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Dynamic analysis of concrete gravity dams considering the effects of Dam – Foundation Contact Conditions

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Dynamic analysis of concrete gravity dams considering the effects of Dam–Foundation Contact Conditions

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ABSTRACT

The stability evaluation of the dams subjected to seismic excitations is really very complex as the earthquake response of the concrete gravity dam depends upon its connection joints with foundation rock. This study presents the seismic response of concrete gravity dams considering welded contact and friction contact and along dam-foundation rock interface. Friction contact is provided using contact elements. Two-dimensional finite element model of OuedFodda concrete gravity dam, located in Chlef at the northwestern part of Algeria, is used for this purpose. Nonlinear analyses of dam-foundation rock system are performed using ANSYS software. The reservoir water is modeled as added mass using the Westergaard approach. The Druker-Prager model is employed in the nonlinear analysis for dam concrete. The surface-to-surface contact elements based on the Coulomb's friction law are used to describe the friction. These contact elements use a target surface and a contact surface to form a contact pair. According to this study, when the friction contact is considered in joints, sliding displacement of dam base occurs along the dam-foundation rock interface. The dam sliding along its foundation decreases the deformation response; principal stresses in the dam body and shear force at both the heel and toe of the dam.

Keywords: *Concrete gravity dam, Dynamic dam-foundation rock interaction, Friction contact, Sliding, Finite element method.*

Dynamic analysis of concrete gravity dams considering the effects of Dam – Foundation Contact Conditions

Introduction

Classic approaches for evaluating the safety of gravity dams were based upon the welded contact that supposes common nodes in the dam-foundation contact interface.

This paper shows the effect of contact friction along the dam-foundation rock interface on the earthquake response of concrete gravity dams. The OuedFodda dam is taken into account in the numerical analyses. For this purpose, two-dimensional finite element model of dam-foundation rock system is employed. The hydrodynamic pressure of the reservoir water is modeled utilizing the added mass concept. In the nonlinear analysis, the Druker-Prager model is used for dam concrete. Welded and friction contact are considered in the joints along dam-foundation rock interface. Surface-to-surface contact elements based on the Coulomb's friction law are used to describe friction using ANSYS software .

Numerical Models

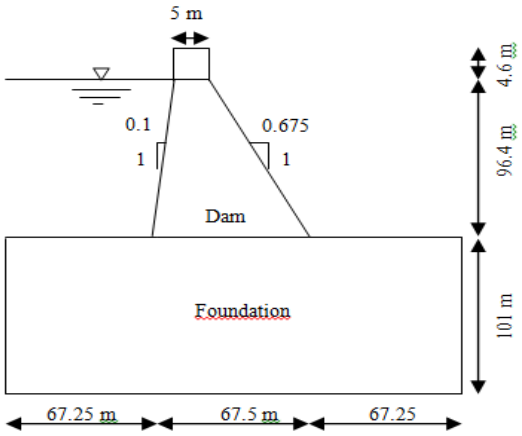

Fig. 1. Geometry of dam-foundation rock system

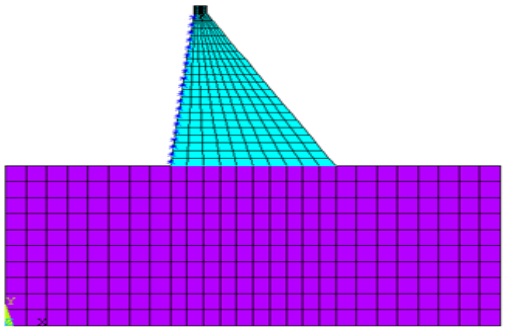

Fig. 2. Finite element discretization of dam-foundation system

Table 1. Material properties of Oued Fodda concrete gravity dam

Material	Material Properties		
	Modulus of Elasticity (MPa)	Poisson's Ratio	Mass Density (kg/m^3)
Dam	24600	0.20	2640
Foundation	20000	0.33	2000
Reservoir water	2070	0.49	1000

This study considers two-dimensional finite element model of OuedFodda concrete gravity dam . The effect of hydrodynamic pressure is incorporated by the added mass concept .The solid finite elements (Plane 82) are used to model the dam and the foundation rock; the structural mass finite elements (Mass 21) are used to model reservoir water. These contact elements use a target surface (Targe169) and a contact surface (Conta172) to form a contact pair. .

Results and Discussion

The horizontal component of the 1980 El Asnam earthquake acceleration scaled by factor of 2.5 is utilized in analyses (Fig.3). The linear and nonlinear time history analyses are performed using ANSYS.

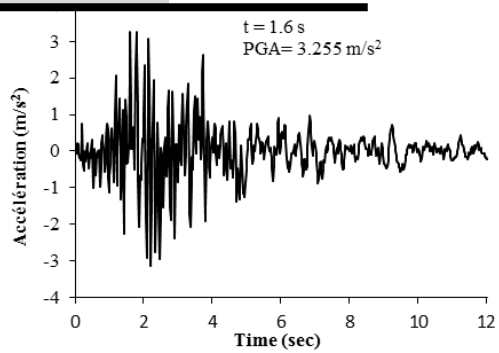

Fig. 3 Time history of horizontal acceleration for 1980 El Asnam earthquake record scaled by factor of 2.5

Displacements

The the time history of horizontal displacement at the dam crest for both two models. The horizontal displacement at the crest decreases from 3.82 cm for welded contact model to 3.35 cm for friction contact model. On the other hand, the time history of sliding displacement at the dam heel is depicted in Fig. 7. The sliding displacement at the heel is negligible (0.32 cm) for welded contact model, while this is 3.23 cm for friction contact model due to existence of contraction joints along dam-foundation rock interface decreasing the contact zone rigidity.

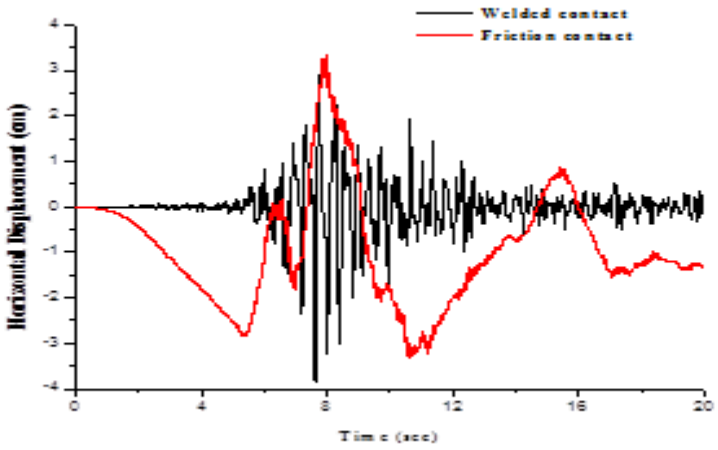

Fig.4 Time history of horizontal displacement at dam crest for welded and friction contact models

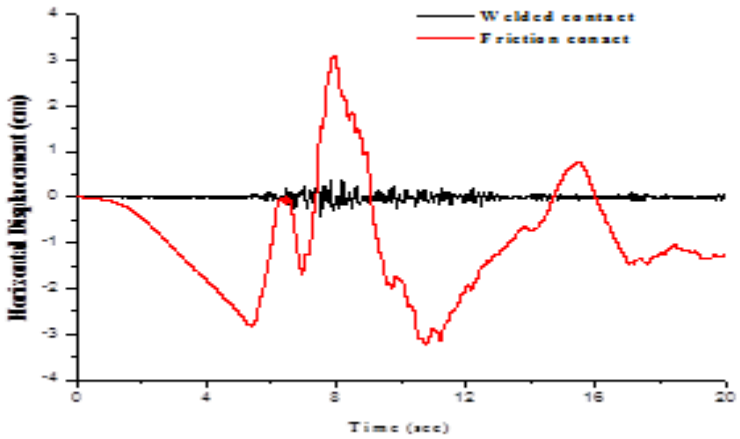

Fig. 5 Time history of sliding displacement at dam heel for welded and friction contact models

Stresses

Fig. 6 illustrates the time history of principal stresses at the dam heel for both two models. Principal tensile and compressive stresses reduce from 2742.73 and -2828.33 KN/m ^{2} for welded contact model to 505.08 and -566.04 KN/m ^{2} for friction contact model.

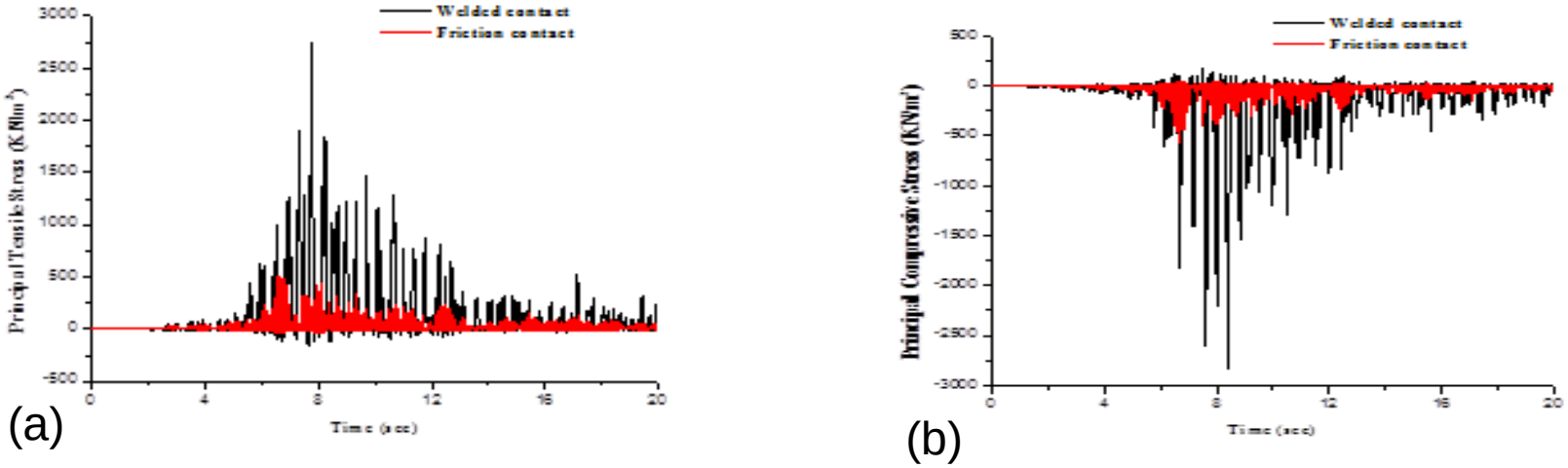

Fig. 6 Time history of principal stresses at dam heel (a) principal tensile stress; and (b) principal compressive stress

Conclusion

This work presents the seismic response analysis of concrete gravity dams considering base sliding.

The results of analyses show a reduction in the deformation response, principal stresses and shear force at the heel and toe of the dam when the dam is able to slide along dam- foundation rock interface.

The dam sliding can be verfied by providing the maximum friction stress at the dam base. Therefore, it is noted that the dam comports much better if it is permited to slide moderately along its foundation as sliding displacement decreases the stresses in the dam body.

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