SOME ASPECTS OF STRENGTHENING OF GRAVITY DAMS

By

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CERTIFICATE

This is to certify that the thesis entitled "**SOME ASPECTS OF STRENGTHENING OF GRAVITY DAMS**" being submitted by Mr. K. K. Mukundan Menon to Indian Institute of Technology, Delhi, for the award of **DOCTOR OF PHILOSOPHY** is a record of the bonafide research work carried out by him. Mr. K. K. Mukundan Menon has worked under our guidance for the submission of this thesis which to our knowledge has reached the requisite standard.

The thesis or any part thereof has not been submitted to any other university or institution for the award of any degree or diploma.

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TO MY MOTHER

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ABSTRACT

Dams constitute the most important component in the development of water resources. With increase in demand of water primarily for irrigation and power generation more and more new dams have been built all over the world. In the beginning, dams were built with inadequate design criteria. With the advancement in technology the design criteria for dams have undergone considerable changes. Many old dams fail to meet the safety requirements according to the present day design criteria. Such a situation has led to some dam failures in the world. In India too, many old dams exist. Some of them are nearly 100 years old. Here also some major dam failures occured. Therefore, it has become necessary and important to evaluate the safety of existing old dams and to provide suitable remedial measures.

In the recent years, the subject of assessing the safety of old dams and suggesting suitable strengthening procedures have been receiving considerable attention. In the present work an extensive literature survey has been carried out covering various aspects related to the safety appraisal and strengthening, such as causes of failure of dams, status of old dams existing in India as regards to their performance over the years, design and construction methods followed, safety evaluation and strengthening measures carried out.

Analysis procedures and computer programs have been developed to investigate the response of dams under static and dynamic loading conditions. Such important factors as material non-linearity and the fluid structure interaction have been included in the analysis.

A systematic study was carried out to investigate various aspects related to safety evaluation and strengthening of dams. Thsese aspects included choice of backing numerical simulation of construction of backing, load transfer mechanism, the type of foundation, loading condition and material non-linearity.

For the investigations a typical gravity dam lying in a seismically active area of the country has been chosen. This dam was unsafe both under static and dynamic loadings.

The first of the studies carried out to arrive at appropriate strengthening measures revealed the following.

Earth backing, is economical and easy to construct, and is suited for strengthening against static loading condition. But under dynamic loading condition separation at the dam-backing interface may occur and earth backing is not suitable in such cases.

Using alternative strengthening measures in the form of masonry backing on the downstream face is more suited in such conditions.

The study on the simulation of the construction of the backing and subsequent loading incorporating the 'design bonding level concept' reveals clearly the behaviour of the dam-backing and the load transfer mechanism between the two.

The selected backing causes considerable reduction in deformation and stresses in the dam both under static and dynamic loading conditions. The pattern of distributions of deformations and stresses become more uniform. Substantial reduction in the tensile stresses and extent of tensile stress zones in the dam are also achieved.

The compressibility of the foundation is found to considerably alter the behaviour of dam-backing system both under static and dynamic loading conditions. In the case of static loadings, the tensile stresses get fully eliminated from the dam body.

Material non-linearity has no significant effect on the behaviour of the dam-backing system both on rigid and compressible foundations under static loadings for the dam considered. Under dynamic loadings, the dam on rigid foundation shows marginal change in the behaviour. However the dam on compressible foundation shows significant changes in the stresses and deformations. Substantial increase in deformations and stresses have been noticed. The interface between the dam and backing also undergoes more deformation and stresses; more undulations are noticed in their distributions due to non-linear material behaviour.

From the overall improvements brought in by the backing it is found that the strengthening measure adopted is adequate for the dam considered.

A systematic step by step procedure for safety evaluation and strengthening of dams has been formulated from the present practices being followed and the studies carried out in this work. By choosing three old dams falling in the height range generally encountered in the country, illustrative studies have been made. The studies indicate that the design bonding level is about 0.75 times the depth of water in the reservoir, and the minimum combined base width required for achieving the safety level is about 1.25 times the height of dam, for static loading condition. The studies also reveal that the configuration of the dam especially the slope of the downstream face very much influence the size of the backing to be provided. Further, aspects like, the seismicity, type of materials used for construction, the design criteria followed in the original designs of dams, vary from dam to dam and region to region. As such, for each region having common features, suitable backing scheme may be evolved for arriving at the required strengthening.

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