STRENGTH PREDICTION OF ANISOTROPIC ROCKS

By

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CERTIFICATE

This is to certify that the thesis entitled, "STRENGTH PREDICTION OF ANISOTROPIC ROCKS" being submitted by Mr. Jagdeep Singh to the Indian Institute of Technology, Delhi, for the award of the degree of DOCTOR OF PHILOSOPHY is a record of the bonafide research work carried out by him. Mr. Jagdeep Singh 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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ABSTRACT

The nature and physico-mechanical response of intrinsically anisotropic rocks is still not properly understood inspite of many attempts made in this direction in the past. Apart from various assumptions and limitations, the failure theories for anisotropic rocks have a common requirement, i.e., a necessity to conduct a number of triaxial tests at the minimum of three orientations to generate minimum pre-evaluation experimental data. On the other hand, a non-linear Mohr-Coulomb criterion for intact rocks, proposed by Ramamurthy and co-workers recently, has shown better results as compared to a number of other available failure theories but, still a scope of improving its precision exists. Keeping the above observations in view, the present investigation is an attempt to:

(i) reveal the nature and engineering behaviour of the three varieties of intrinsically anisotropic phyllite rocks, obtained from a project site in the Himalayan region;

(ii) introduce suitable modifications to Ramamurthy and co-worker's criterion for its better precision; and

(iii) propose a strength criterion for anisotropic intact rocks, having a wider utility and simplicity in its form.

The petrofabric analysis of the three phyllites (i.e., Quartzitic phyllite, Carbonaceous phyllite and Micaceous phyllite) was performed using thin-sections, X-ray diffraction and scanning electron microscope studies. The test procedures suggested by ISRM and Indian

Standards (IS) were followed in estimating the physical and strength properties. The use of cubical specimens for uniaxial compression and triaxial-tests, and square plates for tensile-tests was adopted in order to avoid the core drilling problems arising out of the highly fissile nature of the rocks.

A complete analytical approach towards anisotropic strength behaviour of the phyllites was made possible by varying the orientation (β) of the foliation planes with respect to the direction of major principal stress, at an interval of 15°, i.e., 0, 15, 30, 45, 60, 75 and 90°, in various tests to determine the geotechnical parameters. In triaxial testing, the range of confining pressure (σ_3) was distributed in five intervals i.e., 5, 15, 30, 50, and 70 MPa.

All the anisotropic phyllites have shown maximum compressive strength at β=90° and the minimum between β=30 and 40°, exhibiting "U-shaped" anisotropy curves similar to that of other metamorphic slates. It has been observed for other sedimentary rocks (e.g., shales and sandstones) that they exhibit "shoulder" type anisotropy. Rocks containing more than one set of weak planes (e.g., coal and large specimens made of individual blocks) are prone to have "wavy" or "undulatory" type of anisotropy curves.

The non-linear form of the Mohr-Coulomb criterion proposed by Ramamurthy and co-workers has been analysed through various approaches and suitable modifications have been introduced in order to expand the scope of its applicability to a much wider range of the confining pressures.

Keeping in view, a common limitation posed by various existing failure theories for anisotropic rocks i.e., obtaining a large amount of essential pre-evaluation experimental data, an empirical strength criterion for anisotropic rocks has been proposed having a wider practical utility. The criterion states that:

$$\frac{\sigma_1-\sigma_3}{\sigma_3} = B_j\left(\frac{\sigma_c}{\sigma_3}\right)^{\alpha_j}$$

In this criterion, the uniaxial compressive strength at various orientations, σ_{cj}, is a scaling parameter for the non-dimensional parameters α_j and B_j and the suggested inter-relationships are:

$$\frac{\alpha_j}{\alpha_{90}} = \left(\frac{\sigma_{cj}}{\sigma_{c90}}\right)^{1-\alpha_{90}}$$

and

$$\frac{B_j}{B_{90}} = \left(\frac{\alpha_{90}}{\alpha_j}\right)^{0.5}$$

The use of these key equations enables one to determine the values of α_j and B_j at various orientations through the values of α_{90}, B_{90} and σ_{c90}, which are the corresponding values of α_j, B_j and σ_{cj} at the standard orientation of β=90°. This has resulted in the elimination of triaxial test data at different β (except at β=90°), which is otherwise essential in the evaluation of already existing criteria.

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