and utilized throughout the world. These dams have been exposed in danger with recent strong earthquakes in many seismic regions, including Chile, Japan and China. In this region, damage to these dams has also been reported but most of them are manageable [1–5]. However, the potential risk of seismic consequence still has aroused public deep concerns because the failure of dam can become critical threat to public safety, causing much attention to the seismic safety of dams.

The dynamic response is one of the most important factors for the seismic safety of the dam. ECRD consists of permeable rock-fill zones and a very low permeable clayey core zone, whereas the main body of the CFRD consists of mostly rock material and reinforced concrete face slab on upstream slope for waterproofing. This different zoning and composition influence the seismic response of the dam, including the amplification characteristics, deformation of the dam, and stress on the concrete face slab. Evaluations of seismic behavior of dam have relied mostly on theoretical and numerical analyses [6–8]. However, the seismic behavior of dams still remains not well understood.

Since around 1980 with the development of the in-flight shaking table for use with geotechnical centrifuge equipment, there has been a considerably strong renewal interest in centrifuge modeling of dynamic problems. Because centrifuge modeling can reproduce in-situ stress conditions, which is most important in the simulation of the soil behavior in a small-scale model, this method has become a very useful tool to investigate the reliable behavior of geotechnical system during earthquake loading. Many centrifuge model tests have been conducted to investigate the behavior of dams under seismic conditions. Ng et al. [9] performed centrifuge model tests on loose fill embankments to investigate its dynamic response and liquefaction when subjected to a uni-axial and bi-axial earthquake. Sharp and Adalier [10] simulated a zoned earth embankment sitting on a foundation with a loose liquefiable layer. Peiris et al. [11] investigated the failure mechanism of rock-fill or rubble embankments when the foundation soil is liquefied. The dynamic behavior of an asphalt core dam was studied with centrifuge model tests [12]. Although numerous dynamic centrifuge model tests have been conducted, most previous studies used sinusoidal vibration for input motion instead of real earthquake records. Moreover, they focused on the liquefaction problem. The amplification characteristics of the acceleration, the deformation of the embankment, and the stress

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