# STRENGTH AND DEFORMATIONAL BEHAVIOUR OF JOINTED ROCKS

by

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TO MY PARENTS

# CERTIFICATE

This is to certify that the thesis entitled, "Strength and Deformational Behaviour of Jointed Rocks" being submitted by Mr. V. K. Arora to the Indian Institute of Technology, New Delhi, for the award of the degree of DOCTOR OF PHILOSOPHY is a record of the bonafide research work carried out by him. Mr. V. K. Arora has worked under my guidance for the submission of this thesis which to my knowledge has reached the requisite standard.

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

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ABSTRACT

The most rational approach to design of structures on or in a rock mass is based on the strength and deformational response of the rock mass. Realizing the importance, the present investigation was undertaken to study the strength and deformational response of jointed rock mass. The objective was achieved by simulating joints in rock cores in the laboratory.

Three materials, namely, plaster of Paris, Jamrani sandstone and Agra sandstone were selected. These materials provided a wide range of compressive strength ($\sigma_{ci}$=11.32 to 110 MN/m$^2$). The nature and mineralogical composition of the materials were estimated using X-ray diffration and scanning electron micrographs. The physical and engineering properties of the materials were determined using ISRM and Indian Standard (IS) test procedures. Specimens of 38 mm diameter and 76 mm height were prepared.

Anisotropy was induced into the intact specimens by developing joints at various orientations ($\beta$ =0, 30, 40, 50, 60, 70, 80 and 90°) by adopting special techniques. Triaxial tests on plaster of Paris were conducted at $\sigma_3$=0, 0.3, 0.5, 1.0, 1.5, 2.0, 2.5, 5.0 and 7.0 MPa. Jamrani sandstone was tested under confining pressures of 0, 2.5, 5.0 and 10.0 MPa, whereas Agra sandstone was tested at $\sigma_3$=0, 2.5, 5.0, 7.5 and 10.0 MPa.

Joint frequency or number of joints per meter, $J_n$, joint inclination, $\beta$, and joint roughness have been identi-

fied as the most significant aspect concerning rock joints. The inclination parameter, n, has been evolved to depict the effect of different orientations of joints and roughness parameter, r, has been evolved to depict the condition of the joint. Joint frequency, $J_n$, inclination parameter, n, and roughness parameter, r, are suitably clubbed to form a Joint Factor, $J_f$, which can be expressed as,

$$J_f = J_n/(n.r)$$

The values of n and r are being suggested.

The effect of Joint Factor, $J_f$ on the strength and deformational response of jointed rocks is studied in detail. Based on present experimental results, and Yaji's test data (1984) on jointed rocks, empirical relationships have been developed to predict uniaxial compressive strength, modulus of deformation, and modulus ratio of rock mass. The relationship can be expressed as,

1) $\sigma_{cj} = \sigma_{ci} \exp[-0.008\ J_f]$,

2) $E_j = E_i \exp[-1.15\text{x}10^{-2}\ J_f]$, and

3) $M_{rj} = M_{ri} \exp[-3.72\text{x}10^{-3}\ J_f]$

The Joint Factor, $J_f$ in the above equations may be obtained from the field data. Uniaxial compressive strength, $\sigma_{ci}$, modulus of deformation, $E_i$, and modulus ratio, $M_{ri}$ of intact rock obtained from the parent rock mass may also be evaluated in the laboratory. Knowning the values of $J_f$, $\sigma_{ci}$, $E_i$ amd $M_{ri}$, one can estimate $\sigma_{cj}$, $E_j$ and $M_{rj}$ for parent rock mass using the relationships presented above.

After analysing the present experimental test data, and that of Yaji (1984) on jointed rocks, strength criterion proposed by Ramamurthy et al. (1985) to predict strength of isotropic and anisotropic intact rocks, has been suitably modified for its applicability to the jointed rocks. The modified strength criterion is expressed as,

$$(\sigma_{dj}/\sigma_3) = B_j \ (\sigma_{cj}/\sigma_3)^{\alpha_j}$$

where,

$$\sigma_{cj} = \sigma_{ci} \ \exp[-0.008 \ J_f],$$

$$\alpha_j = \alpha_i \ (\sigma_{cj}/\sigma_{ci})^{0.5}, \text{ and}$$

$$B_j = B_i/0.13 \ \exp[2.037(\sigma_{cj}/\sigma_{ci})^{0.5}]$$

The above criterion may be used to predict the strength of rock mass under any desired confined pressure.

After making predictions of unconfined compresssive strength of rock mass and its modulus ratio using the value of $J_f$, the rock mass could be either individually or combinedly classified as per classification systems suggested.

To give a direct indication of the magnitude of the deformation of rock mass at failure to a designer, a classification based on minimum failure strain has also been proposed. This classification combined with strength classification provides a comprehensive understanding of strength and deformational response of the rock mass more satisfactorily.

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