इंटरनेट मानक

Disclosure to Promote the Right To Information

Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

“जानने का अधिकार, जीने का अधिकार”
Mazdoor Kisan Shakti Sangathan
“The Right to Information, The Right to Live”

“पुराने को छोड नये के तरफ”
Jawaharlal Nehru
“Step Out From the Old to the New”

IS 11315-4 (1987): Method for the quantitative description of discontinuities in rock mass, Part 4: Roughness [CED 48: Rock Mechanics]

“ज्ञान से एक नये भारत का निर्माण”
Satyanarayan Gangaram Pitroda
“Invent a New India Using Knowledge”

Act Number 22 of 2005
The Indian Parliament
RIGHT TO INFORMATION

Made Available By
Public.Resource.Org

“ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है”
Bhartṛhari—Nītiśatakam
“Knowledge is such a treasure which cannot be stolen”

BLANK PAGE

BRUTUM FULMEN
IGNORANTIA JURIS NON EXCUSAT
PROTECTED BY COPYRIGHT

Indian Standard

METHODS FOR QUANTITATIVE DESCRIPTION OF DISCONTINUITIES IN ROCK MASS

PART 4 ROUGHNESS

UDC 624·121 : 550·347·4 : 620·191

© *Copyright* 1988

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

 May 1988

Indian Standard

METHODS FOR QUANTITATIVE DESCRIPTION OF DISCONTINUITIES IN ROCK MASS

PART 4 ROUGHNESS

Rock Mechanics Sectional Committee, BDC 73

Chairman	*Representing*
DR BHAWANI SINGH	University of Roorkee, Roorkee
Members	
ASSISTANT RESEARCH OFFICER (IRI)	Irrigation Department, Government of Uttar Pradesh, Roorkee
DIRECTOR	Central Soil and Materials Research Station, New Delhi
DIRECTOR (CW & PRS)	Central Water and Power Research Station, Pune
SHRI S. L. MOKHASHI (*Alternate*)	
DIRECTOR (CHIEF ENGINEER)	Karnataka Engineering Research Station, Krishnarajasagara
SHRI R. NARA SIMHA IYENGAR (*Alternate*)	
DR A. K. DUBE	Central Mining Research Station (CSIR), Dhanbad
SHRI P. S. GOSAL	Irrigation and Power Department, Amritsar
DR UDAY V. KULKARNI	Hindustan Construction Co Ltd, Bombay
DR G. S. MEHROTRA	Central Building Research Institute (CSIR), Roorkee
SHRI A. GHOSH (*Alternate*)	
SHRI M. D. NAIR	Associated Instrument Manufacturers (India) Pvt Ltd, New Delhi
PROF T. S. NAGARAJ (*Alternate*)	
SHRI P. L. NARULA	Geological Survey of India, Calcutta
SHRI T. K. NATARAJAN	Central Road Research Institute (CSIR), New Delhi
SHRI P. J. RAO (*Alternate*)	
PROF T. RAMAMURTHY	Indian Institute of Technology, New Delhi
DR G. V. RAO (*Alternate*)	
DR Y. V. RAMANA	National Geophysical Research Institute (CSIR), Hyderabad
DR G. V. RAO	Indian Geotechnical Society, Delhi

(*Continued on page* 2)

© *Copyright* 1988
BUREAU OF INDIAN STANDARDS
This publication is protected under the *Indian Copyright Act* (XIV of 1957) and reproduction in whole or in part by any means except with written permission of the publisher shall be deemed to be an infringement of copyright under the said Act.

(*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
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	
SHRI B. D. BALIGA	Central Mining Research Institute (CSIR), Dhanbad
SHRI A. P. BANERJEE	Cemindia Company Limited, Bombay
SHRI D. J. KETKAR (*Alternate*)	
DR R. K. BHANDARI	Central Building Research Institute (CSIR), Roorkee
SHRI A. GHOSH (*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 4 ROUGHNESS

0. FOREWORD

0.1 This Indian Standard (Part 4) was adopted by the Bureau of Indian Standards on 30 August 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 rock 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 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, week 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 standard covering various parameters to describe discontinuities in rock masses is being formulated in various parts, each part covering one parameter. This part covers roughness. The other parts covering other parameters are also being formulated.

0.5 Roughness describes inherent roughness and waviness relative to the mean plane of a discontinuity. Both roughness and waviness contribute to the shear strength. Large scale waviness may also alter the dip locally.

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 (Part 4) covers the method for quantitative description of roughness of discontinuities in rock mass.

2. TERMINOLOGY

2.1 For the purpose of this standard, the definitions of terms given in IS : 11358-1987† shall apply.

3. GENERAL

3.1 The wall roughness of a discontinuity is a potentially important component of its shear strength, specially in the case of undisplaced and interlocked features (for example unfilled joints). The importance of wall roughness declines as aperture, or filling thickness, or the degree of any previous displacement increases.

3.2 In general terms, the roughness of discontinuity walls can be characterized by a waviness (large scale undulations which, if interlocked and in contact, cause dilation during shear displacement since they are too large to be sheared off) and by an unevenness (small scale roughness that tends to be damaged during shear displacement unless the discontinuity walls are of high strength and/or the stress levels are low, so that the dilation can also occur on these small scale features).

3.3 In practice, waviness affects the initial direction of shear displacement relative to the mean discontinuity plane while unevenness affects the shear strength that would normally be sampled in a laboratory or medium scale *in situ* direct shear test (*see* Fig. 1).

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

†Glossary of terms and symbols relating to rock mechanics.

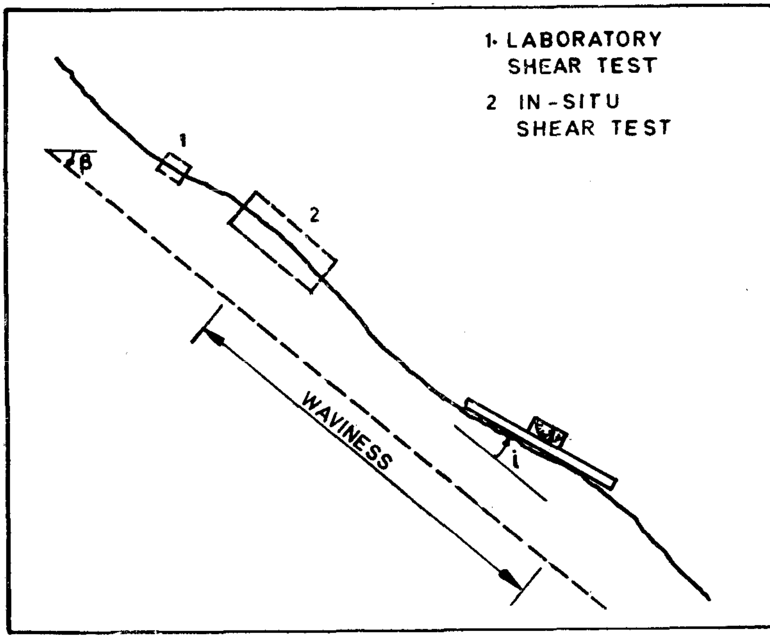

FIG. 1 DIFFERENT SCALES OF DISCONTINUITY ROUGHNESS ARE SAMPLED BY DIFFERENT SCALES OF TESTS. WAVINESS CAN BE CHARACTERISED BY THE ANGLE (i)

3.4 If the direction of potential sliding is known, roughness can be sampled by linear profiles taken parallel to this direction. In many cases, the relevant direction is parallel to the dip (dip vector). In cases where sliding is controlled by two intersecting discontinuity planes, the direction of potential sliding is parallel to the line of intersection of the planes. In the case of arch dam abutment stability, the direction of potential sliding may have a marked horizontal component.

3.5 If the direction of potential sliding is unknown, but nevertheless of importance, roughness must be sampled in three dimensions instead of two. This can be done with a compass and disc-clinometer. Dip and dip direction readings can be plotted as poles on equal-area nets. Alternatively, discontinuity surfaces can be coloured relative to their mean planes using photogrammetric methods. This can be a useful technique if the critical surfaces are inaccessible.

3.6 The purpose of all roughness sampling methods is for the eventual estimation or calculation of shear strength and dilation. Presently available methods of interpreting roughness profiles and estimating shear strength are summarized under **5** on presentation of results and **6** on estimation of shear strength.

3.7 Roughness describes the inherent surface roughness and waviness relative to the mean plane of a discontinuity.

3.8 The linear profiling method of sampling roughness requires the following equipment: (a) folding straight edge of at least 2 m length graduated in mm, (b) compass and clinometer, and (c) 10 m of light wire or nylon with paint markings at 1 m intervals (red) and 10 cm intervals (blue). The line should be attached to small wooden blocks or similar handles at each end, so that it can be tensioned to form a straight reference line above the plane of large undulating discontinuities.

3.9 The compass and disc-clinometer method of sampling roughness requires the following equipment: (a) a geological compass which incorporates a horizontal levelling bubble and a rotatable lid which is connected to the main body of the compass through a graduated hinge for recording dip, and (b) four thin circular plates made of a light alloy, of various diameters (that is 5, 10, 20 and 40 cm) which can be fixed in turn to the lid of the compass.

3.10 The photogrammetric method of sampling roughness requires assorted equipment described under Photogrammetric Method in Part 1 of this standard.

4. PROCEDURE

4.1 Linear Profiling — Discontinuities are selected that are accessible and typical of the surface presumed to be involved if shear failure was to occur.

4.1.1 Depending upon the relevant dimensions of each plane, either the 2 m straight edge or the 10 m wire (or sections of either) are placed or stretched above the plane of the discontinuity parallel to the mean direction of potential sliding. For convenience, they should be in contact with the highest point or points of the discontinuity and they should be as straight as possible. (A small lump of plasticene can be helpful in preventing the straight edge from sliding down steeply dipping joints. It can be placed between the straight edge and the high spots.) The perpendicular distances (y) from the straight edge (or wire) to the surface of the discontinuity are recorded to the nearest mm, for given tangential distances (x) (*see* Fig. 2). It is advisable to be flexible in the choice of (x) since a regular interval (for example, 5 cm) might result in missing a small step or similar feature of potential importance to the shear strength. On average, x intervals equal to approximately 2 percent of the total measuring length are sufficient to give a good overall impression of roughness.

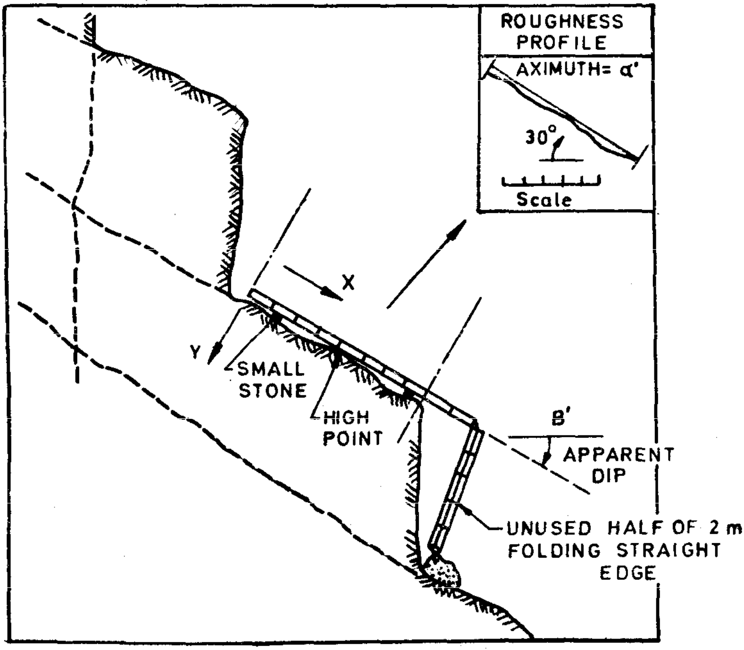

FIG. 2 A METHOD OF RECORDING DISCONTINUITY ROUGHNESS IN TWO DIMENSIONS, ALONG THE ESTIMATED DIRECTION OF POTENTIAL SLIDING

4.1.2 The x and y readings are recorded in parallel, together with the azimuth and dip of the measuring direction. This may by different from the orientation α/β of the discontinuity.

4.1.3 Profiles typical of the minimum, most common and maximum roughness are recorded using the above procedures. These profiles may apply to a whole discontinuity set, to one critical discontinuity, or to each surface measured, depending upon the detail required.

4.1.4 The waviness angle (i) illustrated in Fig. 1 should be recorded using the straight edge and clinometer, if the profile was so short that waviness was not automatically sampled during profiling.

4.1.5 The approximate wave length and amplitude of waviness too large to be sampled by profiling should be estimated, or measured where accessibility is no problem.

4.1.6 Photographs representing the surfaces of minimum, modal and maximum roughness should be taken, with a 1 m rule placed against the surface in question clearly visible.

NOTE 1 — The mm graduated ruler used to measure the perpendicular distances, y, should be tapered to a point so that the fine details of roughness can be recorded if desired. Most of the automatic recording profilographs are suitable for describing the finest details of roughness. They obviously give a much more accurate picture of roughness than that obtained by the present suggested method. Normally, this accuracy is unnecessary for rock mechanics purposes.

NOTE 2 — Offsets or steps dividing a discontinuity surface into several parallel planes are indicative of lack of persistence, and should be carefully profiled.

NOTE 3 — There are many other methods of recording roughness in addition to the profiling method. For example, the wave-length and amplitude of surface features could be measured and recorded for several different scale intervals, that is, < 1cm, 1-10 cm, 10-100 cm, > 1 m. Alternatively, a very large undulating joint exposure could be rapidly recorded by laying a straight edge (for example, 1 m length) against the surface at 1 m intervals in the down-dip direction and recording the dip of each position by means of a clinometer fixed to the straight edge. The length of straight edge could be varied in the same manner as with the compass method, if desired.

4.2 Compass and Disc-Clinometer — Discontinuites are selected that are accessible and typical of the surface presumed to be involved, if shear failure was to occur.

4.2.1 The small scale roughness angles (i) (Fig. 3) are measured by placing the largest circular plate (for example, 40 cm dia) against the surface of the discontinuity in at least 25 different positions, and recording dip direction and dip for each position. (A surface area at least ten times as large as the area of the largest plate is assumed 18.)

4.2.2 This procedure is repeated in turn for the other plate diameters. The overall sensitivity of the measurements is improved if a large number of positions are recorded with the smaller plate diameters, for example, 50 positions with a 20 cm plate, 75 positions with a 10 cm plate and 100 positions with a 5 cm plate.

4.2.3 Each set of dip direction and dip data is plotted on a separate equal area not in terms of poles. Contours are drawn for each set of poles.

4.2.4 Photographs representing surfaces of minimum, modal and maximum roughness should be taken, with a 1 m rule placed against the surfaces in question clearly visible.

NOTE 1 — The smallest base plates give the greatest scatter of readings and also the largest roughness angles. The largest base plates give the least scatter of readings and also the smallest roughness angles.

NOTE 2 — The large number of dip direction and dip readings (from approximately 200 plate positions) represents at least one hours work per sampled plane. This will only be justified in special circumstances. If a large number of discontinuities need to be measured. the photogrammetric method is recommended. Alternatively, if the potential sliding direction is known, the profiling method is recommended, thereby reducing the amount of data collection to the single direction of potential sliding.

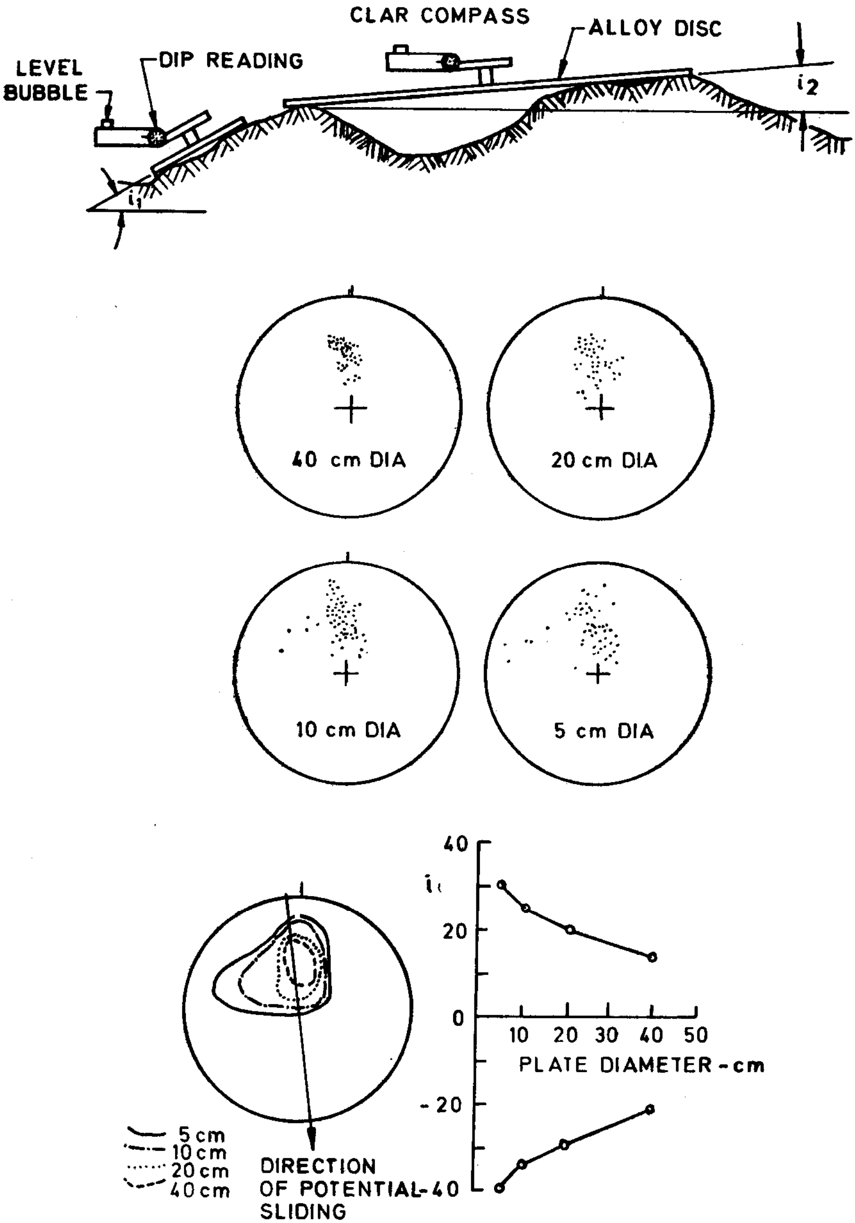

FIG. 3 A METHOD OF RECORDING DISCONTINUITY ROUGHNESS IN THREE DIMENSIONS FOR CASES WHERE THE POTENTIAL, DIRECTION OF SLIDING IS NOT YET KNOWN. CIRCULAR DISCS OF DIFFERENT DIMENSIONS (5, 10, 20 AND 40 CM) ARE FIXED IN TURN TO A CLAR COMPASS AND CLINOMETER. THE DIP DIRECTION AND DIP READINGS ARE PLOTTED AS POLES ON EQUAL-AREA NETS

NOTE 3 — The maximum roughness angles for the given disc sizes can be plotted for any direction of potential sliding (*see* Fig. 3). The tangent of these maximum roughness angles multiplied by the appropriate base length (disc diameter) gives the displacement (dilation) that will occur perpendicular to the discontinuity for a shear displacement equal to the given base length. Several base lengths (disc diameters) are analysed in this way, so that a dilation curve can be obtained. This will give a realistic picture of the shearing process when there is minimal damage to asperities. The method is, therefore, most appropriate to shearing of joints in hard rocks at low effective normal stress levels. (Asperities smaller than the minimum plate diameter are assumed not to influence the process of dilation.)

4.3 Photogrammetric Method — In special cases, terrestial photogrammetry can be used to obtain the coordinates of numerous points on the surface of inaccessible discontinuities using the procedures outlined under photogrammetric method. From this data, it is possible to compute contour maps or profiles of the surface roughness. The minimum contour intervals will depend on the distance of the camera base from the surface in question. In some instances, 1 mm intervals might be achieved, though 1 cm or 5 cm would be more likely, profiles should be, computed for the direction of potential sliding, if this is known.

NOTE — The coordinates representing points on the surface of the given discontinuity are recorded using a stereoscopic plotting instrument or a stereo comparator, with automatic recording equipment (that is, punched tape). Roughness profiles can be drawn by computer. Methods are available for estimating the shear strength and dilation characteristics of discontinuities (specifically unfilled joints), based on statistical analysis of these surface coordinates.

5. PRESENTATION OF RESULTS

5.1 Linear Profiling — The x and y readings should be plotted to the same scale (not distorted) and inclined correctly, as shown digrammatically in the inset to Fig. 2. Profiles representing the minimum, most common, and maximum roughness should be drawn on the same page to make comparison easier. The three profiles may represent a discontinuity set, a single critical discontinuity, or each surface sampled. This will depend on the amount of detail required. A scale should be included in all the drawings. Profiles should be identified clears, and the azimuth and dip of the measuring direction should be stated, in case this differs from the previously recorded orientation α/β of the discontinuity.

5.1.1 Photographs of the relevant surfaces showing minimum, modal and maximum roughness should be presented together with the profiles.

5.2 Compass and Disc-Clinometer — The field measurements of dip direction and dip obtained with the various diameters of disc should be plotted as poles on equal area nets, one for each disc. These can be combined and presented on a single contoured plot, as shown in Fig. 3.

5.2.1 Measurements from several discontinuities of a given set may be grouped on the same equal area net if desired, to show the range of roughness (and the overall variation in orientation caused by any waviness).

5.2.2 Photographs of the relevant surfaces showing minimum, modal and maximum roughness should be presented together with the pole diagrams.

5.3 Photogrammetric Method — For purposes of visual presentation in a report, the most useful figures will be profiles rather than contour diagrams of surface roughness. The profiles, which will normally be plotted by computer, should be presented with 1 : 1 vertical : horizontal scales in preference to exaggerated vertical scales.

5.3.1 If the direction of potential sliding is unknown, the profiles should be computed and presented to represent the roughness in the line of dip (dip vector direction). Correctly oriented profiles can be produced at a later stage.

5.3.2 Photographs of the relevant surfaces showing minimum, modal and maximum roughness should be presented together with the profiles.

5.4 Descriptive Terms — In the preliminary stages of field mapping (that is, during feasibility studies) time limitations may prevent the use of the above roughness measuring techniques. The description of roughness will be limited to descriptive terms which should be based on two scales of observation:

a) Small scale (several centimetres), and

b) Intermediate scale (several metres),

The descriptive terms are:

i) Rough (or irregular), stepped;

ii) Smooth, stepped;

iii) Slickensided, stepped;

iv) Rough (or irregular), undulating;

v) Smooth undulating;

vi) Slickensided, undulating;

vii) Rough (or irregular), planer;

viii) Smooth, planer; and

ix) Slickensided, planer.

5.4.1 The term 'slickensided' should only be used if there is clear evidence of previous shear displacement along the discontinuity.

5.4.2 The intermediate scale of roughness is divided into three degrees : stepped, undulating and planer, and the small scale of roughness superimposed on the intermediate scale is also divided into three degrees, rough (or irregular), smooth, and slickensided. The direction of striations or slikensides should be noted as shear strength may vary with direction. Roughness profiles typical of the nine classes are illustrated in Fig. 4. [The effective roughness angles (*i*) displayed by the nine categories of profile mean that in terms of shear strength, I > II, > III, IV, > V, > VI, VII, > VIII, > IX assuming that mineral coatings are entirely absent, or present in equal amounts. It is also evident that I > IV > VII, II > V > VIII, III > IX and VI > IX. Some of the inequalities are less certain. For example VII might be stronger than III. This would depend on whether or not dilation was inhibited. Around an underground excavation, dilation is usually inhibited by the stiffness of the surrounding rock mass. Beneath a rock slope, it may not be.]

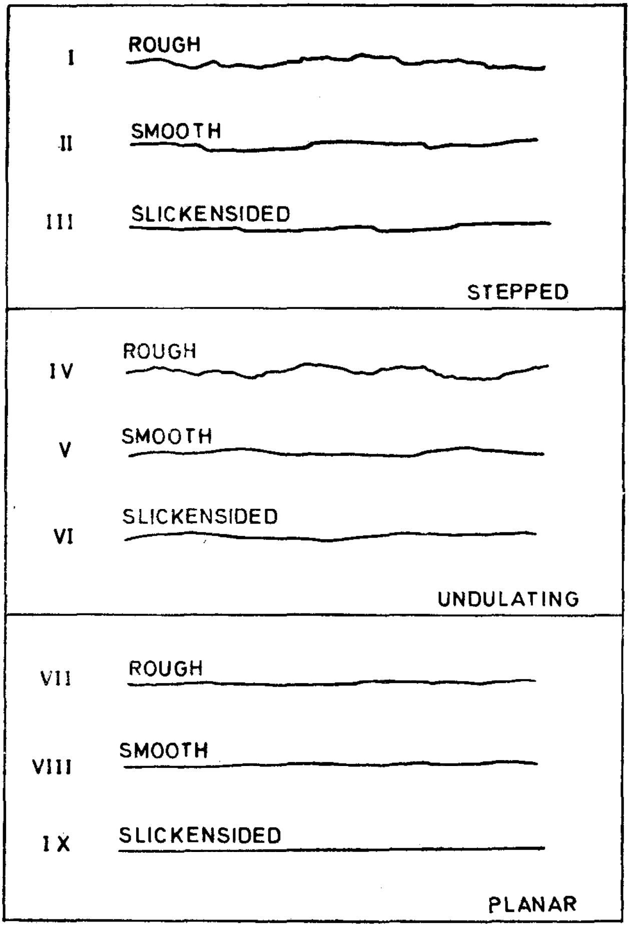

FIG. 4 TYPICAL ROUGHNESS PROFILES AND SUGGESTED NOMENCLATURE, THE LENGTH OF EACH PROFILE IS IN THE RANGE 1 TO 10 METRES. THE VERTICAL AND HORIZONTAL SCALES ARE EQUAL

5.4.3 There may also be a large scale waviness superimposed on the above small and intermediate scales of observation. In such cases, these characteristics should also be noted, that is smooth, undulating (class V) with large scale waviness 10 m wave length, 50 m amplitude.

5.4.4 The descriptions associated with persistence, that is, systematic sub-systematic, non systematic will obviously be of greatest importance in determining the relative importance of the above descriptions of roughness.

6. ESTIMATION OF SHEAR STRENGTH

6.1 The main purpose in describing the roughness of the walls of discontinuities is to facilitate the estimation of shear strength, in particular, in the case of unfilled discontinuities where estimates may be quite accurate.

6.2 In crude terms, shear strength will consist of a maximum (peak) or minimum (residual) friction angle, or some intermediate angle (depending upon the degree of previous shear displacement) plus a contribution (i) due to large scale waviness, if this exists.

thus

$$\tau = \sigma_n \tan (\phi + i)$$

where

τ = shear strength (peak or residual),

ϕ = friction angle (peak or residual),

n = effective normal stress, and

i = waviness (if present).

6.2.1 The value of (peak friction angle) ϕ_p will depend on the value of σ_n and on the degree of roughness. In the case of unfilled joints, ϕ_p values generally range from 30 to 70° and commonly average about 45°. In the case of joints having vertical or very steep steps, or less than 100 percent persistence, there will also be a cohesion (c) to add to the above value of ϕ_p for example profiles I, II and III (*see* Fig. 4).

6.2.2 The value of residual friction angle, ϕ_r depends on degree of weathering of discontinuity walls and on the rock type. In the absence of weathering, ϕ_r usually varies from 25 to 35, and is most commonly around 30°. In the case of strongly weathered walls, the value may fall to around 15°, even in the absence of actual clay fillings. A method of estimating ϕ_r is based on the ratio between the Schmidt hammer rebound (r) obtained on the weathered rock wall and the rebound (r) obtained on the unweathered rock.

6.2.3 Values of ϕ_p can be estimated using the following formula:

$$\phi_p = \text{JRC} \log_{10} \left(\frac{\text{JCS}}{\sigma n} \right) + \phi_r$$

where

JRC = joint roughness coefficient, and

JCS = joint-wall compression strength.

The method of application is illustrated in Fig. 5. Firstly, the measured roughness profiles are matched with the three sets given at the top of Fig. 5, to obtain an estimate of the appropriate JRC value. (More detailed profiles are given in Fig. 6 to facilitate this quantification.) Secondly, the discotinutiy walls are tested with a Schmidt hammer to estimate JCS and ϕ_r. Note that in Fig. 5, ϕ_r has been assumed as 30° in every case. The above method is a surprisingly accurate and cheap method of estimating ϕ_p.

6.2.4 Since peak shear strength is mobilized after relatively small displacements, it may not be realistic to add the large scale wavinees angle (*i*) to .his estimate of ϕ_p. For most practical purposes, ϕ_p can be regarded as the maximum value for a joint of 100 percent persistence. However, ϕ_r is not mobilized until relatively large displacements have occurred, which generally makes the large scale waviness angle (*i*) a realistic addition to shear strength. In the case of completely planer discontinuities or discontinuities that have sheared to the extent that no further dilation is possible, then ϕ_r will be the only shear strength component left, and will represent the absolute minimum shear strength for that discontinuity.

6.2.5 The above method for estimating the JRC value of a measured roughness profile is obviously subjective. Objective methods of analysing profiles are compass and disc-clinometer method and photogrammetric method. As described under notes under **4.2.4**, the method of analyzing compass and disc-clinometer readings results in a dilation curve which is a plot of roughness (*i*) angles *versus* shear displacement. These (*i*) angles are added to ϕ_r, to estimate the shear strength for displacements intermediate between peak and residual strength.

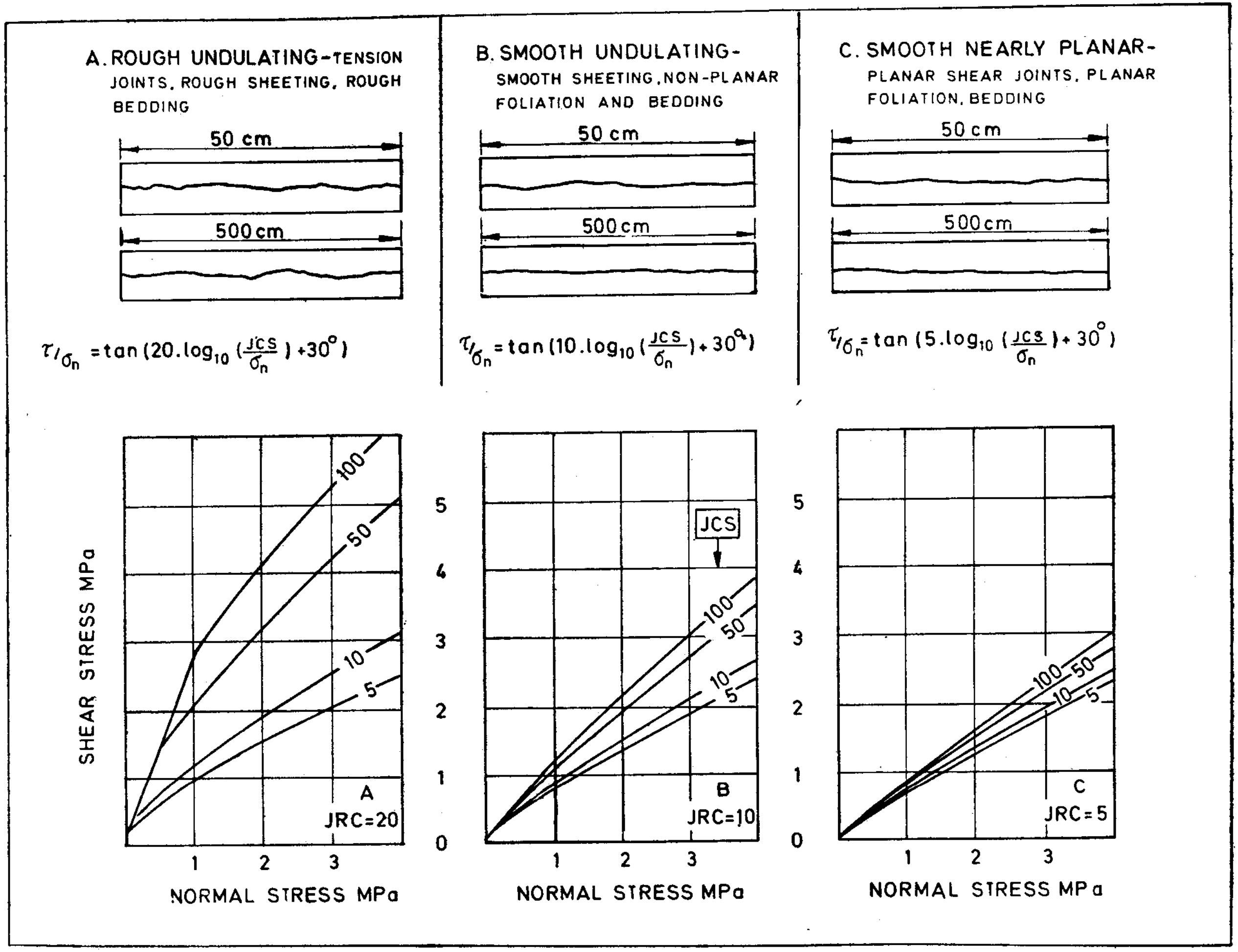

Fig. 5 A Method of Estimating Peak Shear Strength from Roughness Profiles. Each Curve is Numbered with the Appropriate JCS Value (Units of MPa). The Roughness Profiles are Intended as an Approximate Guide to the Appropriate JRC Values 20, 10 and 5. Completely Smooth Planar Joints have JRC = 0

As in the Original Standard, this Page is Intentionally Left Blank

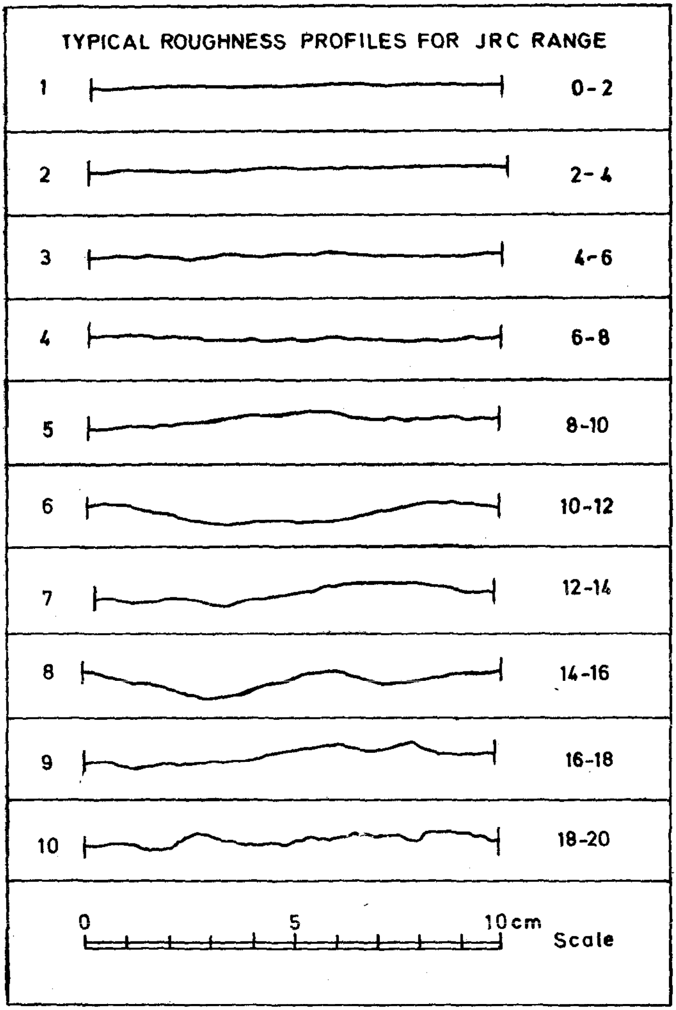

Fig. 6 Roughness Profile and Corresponding Range of JRC Values Associated with Each One

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

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002

Telephones: 331 01 31, 331 13 75 Telegrams: Manaksanstha (Common to all Offices)

Regional Offices:	*Telephone*
Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002	331 01 31 331 13 75
*Eastern : 1/14 C. I. T. Scheme VII M, V. I. P. Road, Maniktola, CALCUTTA 700054	36 24 99
Northern : SCO 445-446, Sector 35-C, CHANDIGARH 160036	2 18 43 3 16 41
Southern : C. I. T. Campus, MADRAS 600113	41 24 42 41 25 19 41 29 16
†Western : Manakalaya, E9 MIDC, Marol, Andheri (East), BOMBAY 400093	6 32 92 95

Branch Offices:	
'Pushpak', Nurmohamed Shaikh Marg, Khanpur, AHMADABAD 380001	2 63 48 2 63 49
Peenya Industrial Area, 1st Stage, Bangalore Tumkur Road, BANGALORE 560058	38 49 55 38 49 56
Gangotri Complex, 5th Floor, Bhadbhada Road T. T. Nagar, BHOPAL 462003	6 67 16
Plot No. 82/83, Lewis Road, BHUBANESHWAR 751002	5 36 27
53/5, Ward No. 29, R.G. Barua Road, 5th Byelane, GUWAHATI 781003	—
5-8-56C L. N. Gupta Marg (Nampally Station Road), HYDERABAD 500001	23 10 83
R14 Yudhister Marg, C Scheme, JAIPUR 302005	6 34 71 6 98 32
117/418 B Sarvodaya Nagar, KANPUR 208005	21 68 76 21 82 92
Patliputra Industrial Estate, PATNA 800013	6 23 05
T.C. No. 14/1421, University P.O., Palayam TRIVANDRUM 695035	7 66 37

Inspection Offices (With Sale Point):	
Pushpanjali, First Floor, 205-A West High Court Road, Shankar Nagar Square, NAGPUR 440010	2 51 71
Institution of Engineers (India) Building, 1332 Shivaji Nagar, PUNE 411005	5 24 35

*Sales Office in Calcutta is at 5 Chowringhee Approach, P. O. Princep Street, Calcutta 700072 27 68 00

†Sales Office in Bombay is at Novelty Chambers, Grant Road, Bombay 400007 89 65 28

Printed at Printograph, New Delhi, India