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METHODS FOR QUANTITATIVE DESCRIPTION OF DISCONTINUITIES IN ROCK MASS

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METHODS FOR QUANTITATIVE DESCRIPTION OF DISCONTINUITIES IN ROCK MASS

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0. FOREWORD

0.1 This Indian Standard (Part 8) was adopted by the Bureau of Indian Standards on 6 April 1987, after the draft finalized by the Rock Mechanics Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 In view of the advancement in the field of rock mechanics, a number of methods for assessing the strength characteristics of rocks and rock masses are being formulated by Rock Slope Engineering and Foundation on Rock and Rock Mass Improvement Subcommittee, of the Rock Mechanics Sectional Committee. The majority of rock masses, in particular those within a few hundred metres from the surface, behave as discontinuous, with the discontinuities largely determining the mechanical behaviour. It is, therefore, essential that the structure of a rock mass and the nature of its discontinuities are carefully described and quantified to have a complete and unified description of rock masses and discontiruities, and it may be possible to design engineering structures in rock with a minimum of expense *in-situ* testing. Careful field descriptions will enhance the value of *in-situ* tests that are performed since the interpretation and extrapolation of results will be made more reliable.

0.3 Discontinuity is the general term for any mechanical discontinuity in a rock mass, along which the rock mass has zero or low tensile strength. It is the collective term for most types of joints, weak bedding planes, weak schistocity planes, weakness zones, shear zones and faults. The ten parameters selected for rock mass survey to describe discontinuities are orientation, spacing, persistence, roughness, wall strength, aperture, filling, seepage, number of sets, and block size. These parameters are also evaluated from the study of drill cores to obtain information on the discontinuities.

0.4 It is essential that both the structures of a rock mass and the nature of its discontinuities are carefully described for determining the mechanical behaviour. This Indian Standard covering various parameters to describe discontinuities in rock masses is being formulated in various parts each part covering one parameter. This part covers seepage.

0.5 Seepage describes water flow and free moisture visible in individual discontinuities or in the rock mass as a whole.

0.6 In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

1. SCOPE

1.1 This standard covers the method for the quantitative description of seepage in the discontinuities in rock mass.

2. TERMINOLOGY

2.1 For the purpose of this standard, the definitions of terms given in IS : 11358-1986† shall apply.

3. GENERAL

3.1 Water seepage through rock masses results mainly from flow through water conducting discontinuities (secondary permeability). In the case of certain sedimentary rocks, the 'primary' permeability of the rock material may be significant such that a proportion of the total seepage occurs through the pores. The rate of seepage is roughly proportional to the local hydraulic gradient and to the relevant directional permeability proportionality being dependent on laminar flow. High velocity flow through open discontinuities may result in increased head losses due to turbulence.

3.2 The prediction of groundwater levels, likely seepage paths and approximate water pressures may often give advance warning of stability or construction difficulties. The field description of rock masses should inevitably precede any recommendation for field permeability tests so these factors should be carefully assessed at this early stage.

3.3 Irregular groundwater levels and perched water tables may be encountered in rock masses that are partitioned by persistent impermeable features such as dykes, clay filled discontinuities or permeable beds. The prediction of these potential flow-barriers and associated irregular water tables is of considerable importance especially for engineering projects where such barriers might be penetrated at depth by tunnelling, resulting in high pressure inflows.

*Rules for rounding off numerical values (*revised*).
†Glossary of terms and symbols relating to rock mechanics.

3.4 Seepage of water caused by drainage into an engineering excavation may have far reaching consequences in cases where a sinking ground water level would cause settlement of structures founded on overlying clay deposits.

3.5 The approximate description of the local hydrogeology should be supplemented with detailed observations of seepage from individual discontinuities or particular sets, according to their relative importance to stability. A short comment concerning recent precipitation in the area, if known, will be helpful in the interpretation of these observations. Additional data concerning groundwater trends and rainfall and temperature records will be useful supplementary information.

3.6 In the case of rock slopes, the preliminary design estimates will be based on assumed values of effective normal stress. If, as a result of field observations one has to conclude that pessimistic assumptions of water pressure are justified (that is, a tension crack full of water with zero exit pressure at the toe of the unfavourable discontinuity) then this will clearly have the greatest consequences for design. So also will the field observation that ice formation is possible or probable. Deterioration of rock slopes and tunnel portals through ice weding and/or increased water pressure caused by ice-blocked drainage paths are serious seasonal problems in many countries.

3.7 Seepage describe water flow and free moisture visible in discontinuity planes and the information is collected by visual observations (in underground excavations good lighting is essential). Air photographs, rainfall, spring flow, and temperature records assist in evaluation of seepage.

4. PROCEDURE

4.1 Available air photograph should be studied to obtain an overall view of the local drainage pattern and likely groundwater levels. (Groundwater may be indicated by growth of vegetation along faults and basic dykes). Information on seasonal variations of groundwater levels, and on rainfall and temperature records should be obtained where possible.

4.2 Description of the local hydrogeology will usually be limited in the preliminary stages of field mapping. There will probably be no boreholes for pumping tests, no wells for water level determination and drawdown tests, no tracer tests, and no piezometer installations. The hydrogeology will therefore have to be assessed from geological predictions of the likely locations of acquifers, from predictions of the likely orientation and location of impermeable flow barriers, and from predictions of the likely resultant seepage directions and groundwater levels. The need for exploratory boreholes for water level determination, tracer testing, piezometer installation and pumping or drawdown tests should be assessed, and their optimum location indicated on appropriate plans.

NOTE — Local rainfall records should be obtained where possible, to help in the interpretation of seepage observations. This is especially important in the case of observation of surface outcrops, slopes, and tunnels at shallow depth.

4.3 The mutual interaction of the planned engineering project and the assumed groundwater flow regime should be assessed and important consequences summarized. The effect of seepage towards or into a planned excavation such as a tunnel or slope should be described with a view to preliminary analysis. The predicted effect of any resultant drawdown of groundwater levels on existing installations, and on the settlement of clay foundations should be summarized.

4.4 Seepage from individual *unfilled* and *filled discontinuities* or from specific sets exposed in a tunnel or in a surface exposure, can be assessed according to the following descriptive scheme:

Unfilled Discontinuities

Seepage Rating	Description
I	The discontinuity is tight and dry, water flow along it does not appear possible.
II	The discontinuity is dry with no evidence of water flow.
III	The discontinuity is dry but shows evidence of water flow, like rust staining, etc.
IV	The discontinuity is damp but no free water is present.
V	The discontinuity shows seepage, occasional drops of water, but no continuous flow.
VI	The discontinuity shows a continuous flow of water (estimate l/min and describe pressure).

Filled Discontinuities

Seepage Rating	Description
I	The filling materials are heavily consolidated and dry, significant flow appears unlikely due to very low permeability.
II	The filling materials are damp, but no free water is present.
III	The filling materials are wet, occasional drops of water.
IV	The filling materials show signs of outwash, continuous flow of water (estimate l/min).

V	The filling materials are washed out locally, considerable water flow along out-wash channels (estimate l/min and describe pressure, that is, low, medium, high).
VI	The filling materials are washed out completely, very high water pressures experienced, especially on first exposure (estimate l/min and describe pressure).

4.5 In the case of a rock engineering construction which acts as a drain for the rock mass, for example a tunnel, it is helpful if the overall flow into individual sections of the structure are described. This should ideally be performed immediately after excavation since groundwater levels or the rock mass storage may be depleted rapidly. Descriptions may be based on the following scheme:

Rock Mass (Tunnel Wall)

Seepage Rating	Description
I	Dry walls and roof, no detectable seepage.
II	Minor seepage, specify dripping discontinuities.
III	Medium inflow, specify discontinuities with continuous flow (estimate in flow of water l/min/10 m length of excavation).
IV	Major inflow, specify discontinuities with strong flows (estimate in flow of water l/min/10 m length of excavation).
V	Exceptionally high inflow, specify source of exceptional flows (estimate in flow of water l/min/10 m length of excavation).

4.6 A field assessment of the likely effectiveness of surface drains, inclined drill holes, or drainage galleries should be made in the case of major rock slopes. This assessment will depend on the orientation, spacing and apertures of the relevant discontinuities.

NOTE 1 — In the case of open pit mines, boreholes are drilled for mineral exploration and rock mechanics is commonly entertained only at a subsequent stage, if mineral evaluation is encouraging. The pre-existence of boreholes will allow a comprehensive hydrogeological study to be performed, including tracer tests, piezometer installation, falling-head and pumping tests. Boreholes walls can be surveyed for seepage horizons by means of periscopes, borehole cameras and TV equipment.

NOTE 2 — Testing performed in drill holes (as falling head and Lugeon tests) for estimating rock mass permeability forms the subject of a separate Indian Standard. The description of any available lugeon values is obviously an important supplement to the present suggested methods for description of rock masses and discontinuities.

NOTE 3 — Bedding joints and beds of sedimentary rocks having high 'primary' permeability tend to be persistent features with the potential for hydraulically connecting large areas of sedimentary rock masses. Such efficient hydraulic connection will be inherently less marked in igneous and metamorphic environments if major regional joints and faults are absent.

NOTE 4 — Faults sometimes contain highly permeable breccia adjacent to highly impermeable clay gouge. The hydraulic conductivity may therefore be strongly anisotropic, and may even be confined to flow parallel to the plane of the fault. It may be premature to describe a fault zone as dry if at tunnel or exploratory adit has not completely penetrated the feature.

NOTE 5 — The highest location of seeping joints on a rock slope may be important indirect input for preliminary stability analysis. Likewise the depth of a tunnel or its location relative to major weakness zones will be important, since this may imply potentially serious inflows.

4.7 The potential influence of frost and ice on the seepage paths through the rock mass should be assessed. Observations of seepage from the surface trace of discontinuities may be misleading in freezing temperatures. The possibility of ice blocked drainage paths should be assessed from the point of view of surface deterioration of a rock excavation, and from the point of view of overall stability.

5. PRESENTATION OF RESULTS

5.1 Air photos, geological maps, or plans of suitable scale should be marked with arrows to indicate the general groundwater flow pattern that has been interpreted as a result of available hydrogeological data. If appropriate, rainfall and temperature records can be appended.

5.2 Anticipated impermeable flow barriers such as dykes, major clayfilled discontinuities and impermeable beds, should be drawn on simplified geological maps and vertical cross-sections, together with anticipated groundwater levels. Optimum locations for investigatory boreholes (and any existing boreholes), should be indicated as appropriate.

5.3 The anticipated mutual interaction of the planned engineering project and the assumed groundwater flow regime should be described where possible. If sufficient data are available for reliable predictions, anticipated pre-construction and post-construction phreatic surfaces should be sketched. The likely effect of extreme weather conditions should be indicated if possible. Possible effects of frost and of artificial drainage measures should be appended.

5.4 Local seepage observations for individual discontinuities for specific sets, or for the rock mass as a whole can be presented as seepage ratings I-VI. If enough observations are available, sketches showing the distributions of ratings can be contoured, drawn as histograms, or, in the case of tunnels, presented on longitudinal sections in parallel with structural data, in the same way that Lugeon values are presented parallel with borehole geology.