Frequency Response of Soil-Structure Interaction for Concrete Gravity Dams

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Abstract

Seismic evaluation of existing dams is a major issue that has been even more highlighted by the recent events in Italy. In this regard, researchers and engineers need a reliable and quick tool to assess the complex behaviour of the structure - fluid - soil system. In this paper the soil-structure interaction for concrete gravity dams is considered, investigating its effect on the dynamic response of the system under earthquake excitation.
The COMSOL® model is able to effectively perform a coupled 2D study in the frequency domain by using both Solid Mechanics and Acoustic modules. In order to estimate the equivalent viscous damping provided by the radial damping for a simplified model, three plane models have been analysed: the dam only on a rigid base, the "massless soil" model, commonly adopted in literature, and the infinite terrain model. In each model the reservoir is implemented both with the simplified added mass approach, proposed by Westergaard (1933), and with the full acoustic coupling. The goal of the simulation is to estimate the amount of energy dispersed through the surrounding endless boundary.
The Perfectly Matched Layern (PML) functionality implemented in COMSOL Multiphysics® is used to simulate the unboundedness of the terrain half-space. In order to make the models comparable, the same horizontal harmonic acceleration has to be imposed at the base of the dam in the three cases. Unfortunately, the application of PMLs on the exterior boundaries of the infinite terrain model makes them no longer available for a displacement condition to be effectively applied. Similarly, by applying the displacement condition to the interface between the PML domain and the ordinary domain, the outgoing waves are blocked.
This problem is overcome by the "global equation" functionality. In particular, leaving the displacement unconstrained, a distributed force load was applied at the PML interface, whose value was "tuned", frequency by frequency, by a global equation, enforcing an average unit acceleration condition at the dam base.
The base shear frequency response curve was obtained for the three models showing the effect of terrain deformability: the massless model displays a frequency shift to lower values and the introduction of a spurious resonance peak that depends on the terrain domain size; the infinite terrain model, on the other hand, also displays a downward frequency shift but with a noticeable reduction of the peak response, indicating an effective radiation damping of the terrain.
As a last step, a parametric study was conducted, modifying the relative density and stiffness of the terrain: it can be shown that a density increase produces a sharpening of the resonant peak, without affecting its frequency, while a higher stiffness produces both

an amplification and an upward frequency shift of the resonance, with the rigid base model as limit case.
The frequency response analysis allows to estimate an equivalent damping to be used in further simplified analyses and to define a meaningful damping factor to be used in standard response spectrum analyses according to Standard Codes (Eurocode 8, Italian "Norme Tecniche per le Costruzioni").

Figures used in the abstract

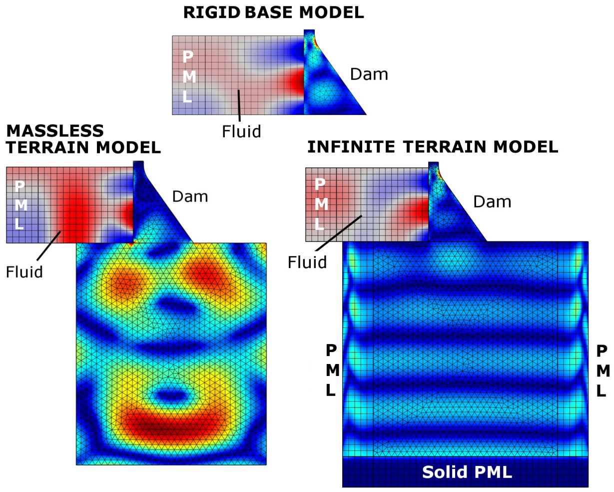

Figure 1: The three dam-soil models, stress and pressure under harmonic base excitation.