I-564 STABILITY ASSESSMENT OF EMBANKMENT DAMS ON THE BASIS OF THE PERMANENT SEISMIC INDUCED DEFORMATIONS

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INTRODUCTION

Permanent seismic-induced deformations represents an important factor that should be accounted when designing earth and rockfill dams, moreover, the reasons for limiting deformations in embankment dams varies from functional to operational and even aesthetics requeriments, so that, the main objective of the present investigation was the stability assessment of embankment dams in terms of the seismic induced deformations. To accomplish this purpose model and numerical experiments were performed in the course of the present study.

METHOD OF THE EXPERIMENTS

Dynamic failure tests, have been conducted to experimentally evaluate the behavior and failure patterns of embankment models due to dynamic loading [1]. The objective model of the dynamic failure tests was homogeneous, symmetric, triangular in shape and with a height of 50 cm and slopes 1:2. The material used to built the models was those of Gifu Sand. In order to measure the vibration in the horizontal direction of each model, 6 acceleration meters were arranged in the model, besides 3 thin metal plates pasted by paper gages were fixed in the model, to catch the beginning of slide, Fig. 1. In the dynamic failure tests the models were excited on a shaking table applying the selected base motion (sine waves), of which frequency was kept constant and its intensity was increased gradually until the model failure has occurred.

EXPERIMENTAL RESULTS

From the experimental results following can be said: (a) the embankment models can withstand large accelerations and no catastrophic failure was observed, (b) failure zones appeared at almost same places and their configurations are similar to each other in spite of the difference of frequency of base motions, though these areas are slightly different, (c) the relative displacements of particles were shortest at the surface and increase with depth. Fig. 2 presents the typical profile of the models once failure has been occurred.

NUMERICAL INVESTIGATION

To perform the numerical simulation of above mentioned tests, the models were idealized as an assemblage of finite elements, and then the equivalent linearlization technique was used to evaluate the response of models due to the simulated earthquakes. The stability of the models was evaluated by using the so-called Watanabe's Method [2]. Because of its capital importance whitin the present research, an outline of the method is given in following lines: (a) A proper dynamic response analysis is carried out to obtain the response acceleration and dynamic shear stresses time histories of the FEM model of the dam. (b) The potential sliding surfaces are investigated on the basis of each element's shear stress. (c) With the response acceleration at every moment acting on a potential sliding circle, the equivalent instantaneous seismic coefficient is defined as

$$k_e=\iint_c \rho a\,dxdy/g\iint_c \rho\,dxdy \qquad (1)$$

where a : response acceleration on any point in the sliding mass, ρ : density and g : acceleration of gravity. Eq. (1) times g is a ratio of the integrated inertia force over the sliding mass to its total weight. The yielding acceleration corresponding to the resisting force is given below in the form of seismic coefficient

$$k_y=FS(k_e)+(FS-1)\tan\beta \qquad (2)$$

here β : the angle between the radius of the sliding circle passing through its CG and the vertical and FS is the dynamic safety factor given by

$$FS=\Sigma\tau_{ri}l_i/\Sigma\tau_i l_i \tag{3}$$

where l_i : length of the line cut out by the i-th element. On these basis the permanent displacements of a sliding mass due to the surplus acceleration (k_e-k_r)times g is computed by

$$D_r=\int_{t_0}^{t_1}\int_{t_0}^{T}(k_e-k_r)gdTdt \tag{4}$$

where t_0 is the time when FS = 1, t_1 is the time when the velocity of the sliding mass becomes zero. Above procedure is graphically depicted on Fig. 3. Fig. 4 presents a case of the computed permanent seismic-induced deformations.

CONCLUSIONS

As a result of the above computations we can say that the permanent deformations increases when the input acceleration increase. This fact agrees with the experimental results obtained during the dynamic failure test program. The method presented herein provides a rational approach for the aseismic design of embankments and offers a significantly improvement over the conventional pseudo-static method, however care must be exercised in reducing the errors involved in the FEM formulation of the dam when the size of the finite-element mesh is comparative to the size of the sliding mass being considered.

REFERENCES

[1] ORTIZ, J. D. A Study on Aseismic Design Method of Embankment Dams on the Basis of Seismic Induced Deformations. (Master's Thesis), 1988.

[2] WATANABE, H. et al. Evaluation of Earthquake-Induced Sliding in Rockfill Dams, Soils and Foundations, Vol. 24, No.3, 1984.

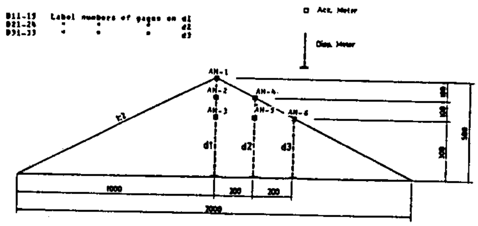

Fig. 1 Arrangement of Gages

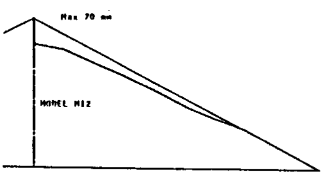

Fig. 2 Typical Profile of Models After Failure

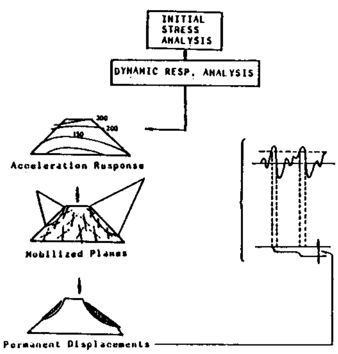

Fig. 3 Schematic Flowchart of Watanabe's Method

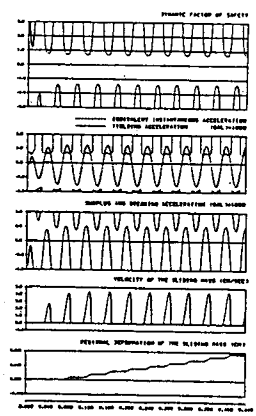

Fig. 4 Computed Permanent Deformations