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METHODS FOR QUANTITATIVE DESCRIPTION OF DISCONTINUITIES IN ROCK MASS

PART 7 FILLING

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METHODS FOR QUANTITATIVE DESCRIPTION OF DISCONTINUITIES IN ROCK MASS

PART 7 FILLING

0. FOREWORD

0.1 This Indian Standard (Part 7) 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 the rocks and rock masses are being formulated by Rock Slope Engineering and Foundation on Rock and Rock Mass Improvement Subcommittee of 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 discontinuities, and it may be possible to design engineering structures in rock within minimum of expensive *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 terms 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 persistance 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 filling.

0.5 Filling describe the material that separates the adjacent rock walls of a discontinuity, which is usually weaker than the parent rock. Typical filling materials are sand, silt, clay braccia gauge, mylonite. Also include thin mineral coatings and healed discontinuities, for example, quartz and veins.

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 filling in the discontinuities in the 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 Filling is the term for material separating the adjacent rock walls of discontinuities, for example, calcite, chlorite, clay, silt, fault gouge, breccia, etc. The perpendicular distance between the adjacent rock walls is termed the width of the filled discontinuity, as opposed to the aperture of a gapped or open feature.

3.2 Due to the enormous variety of occurrences, filled discontinuities display a wide range of physical behaviour, in particular as regards their shear strength, deformability and permeability. Short-term and long-term behaviour may be quite different such that it is easy to be misled by favourable short-term conditions.

3.3 The wide range of physical behaviour depends on many factors of which the following are probably the most important:

a) mineralogy of filling material,

b) grading or particle size,

*Rules for rounding off numerical values (*revised*).

†Glossary of terms and symbols relating to rock mechanics.

c) over-consolidation ratio,
d) water content and permeability,
e) previous shear displacement,
f) wall roughness,
g) width, and
h) fracturing or crushing of wall rock.

3.4 Every attempt should be made to record the above factors, using quantitative descriptions, where possible, together with sketches and/or colour photographs of the most important occurrences. Certain index tests are suggested for a closer investigation of major discontinuities considered to be threat to stability. In special cases, the result of these field descriptions may warrant the recommendation for large scale *in-situ* testing, at least in the case of dam foundations or major slopes.

4. PROCEDURE

4.1 The minimum and maximum widths of simple filled discontinuities (for example, clay filled joints) should be measured to the nearest 10 percent and an estimate made of the most common (modal) width. Marked differences between the minimum and maximum widths may indicate that shear displacement has occurred if the walls are essentially unaltered or unweathered.

4.1.1 In cases where fillings are thin it may be helpful to try to measure the mean amplitude of wall roughness using the straight edge, and compare this with the mean width of the filling as illustrated in Fig. 1. This will be especially valuable when assessing shear strength and deformation characteristics in detailed studies.

4.1.2 The principal dimensions of complex filled discontinuities (for example, shear zones, crushed zones, faults, fault, zones, dykes and lithological contacts) should be estimated, or measured to the nearest 10 percent, when possible. In the case of important occurrences, it is helpful to make field sketches such that the condition of the wall rock (that is, degree of associated fracturing and/or alternation) is also communicated (*see* examples in Fig. 2).

4.2 Filled discontinuities that have originated as a result of preferential weathering along discontinuities may have fillings composed of *decomposed* rock, or *disintegrated* rock. The relevant type should be recorded:

a) *Decomposed* — The rock is weathered to the condition of a soil in which the original material fabric is still intact, but some or all of the mineral grains are decomposed.
b) *Disintegrated* — The rock is weathered to the condition of a soil, in which the original material fabric is still intact. The rock is friable, but the mineral grains are not decomposed.

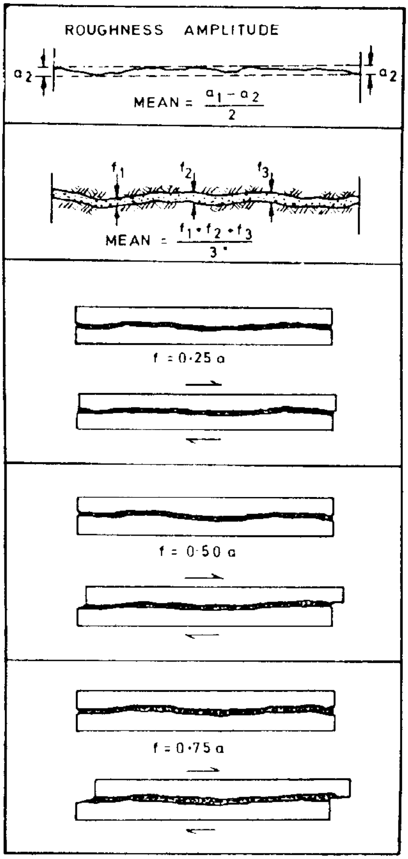

FIG. 1 IN THE CASE OF SIMPLE FILLED DISCONTINUITIES, THE AMPLITUDE OF THE WALL AND THICKNESS OF THE FILLING CAN HELP TO INDICATE THE AMOUNT OF SHEAR DISPLACEMENT REQUIRED FOR ROCK CONTACT (STIFFENING) TO OCCUR (ZERO VOLUME CHANGE ASSUMED DURING SHEAR)

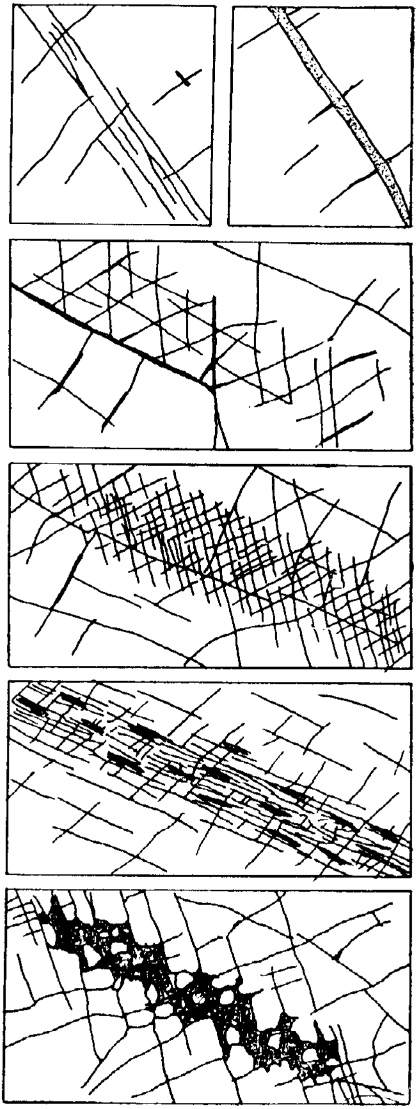

FIG. 2 EXAMPLE OF FIELD SKETCHES OF COMPLEX FILLED DISCONTINUITIES

4.3 For all types of filled discontinuities the finest fraction of the filling or gouge is of most interest since this usually controls the long-term shear strength. The mineralogical composition of the finer filling material should, therefore, be determined, espacially in cases where active clays or swelling clays are suspected. Samples should be taken when in doubt concering the mineralogy.

NOTE — Hydrothermal alternation of gouge material and/or the deposition of hydrothermal products will complicate the mineralogical identification of fillings since products not associated with the petrography of the crushed rock or the wall rock may be present.

4.3.1 In cases where swelling clay such as montmorillonite is identified or suspected, and where this condition might be critical for stability, samples should be taken for free swelling and swelling pressure tests. (It is of advantage of record the *in-situ* water content of these samples, where possible. Such samples should, therefore, be sealed).

4.4 The method of describing the grading or particle size will depend on the type of occurrence. A rough quantitative description of the grading of discontinuity fillings can be given by estimating the percentages of clay, silt, sand and rock particles (± 10 percent). Several kilos of filling material may need to be extracted and fingered before making these estimates.

4.4.1 Particle size can be classified as under according to IS : 1498-1970*:

a) boulders;
b) cobbles;
c) coarse gravel;
d) medium gravel;
e) fine gravel;
f) coarse sand;
g) medium sand;
h) fine sand; and
j) silt, clay.

4.4.2 If a detailed soil mechanics investigation is warranted, the first fraction can be analyzed in the laboratory to determine clay fraction liquid limit and plasticity index, according to relevant method given in relevant part of IS : 2720.

4.5 Filling material, in particular the finer fraction which is usually weakest, can be assessed by means of the manual index tests given in Table 1.

*Classification and identification of soils for general engineering purposes (*first revision*).

TABLE 1 MANUAL INDEX

(*Clause* 4.5)

Grade	Description	Field Identification	Approximate Range of Uniaxial Compressive Strength (MPa)
*S*1	Very soft clay	Easily penetrated several inches by fist	< 0·025
*S*2	Soft clay	Easily penterated several inches by thumb	0·025-0·05
*S*3	Firm clay	Can be penetrated several inches by thumb with moderate effort	0·05-0·10
*S*4	Stiff clay	Readily indented by thumb but penetrated only with great effort	0·10-0·25
*S*5	Very stiff clay	Readily indented by thumbnail	0·25-0·50
*S*6	Hard clay	Indented with difficulty by thumbnail	> 0·50

NOTE — Grades S1 to S6 apply to cohesive soils, for example clays silty clays, and combinations of silts and clays with sand, generally allow draining. Discontinuity wall strength will generally be characterized by grades R0-R6 (rock) (*see* Part 6) while S1-S6 (clay) will generally apply to filled discontinuities.

4.5.1 The undrained shear strengths of the soils represented in grades Sl to S6 are equal to one half of the given uniaxial compressive strengths (care should be taken in applying these estimates to fissured clays).

NOTE — The manual index tests for determining grades S1 to S6 can be replaced by more accurate assessments using a standard soil mechanics penetrometer. This contains a stylus which is pressed into the sample at a constant rate. The maximum resistance can be read off a scale which is calibrated to show the maximum compressive strength of the sample. [This value is equal to twice the undrained shear strength $= \frac{1}{2} (\sigma_1 - \sigma_3)$].

4.5.2 If a detailed soil mechanics investigation is warranted (as in drained shear strength determination) due to critical natures of an individual filled discontinuity, then undisturbed samples of the filling material may be required. Various tube samples are available for this sampling operation.

4.6 Care should be taken to determine whether a given filled dicontinuity has suffered previous shear displacement or not (Slickensides, shears, displaced cross joints, etc). This should be recorded in conjunction with an estimate of the approximate over-consolidation ratio (OCR) of any clay filling.

NOTE — If previous displacement has occurred through the potential weakest layers of a filled discontinuity, that is, through the clay filling or clay gouge, as evidenced by slicken sides and shears, then the over-consolidation ratio (OCR) of the clay will not be important since the discontinuity will be close to residual strength. However, if previous displacement through these weak layers is not suspected, then the over-consolidation ratio will be important since the peak drained shear strength of the intact clay may be much higher than the residual strength. Short-term stability will be deceptively high, especially in the case of unloading, due to the reduced or negative pore pressures. However, in time swelling and softening may occur due to increased pore pressure and water content and possibly also due to strain softening caused by engineering loading, for example, by excavation of an overlying rock slope. This potential for reduction in strength with time should not be underestimated during field assessment.

4.7 The water content and permeability of the filled discontinuity as a whole and of the clay filling, in particular, should be described as below. The decision to make actual measurements of these properties will depend on the importance of the occurrence to the project:

W_1 The filling materials are heavily consolidated and dry, significant flow appears unlikely due to very low permeability.

W_2 The filling materials are damp, but no free water is present.

W_3 The filling materials are wet, occasional drops of water.

W_4 The filling materials show of outwash, continuous flow of water (estimate litres/minute).

W_5 The filling materials are washed out locally, considerable water flow along-out wash channels (estimate litres/minute and describe pressure, that is, low, medium high).

W_6 The filling materials are washed out completely, very high water pressures experienced, especially on first exposure (estimate litrets/minute and describe pressure).

NOTE — Faults frequently contain highly permeable brecciated gouge adjacent to highly impermeable clay gouge. The water conducting capacity will 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 or impermeable, if the tunnel or exploratory adit has not completely penetrated the feature.

5. PRESENTATION OF RESULTS

5.1 The detail of presentation will be dependent on the importance of the individual filled discontinuity (or set) to the project as a whole. In general the description should be arranged as below, so as to include a description of those factors of particular relevance to project in hand:

a) Geometry: width
wall roughness
field sketch

b) Filling type:	mineralogy particle size weathering grade soil index parameters swelling potential
c) Filling strength:	manual index (S1-S6) shear strength over-consolidation ratio displaced/undisplaced
d) Seepage:	water content (rating as $W_1 - W_6$) permeability quantitative data