CONSTITUTIVE MODELLING OF ROCKFILL MATERIALS

by

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Dedicated

TO

MY PARENTS,

My Wife

MAMTA

and

My Children

ASTHA & AKANKSHA

CERTIFICATE

This is to certify that the thesis entitled **"CONSTITUTIVE MODELLING OF ROCKFILL MATERIALS"** being submitted by **Mr. Ashok Kumar Gupta** to the Indian Institute of Technology, Delhi 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 **DOCTOR OF PHILOSOPHY** degree. The research report and the results presented in this thesis have not been submitted, in part or full, to any other University or Institute, for the award of any degree or diploma.

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(Ashok K. Gupta)

ABSTRACT

Rockfill dams are increasingly used in the hydro-power projects. The behaviour of rockfill material used in the construction of these dams is affected by number of factors such as mineral composition, particle size, shape, grading and relative density of the rockfill. The understanding and characterisation of the behaviour of rockfill material are of considerable importance for the analysis and the design of the rockfill dams.

For the present investigation two different types of rockfill materials from two dam sites have been chosen. Drained triaxial tests have been conducted on three modelled rockfill materials under various confining pressures. For the tests, large size triaxial test apparatus have been used. From the results of the experimental investigations it is found that both the materials show increase in the axial strain at failure and the breakage factor, with increase in particle size. The volumetric strain at failure, and the value of ϕ increase with the size of the particles for the river bed material but, these values decrease with the size of the particles for the blasted material.

The behaviour of the modelled rockfill materials has been characterised using the elasto-plastic theory based on disturbed state concept (DSC). Material parameters for the two modelled rockfill materials have been determined. Comparing the material parameters for the two modelled materials, it is found that i) the value of k increases and value of ν decreases with maximum particle size of both materials. But the variations of n' value shows opposite trend, ii) the variation of ultimate constants with maximum particle size is opposite in nature, iii) phase change parameter is same and is constant, iv) variation of hardening parameters with maximum particle size shows opposite trend, v) non-associative parameter is almost constant for both, vi) variation of disturbance parameters with maximum particle size shows opposite trend.

The stress-strain-volume change responses have been predicted for the two types of modelled rockfill materials using the single point method (SPM) and finite element method (FEM).The predicted stress-strain-volume change response by SPM and FEM are same and close to the observed experimental results for both the modelled materials. Material parameters for the prototype rockfill material have been predicted using the material parameters for the various sizes of the modelled rockfill material. A curve fitting procedure has been adopted for this purpose.

Ranjit Sagar rockfill dam has been analysed under construction loading using finite element method. Two dam sections viz. one consisting of only rockfill and another consisting of rockfill in the upstream and down stream shells and a clay core have been used. The two dam sections have been analysed using the two different constitutive models i.e. elasto-plastic model based on DSC and hyperbolic model to compare the results. The material parameters predicted for the prototype size of rockfill material have been used in the analysis. From the results of the two analyses, the following conclusions are drawn:

(i) The nature of displacement contours predicted by the two constitutive models are somewhat similar in nature.

(ii) The magnitudes of the displacements predicted by the hyperbolic model are higher than those predicted by the model based on DSC. The location of the maximum displacement is significantly different in the two cases.

(iii) The nature of variation of the stresses as well as the magnitude of stresses as predicted by the two models are comparable to each other.

In general, it appears that for the prediction of stresses any of the constitutive models can be used but, to predict the accurate displacements more realistic constitutive model (such as DSC) should be adopted in the analysis.

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