Soil Dynamics and Earthquake Engineering 31 (2011) 33–44

Contents lists available at ScienceDirect

Soil Dynamics and Earthquake Engineering

journal homepage: www.elsevier.com/locate/soildyn

Investigation of damping in arch dam-water-foundation rock system of Mauvoisin arch dam

Jin-Ting Wang *

State Key Laboratory of Hydroscience and Engineering, Tsinghua University, Beijing, China

ARTICLE INFO

Article history:
Received 27 April 2010
Received in revised form
29 July 2010
Accepted 20 August 2010

ABSTRACT

The overall damping of linear arch dam-water-foundation rock systems depends on the material damping of dam concrete, the material and radiation damping of semi-unbounded foundation rock, and the dam-water interaction. In this paper, the effective damping ratio of these factors is separately evaluated for Mauvoisin arch dam in Switzerland to quantitatively discuss their contributions, and to guide the damping selection in the numerical analysis. This paper also aims to investigate if the material and radiation damping of the foundation rock can be replaced by increasing the material damping of the dam to simplify numerical analysis models. The seismic responses of Mauvoisin arch dam are analyzed using the semi-unbounded and massless foundation models, respectively. The results show that the overall effective damping ratio of the system can be approximately expressed as the summation of the individual effective damping and thus the increased material damping of the dam can approximate the material and radiation damping of the semi-unbounded foundation rock.

1. Introduction

Damping evaluation is essential for the earthquake design of new dams and the earthquake safety assessment of existing dams. In engineering practice, the damping of arch dams is commonly determined by the field forced vibration test [1–7], the ambient vibration test [5,6], and the earthquake events [4,7]. The measured or recorded response includes all energy dissipation sources of the arch dam-water-foundation rock system, and thus the identified damping ratio is the overall damping ratio. However, in the numerical modeling of arch dams, damping is defined by separately selecting the material damping ratio of dam concrete and foundation rock [8,9], which is not consistent with the identified damping ratio. Investigating the material damping ratio selection of dam concrete and foundation rock to match the identified overall damping of the system is therefore necessary. To this end, this paper focuses on the damping property of arch dam-water-foundation rock systems.

Generally, the damping of an arch dam-water-foundation rock system depends on the following factors [8]: the material damping of dam concrete, the material and radiation damping of semi-unbounded foundation rock, the dam-water interaction, and the reservoir bottom absorption of impounded water. Tan and Chopra [8] discussed detailedly the effects of dam-foundation rock interaction and dam-water interaction on the frequency response functions of arch dams. This paper emphasizes the separate contribution of the aforementioned factors to the overall damping of the system. The effective damping ratio resulted from each factor is investigated based on the complex response function of the system.

This paper also aims to investigate if the material and radiation damping from the semi-unbounded foundation rock can be approximately replaced by the increased material damping of dam concrete. If this is the case, the seismic analysis of arch dam-water-foundation rock system can be greatly simplified using the widely-used massless foundation model.

The 250 m high Mauvoisin arch dam in Switzerland (Fig. 1) is selected for this investigation because its dynamic characteristics have already been measured and analyzed extensively by researchers [9–11]. The base of the dam is at El. 1726 m above sea level and its crest is at El. 1976 m. The dam is composed of 28 blocks for a total crest length of 520 m. The thickness of the crown cantilever varies from 53.5 m at the base to 12 m at the crest.

The response of this selected arch dam to harmonic ground motions in the upstream, vertical, and cross-stream directions are determined by the analysis procedure recently developed by Wang and Chopra [12] for a wide range of important parameters characterizing the properties of the dam, foundation rock, impounded water, and reservoir boundary absorption. The effective damping ratio is evaluated based on the complex response function. The seismic response of the Mauvoisin arch dam due to non-uniform ground motion is further computed with two foundation models: the semi-unbounded mass foundation and the massless foundation. The semi-unbounded mass foundation model considers both the foundation flexibility and inertia, while the massless foundation model considers only the foundation flexibility. However, the material damping of the dam is increased for the massless

* Tel.: +8610 62783165; fax: +8610 62782159.
E-mail address: wangjt@tsinghua.edu.cn

0267-7261/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.soildyn.2010.08.002