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Review Article

Reviewing methods of analysis and evaluation of seismic safety of arched concrete dams

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Extended Abstract

Introduction

Concrete arch dams are three-dimensional structures that transfer the hydrostatic pressure of the reservoir to their rock abutments through their unique shell-like geometry. In addition to self-weight, hydrostatic pressure, and thermal stresses, these dams must withstand dynamic forces induced by earthquakes. During seismic events, nonlinear behavior may occur due to the opening of contraction joints, cracking, crushing of concrete, or nonlinear material behavior. Traditional dynamic time-history analyses, assuming the dam as a monolithic elastic structure, often predict significant tensile arch stresses in the upper sections of the dam, which do not align with real-world observations. Since arch dams are constructed as cantilever blocks, the opening and closing of contraction joints during earthquakes redistribute internal forces from arch action to cantilever action, reducing tensile stresses and dissipating energy. This study investigates the seismic behavior of concrete arch dams, focusing on the effects of contraction joints and nonlinear material behavior.

Materials and Method

The study employs advanced numerical modeling techniques to analyze the seismic response of concrete arch dams. The finite element method (FEM) is used to model the dam-reservoir-foundation system, incorporating nonlinear behavior of contraction joints and concrete. The dam is discretized using solid elements, while the reservoir is modeled using fluid elements to account for hydrodynamic effects. Contraction joints are simulated using interface elements capable of capturing opening, closing, and sliding behaviors. The analysis considers various seismic loading scenarios, including near-fault and far-field ground motions, to evaluate the dam's response under different conditions. Key parameters such as joint stiffness, friction coefficients, and concrete tensile strength are varied to assess their influence on the dam's seismic performance.

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Results and Discussion

The results demonstrate that the opening of contraction joints significantly reduces tensile arch stresses in the upper sections of the dam. During seismic events, the redistribution of forces from arch action to cantilever action leads to a decrease in tensile stresses and an increase in compressive stresses at the joint interfaces. The energy dissipation due to joint opening and sliding contributes to the overall stability of the dam. The study also highlights the importance of joint stiffness and friction coefficients in controlling the dam's seismic response. Higher joint stiffness results in greater stress concentrations, while lower stiffness allows for more energy dissipation through joint movement. The analysis reveals that the dam's response is highly sensitive to the characteristics of the input ground motion, with near-fault earthquakes inducing more severe nonlinear behavior compared to far-field events.

Conclusion

The study concludes that the nonlinear behavior of contraction joints plays a critical role in the seismic performance of concrete arch dams. The opening and sliding of joints reduce tensile stresses and dissipate energy, enhancing the dam's ability to withstand seismic forces. The findings emphasize the need for accurate modeling of joint behavior in seismic analyses to ensure the safety and stability of arch dams. Future research should focus on refining joint models, investigating the effects of near-fault ground motions, and exploring the influence of material nonlinearity on the dam's response. These advancements will contribute to improved design and assessment practices for concrete arch dams in seismic regions.

Keywords*:* Seismic analysis, Arched concrete dam, Contraction seams, Earthquake