FAILURE PHENOMENON OF ROCKFILL DAM SUBJECTED TO EARTHQUAKE

By

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CERTIFICATE

This is to certify that the thesis entitled, "Failure Phenomenon of Rockfill Dam Subjected to Earthquake" being submitted by K.G. Bhatia to the Indian Institute of Technology, Delhi, for the award of degree of Doctor of Philosophy in Applied Mechanics Department, is a record of bonafide research work carried out by him under my supervision and guidance. The thesis work, in my opinion, has reached the standard fulfilling the requirements for the Degree of Doctor of Philosophy. The research report and the results presented in this thesis have not been submitted in part or in full to any other University or Institution for the award of any degree or diploma.

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ABSTRACT

Since the failure of a dam is far more disastrous to a community than other structures, its safety is of vital importance. This is more so during earthquakes. Rock-fill dams have complex dynamic properties and their behaviour during earthquake has not yet been fully understood. Damages like sliding of slopes and collapsing have been observed during earthquakes.

The stability of rockfill dam during earthquake have been investigated by several authors based on analytical and experimental studies. Since conventional methods do not take into account the stress distribution within the dam, the factor of safety of a dam, thus evaluated, needs critical examination. The other methods, based on the response calculation, give only qualitative assessment of the safety of the dam. The quantitative evaluation of safety or the failure acceleration for a dam, using these methods, has not been reported. However, since the rockfill material is week in tension, the effect of tension on the failure acceleration and thereby on the safety of the dam, has also bot been reported in presently available methods for evaluation of seismic stability. Since, the nonlinear properties of the rockfill material significantly affect the tension developed in the dam and thereby the safety, the effect of this aspect on the safety, also needs to be investigated. These shortcomings in the existing literature have been overcome in the present research programme.

An analysis procedure, using finite element method, has been developed. Pseudo-static analysis, using elastic material properties, has been presented in the first part of the thesis. A consistent definition of failure acceleration, based on tension area developed in the dam, has been arrived at. Failure

accelerations for various dam sections, having different upstream and downstream slope combinations, have thus been evaluated. The results have been compared with the available experimental data. The effects of various parameters, like core inclination, core stiffness, reservoir conditions, variation in seismic coefficient along the height of the dam etc. on the failure acceleration have been investigated. The factor of safety, along assumed slip surfaces, has been computed based on stress distribution in the dam and compared with that obtained by conventional method.

In the second part of the thesis, effect of material nonlinearity has been included in the finite element formulation. Three mathematical no-tension models, accounting for material nonlinearity, have been developed. The one giving best convergence of tensile stresses, has been used for further analysis. Using pseudo-static approach, the failure accelerations are evaluated for various dam sections, as in part one above, and the results are compared with those experimentally available. The effects of various parameters, as in part one above, on the failure acceleration, have been investigated. Here also factor of safety has been computed and compared with that by conventional method.

In part three of the analysis, the response of the dam, for elastic material properties, have been computed using dynamic analysis procedures. The effects of core inclination and core stiffness on the response have been investigated. The results are compared with those of pseudo-static no-tension analysis, as well as, those of dynamic elastic analysis.

In the fourth part, the dynamic response is computed for nonlinear material properties. The effects due to parameters as in part three are investigated. The results thus obtained are compared with those of pseudo-static no-tension analysis, as well as, those of dynamic elastic analysis.

The important conclusions from the foregoing analysis are drawn and presented.

In brief, the present study provides a validated approach for the analysis and design of rockfill dam using nonlinear material properties. The estimate of adequacy of the pseudo-static approach for evaluating failure acceleration of a rockfill dam is discussed and the limitations of conventional factor of safety formulation are highlighted.

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