FINITE ELEMENT ANALYSES OF GRAVITY DAM FOUNDATION WITH SEAMS

by

C. CHINNASWAMY

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CERTIFICATE

This is to certify that the thesis entitled "FINITE ELEMENT ANALYSES OF GRAVITY DAM FOUNDATION WITH SEAMS" being submitted by Mr. C. Chinnaswamy to Indian Institute of Technology, Delhi, for the award of the DOCTOR OF PHILOSOPHY is a record of bonafide research work carried out by him. The thesis work, in our opinion, has reached the standard fulfilling the requirements for the award of Doctor of Philosophy. The research report and the results presented in the thesis have not been submitted in part or in full to any other University or Institute for the award of any degree or diploma.

A. Varadarajan
Professor,
Deptt. of Civil Engg.
Indian Institute of Technology,
Hauz Khas, New Delhi-110016

K.G. Sharma
Assistant Professor
Deptt. of Civil Engg.
Indian Institute of Technolc
Hauz Khas, New Delhi-110016

To My Father

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C. CHINNASWAMY

ABSTRACT

In the design of gravity dams, clear understanding of dam-foundation interaction is essential to arrive at a safe and economical section. The problem becomes complicated due the the presence of seams and faults in the foundation. Further, to have more realistic results, the seepage forces in the foundation must be taken into account in addition to the normal loads.

Generally, gravity dams are designed by assuming the foundation medium to be linear elastic and homogeneous. In addition to self weight, the loads considered due to the reservoir filling are hydrostatic thrust on the upstream face and uplift pressure at the base of the dam, which is assumed to be with linear variation. In many cases, the foundation has weaknesses such as joints, faults, which cause excessive local deformations inconsistent with assumption of linear elasticity and homogeneity in the foundation.

With the rapid pace of development for harnessing water resources for irrigation and generation of power, the ideally tailored sites have been virtually utilised. The inevitability of using somewhat less favourable foundations cannot be avoided. In India, a number of dams are being constructed in Himalayan region where the foundation rocks are with seams and layered strata with varying material properties. It is difficult to find a site without seams/ faults.

The seams in the foundation may be sub-horizontal or sub-vertical at different locations and very little information is available about the effects of orientation and location in case of sub-horizontal seams on the behaviour of the structure. Even in the studies where the effect of different orientations and locations of sub-vertical seams were considered, the seams were modelled by regular finite elements and the effect of seepage was not considered. The main objective of this thesis has been to make a rational analysis and suggest solutions to estimate the effects of presence of thin seams at different orientations and locations on seepage flow as well as structural behaviour.

In the present work, formulation of a new joint element for problems of seepage flow has been presented. This joint element helps to utilize the same Finite element for both stress and seepage analysis, which is essential in case of coupled problems.

The use of finite element method necessitates preparation and checking of enormous amount of data and in case of problems with large finite element mesh, it requires large number of man hours. In this work, since different conditions in the foundation are to be investigated, preparation and input of data, manually, becomes a tough task. Without the facilities of graphics, interpretation of finite element analysis results is equally laborious in case of big problems. Therefore, for the purpose of conducting the above study, the following programs have been developed.

i. a program for data generation to generate the data for foundation with seams at different locations and orientations.

ii. a general purpose program for seepage analysis for problems of flow through media with joints.

iii. a two dimensional elasto-plastic finite element program with provision to simulate the sequential loadings of dam construction and reservoir filling.

The programs have been test run for reliability and problem of a dam on foundation with seam has been studied in detail using the three programs. The two distinct aspects in the seepage through dam-foundation viz. (i) the flow pattern and (ii) the uplift at dam-base have been studied in detail for various cases of presence of seam like, location, orientation and permeability ratio. The results of the analyses are presented in a user friendly form for the designers.

Elastic and elasto-plastic stress analyses have been carried out for dam-foundation with a horizontal seam located at different depths. By using the strength reduction factor concept, the overall factor of safety has been determined for various depths of seam. It is observed that if the seam depth is located at adepth greater than or equal to 0.25 times the basewidth, the structure will be stable irrespective of the strength parameters. A correlation between the overall factor of safety and local factor of safety has been presented. The effects of inclined seams in the dam-foundation on structura behaviour has been studied. It is observed that a seam inclined in the direction of the resultant of the external loads results in more adverse conditions as compared to other orientations.

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