PASSIVE CONTROL OF SEISMICALLY ACTIVATED ARCH DAMS WITH MULTIPLE TUNED LIQUID COLUMN GAS DAMPERS (TLCGDS)

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Increasing the structural damping of arch dams in the lower frequency range by means of several tuned liquid column gas dampers (TLCGD) built-in at the crown is made evident in this paper.

The arch dam discretized on the basis of the finite element method. By the truncated modal analysis of the dam, the first J≤10 vibration modes are estimated and the natural frequencies and mode shapes are defined (Zienkiewicz and Taylor, 2000). In each mode, the nodes with maximum relative displacements in the cross section of the dam on the level of the uplift is determined within the numerical program ANSYS. The locations of these nodes are determined with respect to the fixed global coordinate system of the dam.

The control forces of the TLCGDs are defined by conservation of the momentum of the instantly displaced fluid mass in the piping system (Chuan and Ziegler, 2009). The absolute acceleration of the center of mass of the fluid (commonly water) is to be considered.

The equation of motion of the coupled system is approximately analyzed by substructure synthesis (Den Hartog, 1956; Soong and Dargush, 1977). The light modal damping of the free standing dam is neglected. For dynamic analysis of the coupled system during the seismic strong motion phase, modal synthesis is applied for the case of empty reservoir (i.e. at low water level) to preserve the integrity of the dam in that critical situation (Editura Academiei, 1977). Hence, neither the hydrostatic pressure nor the hydrodynamic effects in the reservoir are considered, and thus the radiation damping into the water is absent.

The equation of motion of an incompressible liquid in the rigid and sealed piping system moving with the dam is described with regard to the piston theory of relative flow by a generalized (non-stationary) Bernoulli-type equation with quasi-static gas compression taken into account (Ziegler, 1995; Ziegler, 2008).

The substructure synthesis of the coupled system is (approximately) studied and the equations of motion are given in matrix form. By transferring the problem setting into state space and following a standard optimization procedure (fminsearch of Matlab), the optimal parameters of TLCGDs (eigen frequency and damping) are defined (Hochrainer and Ziegler, 2006). Conclusions of this research are as follows:

- The response analysis of the coupled system shows the effectiveness of the absorbers for decreasing the deformations of the dam under severe seismic excitation;
- Upgrading the structural damping of existing arch dams, by proposing passive TLCGDs to be coupled as seismic passive vibration control system;
- Modal analysis synthesis of the coupled system for several vibration modes is presented and the procedures of optimization, including fine-tuning of TLCGDs are described;
- Modally equation of the coupled system of dam with TLCGDs for several modes is expressed and the elements of state space are presented.

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