IS 11315-3 (1987): Method for the quantitative description of discontinuities in rock mass, Part 3: Persistence [CED 48: Rock Mechanics]

BLANK PAGE

IS : 11315 (Part 3) - 1987

(Reaffirmed 2005)

Indian Standard

METHODS FOR QUANTITATIVE DESCRIPTION OF DISCONTINUITIES IN ROCK MASS

PART 3 PERSISTENCE

UDC 624·121 : 550·347·4 : 620·191

BUREAU OF INDIAN STANDARDS

MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG

NEW DELHI 110002

Gr 3 *November* 1987

Indian Standard

METHODS FOR QUANTITATIVE DESCRIPTION OF DISCONTINUITIES IN ROCK MASS

PART 3 PERSISTENCE

(*Continued on page* 2)

(*Continued from page* 1)

Members	*Representing*
RESEARCH OFFICER (MERI)	Irrigation Department, Government of Maharashtra, Nasik
SECRETARY	Central Board of Irrigation & Power, New Delhi
DIRECTOR (C) (*Alternate*)	
SHRI C. D. THATTE	Irrigation Department, Government of Gujarat, Ahmadabad
SHRI G. RAMAN, Director (Civ Engg)	Director General, BIS (*Ex-officio Member*)

Secretary

SHRI K. M. MATHUR
Joint Director (Civ Engg), BIS

Rock Slope Engineering, Foundation on Rock and Rock Mass Improvement Subcommittee, BDC 73 : 4

Convener	
PROF L. S. SRIVASTAVA	University of Roorkee, Roorkee
Members	
DR R. K. BHANDARI	Central Building Research Institute (CSIR), Roorkee
SHRI A. GHOSH (*Alternate*)	
SHRI B. D. BALIGA	Central Mining Research Institute (CSIR), Dhanbad
SHRI A. P. BANERJEE	Cemindia Company Limited, Bombay
SHRI D. J. KETKAR (*Alternate*)	
SHRI D. G. KADKADE	Jaiprakash Associates Pvt Ltd, New Delhi
SHRI R. K. JAIN (*Alternate*)	
SHRI T. K. NATARAJAN	Central Road Research Institute (CSIR), New Delhi
SHRI P. J. RAO (*Alternate*)	
DR T. RAMAMURTHY	Indian Institute of Technology, New Delhi
DR K. G. SHARMA (*Alternate*)	
DR YUDHBIR	Indian Institute of Technology, Kanpur

Indian Standard

METHODS FOR QUANTITATIVE DESCRIPTION OF DISCONTINUITIES IN ROCK MASS

PART 3 PERSISTENCE

0. FOREWORD

0.1 This Indian Standard (Part 3) was adopted by the Bureau of Indian Standards on 30 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 rock and rock masses are being formulated by Rock Slope Engineering, 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 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 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 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 persistence.

0.5 Persistence describes the discontinuity trace length as observed in a exposure and provide a measure of the areal extent or penetration length of a discontinuity. Termination of a discontinuity in solid rock or against other discontinuities reduce the persistence.

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 persistence of discontinuities in rock mass.

2. TERMINOLOGY

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

3. GENERAL

3.1 Persistence implies the areal extent or size of a discontinuity within a plane. It can be crudely quantified by observing the discontinuity trace lengths on the surface of exposures. It is one of the most important rock mass parameters, but one of the most difficult to quantify in anything but crude terms.

3.2 The discontinuities of one particular set will often be more continuous than those of the other sets. The minor sets will, therefore, tend to terminate against the primary features or they may terminate in solid rock.

3.3 In the case of rock slopes and dam foundations, it is of the greatest importance to attempt to assess the degree of persistence of those discontinuities that are unfavourably orientated for stability. The degree to which discontinuities persist beneath adjacent rock blocks without terminating in solid rock or terminating against other discontinuities determines the degree to which failure of intact rock would be involved in eventual failure. Persistence determines the degree to which 'downstopping' would have to occur between adjacent discontinuities for a failure surface to develop. Persistence is also of the greatest importance to tension crack development behind the crest of a slope.

3.4 In the case of tunnelling, failure in the first instance may be a rather local affair, and persistence across a limited number of blocks may be all that is required provided that other conditions are compatible with

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

†Glossary of terms and symbols relating to rock mechanics.

failure, that is, the existence of smooth or clay filled discontinuities or at least three sets. Planer discontinuities that can be traced without offset for 5-10 m in a tunnel construction may be of major significance to stability, while being of minor importance in the case of a 100 m high rock slope or large dam abutment.

3.5 Frequently, rock exposures are small compared to the area of length of persistent discontinuities and the real persistence can only be guessed. Less frequently it may be possible to record the dip length and the strike length of expoted discontinuities, and thereby estimate their persistence along a given plane through the rock mass using probability theory. However, the difficulties and uncertainties involved in the field measurements will be considerable for most rock exposures encountered.

3.6 Persistence described the modal trace length of sets of discontinuities as observed in an exposure and distinguished as *systematic*, *sub-systematic* or *non-systematic* according to their relative persistence. Measurements are made with a measuring tape of at least 10 m length.

4. PROCEDURE

4.1 Individual rock exposures or recognized domains should first be described according to the relative persistence of the different discontinuity sets present. The sets of discontinuities can be distinguished by the terms *persistent*, *sub-persistent* and *non-persistent* respectively. Simple labelled field sketches such as those illustrated in Fig. 1 are useful aids in subsequent interpretation.

4.2 Discontinuity lengths should be measured in the direction of dip and in the direction of strike. This may be impossible in the case of limited planar exposures. However, in the case of large three-dimensional exposures such as curved open pits with benches, or underground openings with intersecting tunnels, it may be possible to obtain useful size-frequency histograms for each of the discontinuity sets.

4.3 The modal trace lengths measured for each set are described according to the following scheme:

Very low persistence	< 1 m
Low persistence	1-3 m
Medium persistence	3-10 m
High persistence	10-20 m
Very high persistence	> 20 m

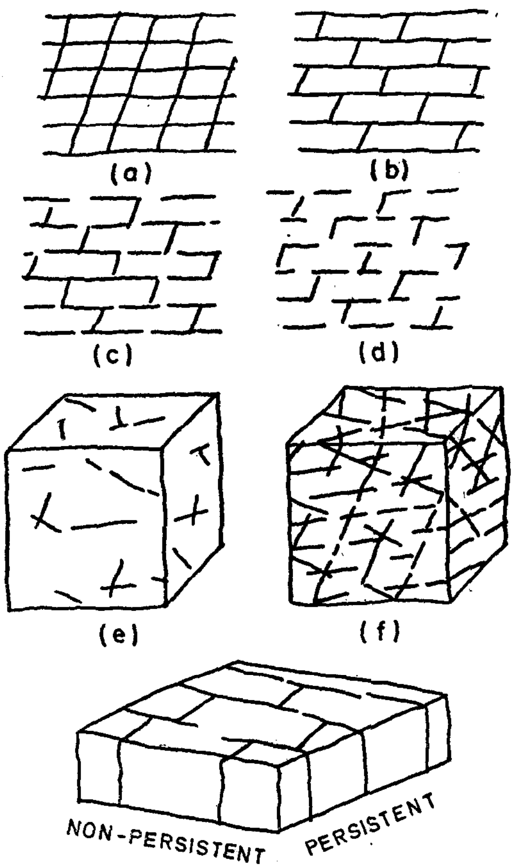

FIG. 1 SIMPLE SKETCHES AND BLOCK DIAGRAMS HELP TO INDICATE THE RELATIVE PERSISTENCE OF VARIOUS SETS OF DISCONTINUITIES

4.4 A useful procedure during the mapping of discontinuity lengths is to record the type of termination according to the following scheme. Discontinuities which extend outside the *exposure* (*x*), should be differentiated from those that visibly terminate in *rock* in the exposure (*r*), and from those that terminate against other *discontinuities* in the exposure (*d*). A *systematic* set of discontinuities with a high score in (*x*) is obviously more persistent than a *sub-systematic* set with predominant scores in (*d*). *Non-systematic* discontinuities will tend to have highest scores in (*r*).

4.5 Termination data (*x*, *r* or *d*) should be recorded for each end of the relevant discontinuities, together with the length in metres.

[*Example*: 6(*dx*) — discontinuity length of 6 m, one termination against another *discontinuity*, other termination invisible because feature extends beyond the limits of the exposure]. It is important to specify the dimensions of the exposure on which measurements are made since this will obviously influence both the number of (*x*) observations and the relevant lengths.

NOTE 1 — Discontinuities where both terminations can be seen are generally smaller than discontinuities where one or no terminations can be seen.

NOTE 2 — Analyses of dip lengths and strike lengths have indicated that discontinuities tend to be of approximately isotropic dimensions. When terminating in solid rock they may, therefore, tend to be circular, and presumably rectilinear when terminating against other discontinuities.

NOTE 3 — Statistical tests simulating circular outline discontinuities with a normal distribution of diameters randomly spaced in the rock mass, indicate that the mean trace length can range from slightly smaller to slightly larger than the mean diameter. This is the result of the greater probability of intersecting the larger discontinuities outweighing the fact that trace lengths (that is, chords) are inherently shorter than diameters.

NOTE 4 — Statistical methods can be used to analyse the maximum lengths of discontinuities. Using such techniques it is possible to estimate the expected recurrence interval for discontinuities of any specified length. Alternatively it is possible to estimate the mean probability of a discontinuity exceeding a specified length occurring in any portion of the rock mass. For example, if after analysis it is found that major discontinuities with strike lengths of 50 m or more are spaced on the average at 150 m, it is possible to estimate the probability of strike lengths of 50 m or more occurring in any 100 m interval measured normal to the strike. The probability is equal to $\frac{100}{150} = 0{\cdot}66$.

If the complete distribution of sizes is known the probability of occurrence of a discontinuity of a certain size can be evaluated on the basis of extreme value statistics. It may be noted that the ill defined lower bound to observations of trace length (inevitable if the shortest features are ignored) leads to underestimation of the frequency of discontinuities and overestimation of their size.

NOTE 5 — The descriptive term 'persistence' may in theory be quantified by defining it as the percentage of the total area of a plane through the rock mass which is formed by discontinuities coincident (co-planar) with this reference plane. In practice, waviness of most discontinuities frustrates strict interpretation. A practical alternative is to select a band width equal to the mean spacing of the discontinuities in the particular set, and to estimate the persistence within this reference band. Since, on a probability basis, only one discontinuity would be expected to occur within this band, a slightly more realistic estimate of persistence is obtained.

NOTE 6 — When assessing the persistence of the various discontinuity sets it is important to investigate the possibility of a stepped failure surface forming, as illustrated by failure modes (2) and (3) in Fig. 2. This mode of failure may tend to occur when the set involved in shear has less than 100 percent persistence. Down-stepping will tend to develop such that only a minimum percentage of the resulting shear surface passes through intact rock. The persistence of a potential failure surface will normally be higher than that along planes or bands parallel to a single set, unless the latter have 100 percent persistence.

NOTE 7 — Estimates of persistence for given planes, bands or specific failure surfaces have at present to be based on engineering judgement and should be purposely weighted in the direction of conservatism (that is, closer to 100 percent persistence) since the shear strength of the intact rock bridges will form dangerously high percentage of the total shear strength of the compound failure surface. The shear strength (cohesion) due to any intact rock bridges can be crudely estimated from the Mohr diagram, assuming a linear shear strength envelope:

$$C = \tfrac{1}{2} (\sigma \ \sigma_t)^{\frac{1}{2}}$$

where

σ_c = uniaxial compressive strength of the intact rock, and

σ_t = tensile strength of the intact rock.

If it is assumed for simplicity that $\sigma_c/\sigma_t = 9$, then the cohesive strength is equal to one sixth of the unconfined compressive strength. It is safer to assume 100 percent persistence when in doubt, since the above cohesion is usually one to two orders of magnitude greater than the shear strength of the discontinuities.

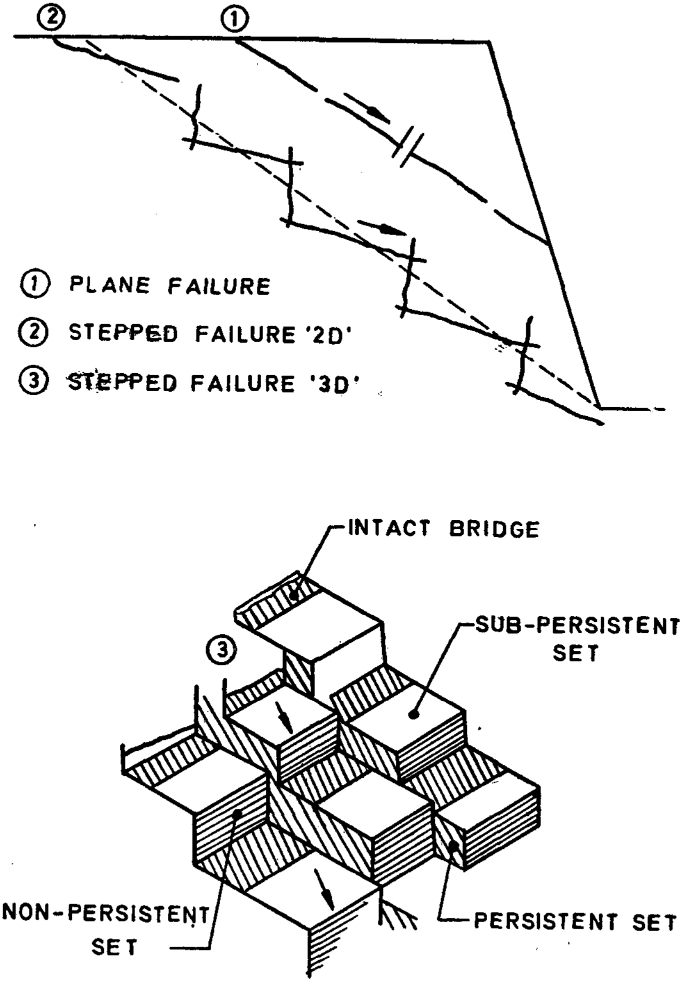

Fig. 2 Idealised Examples of Potential Failure Planes Showing the Importance of 'Intact Bridges' and 'Down Stepping'

5. PRESENTATION OF RESULTS

5.1 The various sets of discontinuities should be described as systematic, sub-systematic or non-systematic according to their relative persistence. Block diagrams or photographs should be labelled accordingly.

5.2 Where exposures are of suitable dimensions, size-frequency histograms of trace lengths observed for each set of discontinuities should be given. (This is necessary if probability theory is to be applied subsequently.) Mean trace lengths (in both strike and dip directions) should be quoted.

5.3 Termination data which has been recorded for each discontinuity sampled [for example, 6(*dx*)], should be presented in the form of a 'termination index' (T_r) for the rock mass as a whole, or for chosen domains. T_r is defined as the percentage of the discontinuity ends terminating in rock (Σr) compared to the total number of terminations ($\Sigma r + \Sigma d + \Sigma x$). The latter is equal to twice the total sample since each trace has two ends.

$$T_r = \frac{(\Sigma r) \times 100}{2\ (\text{No. of discontinuities observed})} \text{ percent}$$

NOTE — It is to be hoped that systematic collection of dataco ncerning T_r will eventually improve the estimation of 'persistence'.

5.4 The persistence of potential failure surfaces (including stepped surfaces) should be estimated, if this is appropriate to the project being investigated. The estimate should perhaps be rounded upwards, to the next multiple of 10 percent (that is, 92 percent is assumed to be 100 percent).

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

QUANTITY	UNIT	SYMBOL
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

QUANTITY	UNIT	SYMBOL
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

QUANTITY	UNIT	SYMBOL	DEFINITION
Force	newton	N	$1\ N = 1\ kg.m/s^2$
Energy	joule	J	$1\ J = 1\ N.m$
Power	watt	W	$1\ W = 1\ J/s$
Flux	weber	Wb	$1\ Wb = 1\ V.s$
Flux density	tesla	T	$1\ T = 1\ Wb/m^2$
Frequency	hertz	Hz	$1\ Hz = 1\ c/s\ (s^{-1})$
Electric conductance	siemens	S	$1\ S = 1\ A/V$
Electromotive force	volt	V	$1\ V = 1\ W/A$
Pressure, stress	pascal	Pa	$1\ Pa = 1\ N/m^2$