STRESS ANALYSIS OF DAMS, FOUNDED ON FAULTED ROCKS

By

DAYA KRISHAN SEHGAL

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CERTIFICATE

This is to certify that the thesis entitled "Stress Analysis of Dams, Founded on Faulted Rocks" being submitted by D.K.Sehgal to the Indian Institute of Technology, Delhi (India) for the award of the degree of Doctor of Philosophy in Applied Mechanics Department is a record of bonafide research work carried out by him under our supervision and guidance. The thesis work, in our opinion, has reached the standard fulfilling the requirements for the Doctor of Philosophy Degree. The research report and the results presented in this thesis have not been submitted in part or in full to any other University or Institute for the award of any degree or diploma.

(S.M.A.Kazimi)
Professor & Head,
Dept. of Applied Mechanics,
Indian Institute of Tech.,
New Delhi-110016

(R.Natarajan)
Professor,
Dept. of Applied Mechanics
Indian Institute of Technology,
New Delhi-110016

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D.K. Sehgal

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SUMMARY

In the present era of energy crisis, more and more emphasis is being given to hydroelectric power generation. With the virtual exhaustation of geologically ideal dam sites in most of the countries, many dams are now being constructed at sites not so ideal; where the rocks are not compact and have layered strata with varying elastic properties. This produces a lot of complexities in the design and, therefore, precise determination of stresses and deformations in the dam proper and foundation region is necessary. Safe and economical design of dam structure and planning for economic and effective foundation treatment is based on such studies. Photoelasticity and Finite-element method are widely used for experimental and theoretical determination of stresses, for such faulted foundations.

For some dam sites; fairly high modular ratios among the materials of superstructure, foundation rock and foundation faults exist. In order to represent them exactly in the model, photoelastic materials having same modular ratios as the prototype should be used. Keeping this in mind, a technique is developed, which can continuously evolve different modulus photoelastic materials over a wide range (upto modulus ratio of 1:1000). The variation of critical temperature from higher modulus to lower modulus materials is small, hence the composite

model can be stress freezed easily for three-dimensional work.

Faulted foundation of a concrete gravity dam is analysed, using two-dimensional photoelastic models. Different modulus photoelastic materials have been used to simulate the properties of concrete, rock and faults, having modular ratios of 49:7:1. Forces due to the following effects are considered acting on the dam:

1. Self weight of the dam.
3. Hydrostatic pressure of water.
3. Weight of water on upstream and downstream side.
4. Uplift in dam proper.
5. Silt pressure.
6. Hydrodynamic pressure of water.
7. Earthquake.

For comparing the experimental results, a two-dimensional finite-element computer program (Dam 2D) is developed, taking into consideration the actual loading conditions of the concrete gravity dams. For the discretization of the dam, combined eight noded isoparametric quadratic quadrilaterals and six noded isoparametric quadratic triangular types of elements can be used. The program takes into consideration, the loads mentioned earlier for the photoelastic model, plus any other forces normally existing in actual practice. Dynamic forces are, however, taken a as quasistatic forces. Frontal solution technique is used to solve large number of resulting equations.

Finite-element program, Dam 2D, is used for the stress analysis of a concrete gravity dam (same dam as used for photoelastic investigation). Photoelastic and finite-element results are compared at various critical positions in the foundation. Initially maximum shear stresses were compared, but finally photoelastic stresses were separated using shear difference method and were compared with finite-element stresses.

Numerical method of stress separation for photoelastic models, is generally preferred, as it gives fast and accurate results. Keeping this in mind, a new analytical formulation is proposed to separate the stresses numerically, for a photoelastic model composed of different modulus materials. This formulation is applied to separate the stresses for a composite dam model. For this model, two different modulus materials are used to simulate the dam concrete and rock foundation. The results are compared with those obtained by a finite-element analysis.

Using the computer program, Dam 2D, three important case studies are done on concrete gravity dams, which are as follows:

i) In the first case study, effect of time-dependent modulus variation of newly laid concrete, on the resulting stress behaviour of a concrete gravity dam (if it is loaded within short period after its completion), is evaluated.

ii) In the second case study, effect of inaccurate foundation data on the ultimate behaviour of a concrete gravity dam, is evaluated. It has been shown that lot of financial resources can be saved, if parametric studies with the help of finite-element computer program are done beside the actual subsurface exploration.

iii) In the third case study, effect of prescribed boundary conditions (for the finite-element solution) on the computed stresses for a concrete gravity dam, is evaluated.

In the second phase of research programme, a three-dimensional finite-element computer program (Dam 3D) is developed, taking into consideration the actual loading conditions of concrete gravity dams. For the discretizaton of the dam either 20 noded or 8 noded isoparametric rectangular prism type of element can be used. Dynamic forces are again considered as quasistatic forces.

Using the computer program, Dam 3D, a three-dimensional analysis of a concrete gravity dam is done. The foundation rock is considered having a fault, the location of which changes along the longitudinal direction of the dam. The three-dimensional results are compared with the corresponding two-dimensional results, for various transverse sections of dam, to assess the magnitude of the inaccuracies involved in the plane strain analysis for such complex problems.

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