भारतीय मानक
Indian Standard

IS 18300 : 2023

भूस्खलन प्रभावित ढलानों के रॉक मास शीयर की ताकत का निराधारण के लिए — दिशानिर्देश

Determination of Rock Mass Shear Strength of Landslide Affected Slopes — Guidelines

ICS 93.060

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुर शाह ज़फर मार्ग, नई दिल्ली - 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI - 110002
www.bis.gov.in www.standardsbis.in

July 2023 **Price Group 7**

Rock Mechanics Sectional Committee, CED 48

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Rock Mechanics Sectional Committee had been approved by the Civil Engineering Division Council.

A substantial part of India especially the region belonging to Himalayas and north-east is primarily mountainous. This region is severely affected by occurrences of landslides. Landslides occur due to downslope movement of soil or rock on a failure plane. It is estimated that the country suffers hundreds of crores of rupees per year and number of casualties. The landslide affected areas in Himalayan regions generally have heterogeneous mixture of geomaterials. To effectively analyse and design mitigation measures, it is essential that the engineers and geologists should have adequate understating of the shear strength of the geomaterials along which the failure occurs during landslides. Most often the talus deposits and debris is underlain by bedrock and the shear strength response of bed rock is a complex phenomenon. The rock mass at landslide location acts under unconstrained condition which results in substantial dilation thereby introducing complexities in failure mechanism. Assessment of rock mass shear strength is a challenging task.

In case of soils, the samples can be retrieved and tested either in the field or in laboratory to obtain shear strength parameters. Small specimens of soils having a diameter of 38 mm and length 76 mm may be treated to represent the behaviour of the actual soil mass as the specimen comprises of millions of soil particles and failure would occur due to sliding, translation, rotation, overriding of the constituent grains. There would be minimum breakage of grains and specimen would fail due to failure of ‘mass’ and not the ‘grains’. In case of rock masses also, the failure is mainly governed by the presence of joints, fractures, foliation and schistocity planes and extent of weathering. During failure of the rock mass, the rock blocks slide, translate, and rotate. The representative volume of the rock mass, which will replicate the failure in the field, would be very large. It is extremely difficult, to load these large specimens of rock mass in the field up to failure. It is also not feasible to bring such a big undisturbed specimen of rock mass to laboratory and test for strength. This constraint of requirement of very large representative volume compels the engineers to derive the shear strength parameters indirectly, rather than obtaining them directly through laboratory or field testing. For this purpose, the intact rock specimens are tested in the laboratory and the effect of weathering, jointing and fracturing is separately incorporated.

Though a great deal of progress has been made during last few decades in the direction of assessment of shear strength of jointed and weathered rocks, the field engineers face challenge in resolving the issues as no guidance document is available to the engineering community for guiding how systematically the shear strength response of jointed and weathered rocks could be assessed.

The aim of this Indian Standard is to provide a guidance to field engineers to readily assess the shear strength of rocks encountered at the landslide site. This standard is the outcome of a study done at Indian Institute of Technology Roorkee and funded by National Disaster Management Authority, New Delhi.

This standard contributes to the following United Nations Sustainable Development Goal 9 'Industry, innovation and infrastructure' towards building resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation; and Goal 11 ‘Sustainable cities and communities' towards making cities and human settlements inclusive, safe, resilient and sustainable.

The composition of the Committee responsible for the formulation of this standard is given in Annex C.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

DETERMINATION OF ROCK MASS SHEAR STRENGTH OF LANDSLIDE AFFECTED SLOPES — GUIDELINES

1 SCOPE

This standard covers general guidelines for assessing rock mass shear strength of landslide affected slopes.

2 REFERENCES

The standards listed in Annex A contain provisions that, through references in the text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of these standards.

3 INVESTIGATIONS

Detailed investigations will be done as per IS 17163.

The investigations will include surface, subsurface investigations, collections of rock samples, field and laboratory tests. The drill holes should be properly logged (as per IS 4464) to extract as much information as possible. The bore hole logs should include the detailed information such as: geology, colour, hardness, lithology, degree of weathering, alterations and fractures, strike and dip of bedding/foliation and other joints/discontinuities, core recovery, rock quality designation (RQD) disturbed washed sample and ground water levels.

3.1 Field Tests

The following field tests should be done as per the Indian standards:

Field Tests	*Indian Standard*
Uniaxial jacking test for deformation modulus of rock mass	IS 7317
In-situ shear test on rock mass	IS 7746
Quantitative description of discontinuities in rock mass for drill core study	IS 11315 (Part 12)
Method for determination of hardness of rock	IS 12608
Rock joints direct shear strength	IS 12634
In-situ determination of rock mass deformability	IS 12955 (Part 2)
Quantitative classification system of rock mass — Rock mass rating	IS 13365 (Part 1)
Quantitative classification system of rock mass — Determination of slope mass rating	IS 13365 (Part 3)
Quantitative classification system of rock mass — Geological strength index	IS 13365 (Part 4)
Borehole jack test for determination of modulus of deformation of rock mass	IS 17511

3.2 Laboratory Tests

On intact rock specimens or on lumped rock samples, the following tests may be carried out as per the Indian standards:

Laboratory Tests	*Indian Standard*
Point load strength index of rocks	IS 8764
Unconfined compressive strength of rock materials	IS 9143
Preparation of rock specimen	IS 9179
Modulus of elasticity and poison’s ratio of rock materials in uniaxial compression	IS 9221
Slake durability index of rock	IS 10050
Tensile strength by indirect tests on rock specimens	IS 10082
Water content, porosity, density and related properties of rock material	IS 13030
Strength of rock materials in triaxial compression	IS 13047

4 CLASSIFICATION APPROACHES

4.1 Rock Mass Classifications

Rock mass classifications should be done as per the relevant Indian standards. The relevant standards for individual rock mass parameter are as given below:

Classification	*Indian Standard*
Quantitative classification system of rock mass — Rock mass rating for predicting of engineering properties	IS 13365 (Part 1)
Rock mass quality for prediction of support pressure, support system and engineering properties in underground openings	IS 13365 (Part 2)
Determination of slope mass rating	IS 13365 (Part 3)
Geological strength index (GSI)	IS 13365 (Part 4)

4.2 Intact Rock Classification

Intact rock will be classified based on compressive strength and modulus of the rock (Table 1 and Table 2). Extended version of Deere-Miller Classification system will be used. The rocks shall be classified by using two lettered symbol for example, (CD). The first letter indicates the range of the strength and the second letter represents class of modulus ratio. The modulus ratio will be obtained as follows:

$$M_{\mathrm{ri}} = \frac{E_{\mathrm{ti}}}{\sigma_{\mathrm{ci}}} \qquad \dots (1)$$

where, M_{ri} is the modulus ratio, E_{ti} is the tangent modulus and σ_{ci} is the uniaxial compressive strength (UCS) of the intact rock.

The ranges of strength and modulus ratio for different classes are presented in Table 1 and Table 2. The classification chart is shown in Fig. 1 with envelopes for different rock groups.

5 KINEMATIC ANALYSIS

Depending on attitude of the discontinuities and exposed rock face, there may exist possibility of planar, wedge, circular, flexure and toppling failure of rock mass. The shear strength parameters of the joint surfaces should be obtained and kinematic analysis should be performed.

6 ROCK MASS SHEAR STRENGTH

The rock masses in landslide affected area acts under low confinement. Due to high dilation under low confinement, the shear strength behaviour is highly non-liner. Non-linear failure criteria should be used to assess the shear strength.

Table 1 Strength Classification of Intact Rock

(*Clause* 4.2)

Sl No. (1)	**Class** (2)	**Description** (3)	$\boldsymbol{\sigma_{\mathrm{ci}}}$ **(MPa)** (4)
i)	A	Very high strength	> 250
ii)	B	High strength	100 to 200
iii)	C	Moderate strength	50 to 100
iv)	D	Medium strength	25 to 50
v)	E	Low strength	5 to 25
vi)	F	Very low strength	< 5

Table 2 Modulus Ratio Classification of Intact Rock

(*Clause* 4.2)

Sl No. (1)	**Class** (2)	**Description** (3)	$\boldsymbol{\sigma_{\mathrm{ci}}}$ **(MPa)** (4)
i)	A	Very high modulus ratio	> 250
ii)	B	High modulus ratio	100 to 200
iii)	C	Medium modulus ratio	50 to 100
iv)	D	Low modulus ratio	25 to 50
v)	E	Very low modulus ratio	5 to 25

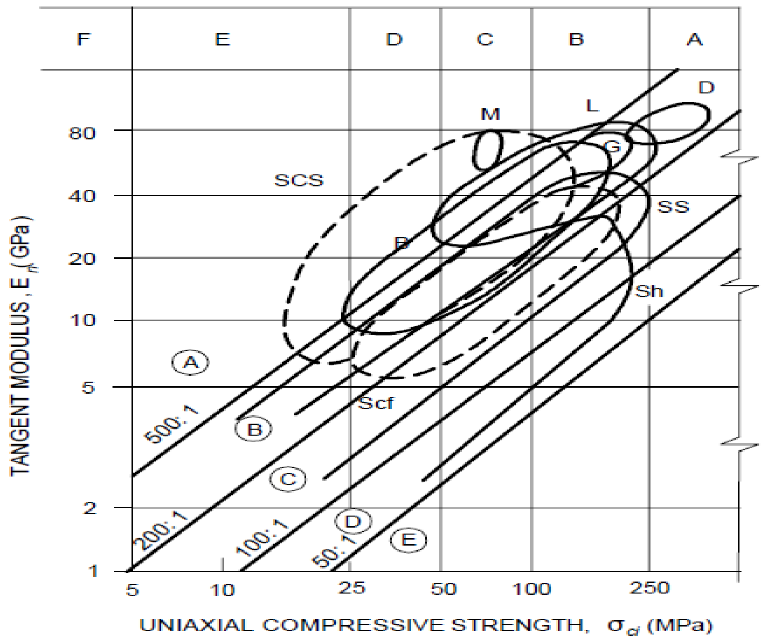

FIG. 1 CLASSIFICATION CHART FOR INTACT ROCK

6.1 Jointed Fresh Rock Mass

To obtain shear strength parameters, the triaxial strength of the rock mass will be simulated by using a non-linear strength criterion. Values of major principal stress at failure (σ_1) will be obtained for varying values of minor principal stress (σ_3). Using this data the equivalent Mohr-Coulomb parameters c and ∅ will be obtained. The following strength criterion is suggested for rock mass:

$$\left(\frac{\sigma_1-\sigma_3}{\sigma_3}\right) = B_\mathrm{j}\left(\frac{\sigma_\mathrm{cj}}{\sigma_3}\right)^{\alpha_\mathrm{j}} \qquad \ldots (2)$$

where σ_cj : UCS of the jointed rock.

$\alpha_\mathrm{j}, \beta_\mathrm{j}$: Criterion parameters for rock mass defined as follows:

$$\frac{\alpha_\mathrm{j}}{\alpha_\mathrm{i}} = \left(\frac{\sigma_\mathrm{cj}}{\sigma_\mathrm{ci}}\right)^{0.5} \qquad \ldots (3)$$

$$\frac{B_\mathrm{i}}{B_\mathrm{j}} = 0.13\exp\left[2.037\left(\frac{\sigma_\mathrm{cj}}{\sigma_\mathrm{ci}}\right)^{0.5}\right] \qquad \ldots (4)$$

where, $\alpha_\mathrm{i}, \beta_\mathrm{i}$: are criterion parameters obtained for intact rock.

Triaxial strength tests will be conducted on intact rock specimens and the following non-linear strength criterion will be used and best fitting parameters $\alpha_\mathrm{i}, \beta_\mathrm{i}$ will be obtained.

$$\left(\frac{\sigma_1-\sigma_3}{\sigma_3}\right) = B_\mathrm{i}\left(\frac{\sigma_\mathrm{ci}}{\sigma_3}\right)^{\alpha_\mathrm{i}} \qquad \ldots (5)$$

To fit experimental data, the expression given above can be converted into linear form by taking log of both side. An example is given in Annex B.

6.2 Assessment of UCS of Rock Mass (σ_cj)

6.2.1 *Rock Mass Strength from Deformability Test*

In-situ deformability tests provide information on deformability of the rock mass. The following empirical relation may be used to get the UCS of the rock mass from deformability tests:

$$\frac{\sigma_\mathrm{cj}}{\sigma_\mathrm{ci}} = \left(\frac{E_\mathrm{j}}{E_\mathrm{i}}\right)^{0.63} \qquad \ldots (6)$$

where, σ_cj is the rock mass strength; σ_ci is the intact rock strength; E_j is the elastic modulus of rock mass; and E_i is the intact rock modulus available from laboratory tests and taken equal to the tangent modulus at stress level equal to 50 percent of the intact rock strength.

It should be ensured that the deformability results are obtained under nearly unconfined state of the rock mass.

The elastic modulus of rock mass, E_j may be obtained in the field by conducting uniaxial jacking tests (IS 7317) in drift excavated for the purpose. Alternatively, cyclic plate load tests may also be performed on the rock to get the elastic modulus. The modulus should preferably be obtained from 2nd or higher cycle.

6.2.2 *Joint Factor Approach*

If the joints are well developed the effect of joint may be taken into account by considering joint frequency, critical joint orientation and strength along the critical joint. Joint/joint set orientation close to $45 - \emptyset_j/2$ with vertical direction will be considered most critical.

Joint factor will be calculated as:

$$J_f = \frac{J_n}{n.r} \quad \ldots (7)$$

where J_n is joint frequency in vertical direction; n is inclination parameter that depends on inclination of critical joint (Table 3) and r is joint strength parameter, which depends on condition of joints that is, cemented, tight, open, weathered or filled with gouge.

Table 3 Values of Parameter n for Different Joint Orientations β°
(Angle of joint plane with loading direction)

(*Clause* 6.2.2)

Sl No.	β°	Range of Parameter n
(1)	(2)	(3)
i)	0	0.82 to 0.86
ii)	10	0.46 to 0.60
iii)	20	0.11 to 0.20
iv)	30	0.05 to 0.06
v)	40	0.09 to 0.12
vi)	50	0.30 to 0.45
vii)	60	0.46 to 0.80
viii)	70	0.64 to 0.90
ix)	80	0.82 to 0.95
x)	90	0.95 to 0.98

The joint strength parameter r, will be obtained from direct shear tests.

$$r = \frac{\tau_{fj}}{\sigma_{nj}} = \tan\emptyset_j \quad \ldots (8)$$

where

τ_{fj} = shear strength along joint;
σ_{nj} = normal stress on the joint; and
$\emptyset_j$ = equivalent value of friction angle (including effect of cohesion in case of cemented joints).

If direct shear test data is not available for rock with tight unfilled joints, UCS of the rock is suggested to be used (Table 4). For filled up joints the value of parameter r will be used as per Table 5.

Table 4 Suggested Values of r if Direct Shear Test Data is not Available

(*Clause* 6.2.2)

Sl No.	Uniaxial Compressive Strength, MPa	Joint Strength Parameter, r
(1)	(2)	(3)
i)	2.5	0.30
ii)	5.0	0.45
iii)	15.0	0.60
iv)	25.0	0.70
v)	45.0	0.80
vi)	65.0	0.90
vii)	100	1.00

Table 5 Joint Strength Parameter r for Filled up Joints at Residual Stage

(*Clause* 6.2.2)

Sl No.	Gouge Material	Friction Angle	Joint Strength Parameter $r = \tan(\emptyset_j)$
(1)	(2)	(3)	(4)
i)	Gravelly sand	45°	1.80
ii)	Coarse sand	48°	0.84
iii)	Fine sand	35°	0.70
iv)	Silty sand	32°	0.62
v)	Clayey sand	30°	0.58
vi)	Clay silt:		
	Clay – 25 percent	25°	0.47
	Clay – 50 percent	15°	0.27
	Clay – 75 percent	10°	0.18

Based on J_f the following equations is suggested for computing UCS of rock mass

$$\sigma_{cj} = \sigma_{ci}\exp(-0.008\, J_f) \quad \ldots (9)$$

The strength should be calculated for all joint sets and minimum value out of these should be considered.

6.3 Use of Weathering Rock Mass Classification System

6.3.1 The classification system incorporates the weathering indices on the basis of total core recovery and rebound hammer values for assessing strength of various chemically weathered rock mass. This quantitative weathering classification system has been developed on the basis of field study of more than 30 weathered profiles and laboratory testing for index and material properties. The material and mass parameters used for the classification are:

a) Strength ratio, R_s;
b) State of joint weathering, J_{wt};
c) Number of joints, J_n; and
d) Joint width, J_{wd}.

All the important elements of rock mass, affected by weathering, have been considered by using a rating system as in Table 6. All the parameters are not of equal importance in the assessment of rock mass strength thus, it is necessary to assign a numerical weightage to each parameter according to influence of weathering on it. Summing up the weighted values determined for the individual parameter in each zone marks the final rating for the rock mass. Higher value of final rating, R/w reflects less weathering. The recommended rating for each parameter and each class is presented in Table 7. Based on final rating, the zones of profile may be classified according to the range of total ratings suggested in Table 7.

6.3.2 *Strength Prediction*

The strength criterion as given below should be used for predicting the strength of weathered rocks:

$$(\sigma_1 - \sigma_3) = B_w(\sigma_{cw})^{\alpha_w}(\sigma_3)^{(1-\alpha_w)} \quad \text{... (10)}$$

where, B_w and α_w are weathered material constants and σ_{cw} is the UCS of weathered rock. Based on the available data and test results, the following equations are suggested for evaluating material constants:

$$\frac{B_w}{B_i} = e^{\left[\frac{R_w-100}{30}\right]} \quad \text{... (11)}$$

Table 6 Rock Weathering Classification Based on Rating System

(*Clause* 6.3)

Sl No.	**Weathered Material Grade**	**Symbol**	**Fresh**	**Slightly Weathered**	**Moderately Weathered**	**Highly Weathered**	**Completely Weathered**
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Strength Ratio	R_s	80 to 100	50 to 80	25 to 50	10 to 25	< 10
ii)	Rating	—	30	25	15	7	3
iii)	State of Joint Weathering	J_{wt}	Fresh	Slightly weathered	Moderately weathered	Highly weathered	Completely weathered
iv)	Rating	—	35	28	17	8	3
v)	Number of Joints per meter	J_n	< 2	2 to 4	4 to 8	8 to 16	> 16
vi)	Rating	—	25	20	13	6	3
vii)	Joint aperture, mm	J_{wd}	< 1.0	1 to 2	2 to 5	5 to 20	> 20
viii)	Rating	—	10	8	5	2	1

Table 7 Classified Range of Final Rating

(*Clause* 6.3)

Sl No.	**Symbol**	**Zone**	**Final Rating, R/w**
(1)	(2)	(3)	(4)
i)	Z0	Fresh rock	100 to 81
ii)	Z1	Slightly weathered	80 to 51
iii)	Z2	Moderately weathered	50 to 26
iv)	Z3	Highly weathered	25 to 11
v)	Z4	Completely weathered	10 to 1
vi)	Z5	Residual soil	0

$$\frac{\alpha_w}{\alpha_i} = e^{\left[\frac{R_W - 100}{140}\right]} \quad \text{... (12)}$$

where

R_w = rating through weathering classification, rest defined already.

Based on triaxial tests on fresh rock and UCS tests on fresh (σ_{ci}) and weathered (σ_{cw}) rock using the 'R_S', the following correlations also may be used for estimating the material constants B_W and α_W for the strength prediction at any σ_3.

$B_w/B_i = 0.008\ 9R_S + 0.09$, for granite … (13)

$B_w/B_i = 0.007\ 3R_S + 0.28$, for quartzite … (14)

$B_w/B_i = 0.008\ 3R_S + 0.17$, for basalt … (15)

$\frac{\alpha_w}{\alpha_i} = 0.002R_s + .81$,

for quartzite and granite … (16)

$\alpha_w/\alpha_i = 0.003R_S + 0.72$, for basalt … (17)

7 COMPUTATION OF EQUIVALENT MOHR-COULOMB SHEAR STRENGTH PARAMETE RS

The equivalent Mohr-Coulomb shear strength parameters c and ∅ may be obtained by simulating triaxial strength of the rock mass by using the strength criteria discussed above. A range of confining pressure (σ_3) values will used and triaxial strength (σ_1) values will be calculated. Using this set of simulated triaxial test data, the parameters c and ∅ will be obtained. The values of parameters c and ∅ will be sensitive to the range of confining pressure values used in simulating triaxial test data. The range of confining pressure values will be decided based height of slope and geological conditions so that the confinement acting over the potential failure surface in the field is closely represented. At very low confinement, the computed ∅ values may be extremely high. Personal judgement and experience should be used in such cases to reduce the computed value. Also, suitable modifications should be made for saturation conditions. Due consideration should be given to uncertainties at it is advisable that a range of values are worked out rather than a fix value of the parameter.

ANNEX A

(*Clause* 2)

LIST OF REFFERED STANDARDS

IS No.	*Title*
IS 4464 : 2020	Code of practice for presentation of drilling information and core description in geotechnical investigation (*second revision*)
IS 7317 : 2020	Uniaxial jacking test for deformation modulus of rock mass — Code of practice (*second revision*)
IS 7746 : 2022	*In-situ* shear test on rock mass — Code of practice (*second revision*)
IS 8764 : 1998	Method for determination of point load strength index of rocks (*first revision*)
IS 9143 : 1979	Method for the determination of unconfined compressive strength of rock materials
IS 9179 : 1979	Preparation of rock specimen for laboratory testing
IS 9221 : 1979	Method for determination of modulus of elasticity and poison's ratio of rock materials in uniaxial compression
IS 10050 : 1981	Method for determination of slake durability index of rock
IS 10082 : 1981	Method of test for determination of tensile strength by indirect tests on rock specimens
IS 12608 : 1989	Method for determination of hardness of rock
IS 12634 : 1989	Rock joints direct shear strength laboratory method of determination
IS 12955 (Part 2) : 1990	*In-situ* determination of rock mass deformability using a flexible dilatometer — Code of practice: Part 2 With radial displacement
IS 13030 : 1991	Method of test for laboratory determination of water content, porosity, density and related properties of rock material
IS 13047 : 1991	Method for determination of strength of rock materials in triaxial compression
IS 13365	Quantitative classification system of rock mass — Guidelines:
(Part 1) :1998	Rock mass rating (RMR) for predicting engineering properties
(Part 2) : 2019	Rock mass quality for prediction of support pressure, support system and engineering properties in underground openings (*first revision*)
(Part 3) : 1997	Determination of slope mass rating
(Part 4) : 2014	Geological strength index (GSI)
IS 17163 : 2020	Site specific investigation and stability analysis of landslides — Guidelines

ANNEX B

(*Clause* 6.1)

EXAMPLE PROBLEM FOR OBTAINING CRITERION PARAMETERS FOR INTACT ROCK

UCS and triaxial tests were performed on samples of an intact rock. The average UCS was found to be 42.9 MPa and the traixial strength was observed as follows:

σ_3, MPa	6.5	13.7	20.3	27.9
σ_1, MPa	63.3	81.7	96.5	111.1

Solution:

The criterion is written as:

$$\left(\frac{\sigma_1-\sigma_3}{\sigma_3}\right) = B_{\mathrm{i}}\left(\frac{\sigma_{\mathrm{ci}}}{\sigma_3}\right)^{\alpha_{\mathrm{i}}} \qquad \dots (18)$$

where, α_{i}, β_{i} : are criterion parameters obtained for intact rock.

Taking log of both the sides of the criterion,

$$\log_{10}\left(\frac{\sigma_1-\sigma_3}{\sigma_3}\right) = \log_{10}B_{\mathrm{i}} + \alpha_{\mathrm{I}}\log_{10}\left(\frac{\sigma_{\mathrm{ci}}}{\sigma_3}\right) \qquad \dots (19)$$

The above equation is written as an equation of straight line as follows:

$$Y = C + \alpha_{\mathrm{i}}X \qquad \dots (20)$$

where

$$X = \left(\frac{\sigma_{\mathrm{ci}}}{\sigma_3}\right) Y = \log_{10}\left(\frac{\sigma_1-\sigma_3}{\sigma_3}\right) \qquad \dots (21)$$

The values of X and Y are obtained as follows and straight line is fitted (Fig. 2)

σ_3, MPa	σ_1, MPa	$X = \left(\frac{\sigma_{\mathrm{ci}}}{\sigma_3}\right)$	$Y = \log_{10}\left(\frac{\sigma_1-\sigma_3}{\sigma_3}\right)$
6.5	63.3	0.8	0.94
13.7	81.7	0.5	0.70
20.3	96.5	0.3	0.57
27.9	111.1	0.2	0.47

From Fig. 2, $\alpha_{\mathrm{i}} = 0.738\,7 \approx 0.7$

$\log_{10}B_{\mathrm{i}} = 0.3201$

$\Rightarrow B_{\mathrm{i}} = 2.09$

The criterion parameters: α_{i}= 0.74; B_{i} = 2.09

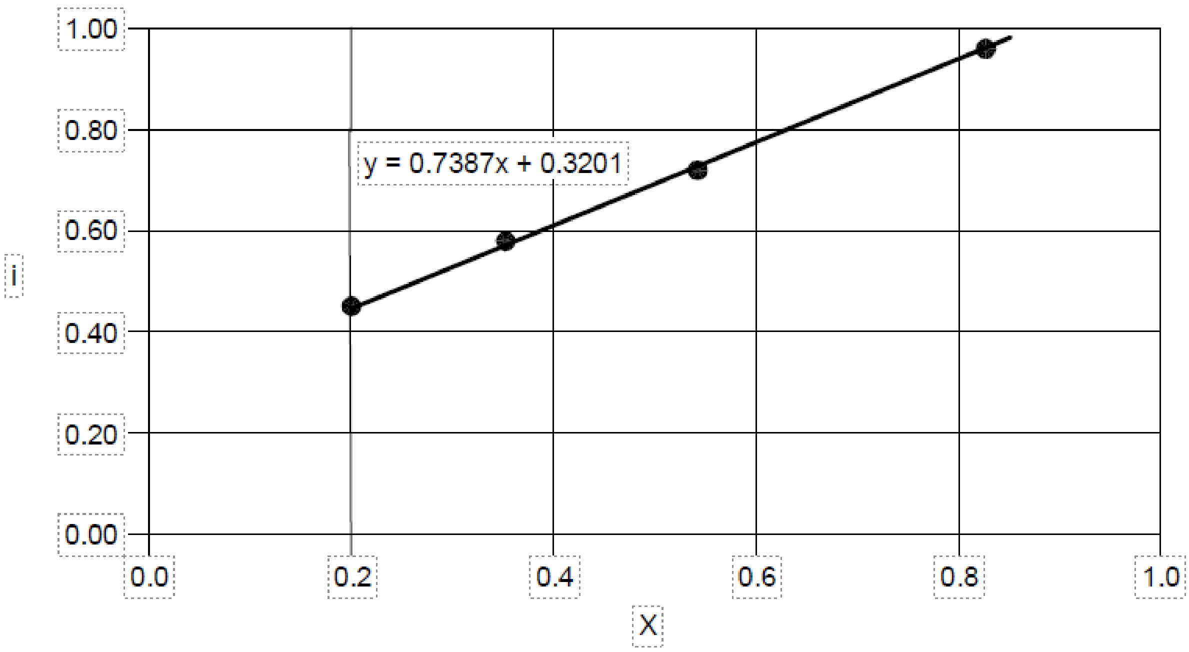

FIG. 2 FITTING OF EXPERIMENTAL DATA INTO THE FAILURE CRITERION

ANNEX C

(*Foreword*)

COMMITTEE COMPOSITION

Rock Mechanics Sectional Committee, CED 48

Organization(s)	*Representative(s)*
Indian Institute of Technology, Roorkee	DR N. K. SAMADHIYA **(*Chairperson*)**
AIMIL Limited, New Delhi	SHRI AKHIL RAJ
Amberg Technologies, Gurugram	SHRI KRIPAL CHOUDHARY SHRI RAKESH PANDITA (*Alternate*)
Border Roads Organisation, New Delhi	LT COL ANIL RAJ
Central Board of Irrigation & Power, New Delhi	SHRI G. P. PATEL SHRI UDAY CHANDER (*Alternate*)
Central Soil & Materials Research Station, New Delhi	SHRI HARI DEV SHRI MAHABIR DIXIT (*Alternate*)
Central Water and Power Research Station, Pune	SHRI RIZWAN ALI DR S. A. BURELE (*Alternate*)
Central Water Commission, New Delhi	SHRI DARPAN TALWAR M. S. HARSHITHA (*Alternate*)
CSIR - Central Building Research Institute, Roorkee	DR SHANTANU SARKAR SHRI KOUSHIK PANDIT (*Alternate*)
CSIR - Central Institute of Mining & Fuel Research, Dhanbad	DR J. K. MOHNOT DR R. D. DWIVEDI (*Alternate*)
CSIR - Central Road Research Institute, New Delhi	DR PANKAJ GUPTA SHRI R. K. PANIGRAHI (*Alternate*)
Engineers India Limited, New Delhi	DR ALTAF USMANI SHRI SAIKAT PAL (*Alternate*)
Geological Survey of India, New Delhi	SHRI SANTOSH KUMAR TRIPATHI SHRI D. P. DANGWAL (*Alternate*)
Indian Institute of Technology, New Delhi	PROF R. AYOTHIRAMAN PROF PRASHANTH VANGLA (*Alternate*)
Indian Institute of Technology, Roorkee	DR MAHENDRA SINGH DR PRITI MAHESHWARI (*Alternate*)
Indian Institute of Technology - ISM, Dhanbad	PROF A. K. MISHRA DR R. K. SINHA (*Alternate*)
Indian Society for Rock Mechanics and Tunnelling Technology, New Delhi	DR C. S. KHOKHAR
Irrigation Research Institute, Roorkee	SHRI DINESH CHANDRA SHRI SHANKAR KUMAR SAHA (*Alternate*)

Organization	*Representative(s)*
Indian Institute of Technology - ISM, Dhanbad	JS (MITIGATION) DR RAVINDER SINGH (*Alternate*)
National Highways & Infrastructure Development Corporation Limited, Delhi	SHRI SANJEEV MALIK SHRI ASHOK KUMAR JHA (*Alternate*)
National Highways Authority of India, New Delhi	REPRESENTATIVE
National Hydroelectric Power Corporation Limited, Faridabad	SHRI RAJESH KUMAR SHRI AJAY KUMAR VERMA (*Alternate* I) SHRI PRADEEP KUMAR GARNAYAK (*Alternate* II)
National Institute of Rock Mechanics, Bengaluru	DR A. RAJAN BABU SHRI G. GOPINATH (*Alternate*)
NTPC Limited, New Delhi	SHRI N. K. JAIN SHRI PRAKASH RAWAT (*Alternate*)
Rail Vikas Nigam Limited, New Delhi	SHRI SUMIT JAIN SHRI VIJAY DANGWAL (*Alternate*)
Reliance Industries Limited, Mumbai	SHRI ABHISHEK SAMPATRAO BHOSALE
RITES Limited, Gurugram	SHRIMATI JYOTSNA DIXIT SHRI SANDEEP SINGH NIRMAL (*Alternate*)
THDC India Limited, Rishikesh	SHRI T. S. ROUTELA SHRI SAMRAT MUKHERJEE (*Alternate*)
In Personal Capacity, (*Flat No. 4123, Tower 4, ACE Golfshire, Sector-150, Noida - 201310*)	SHRI R. K. GOEL
In Personal Capacity (*Naimex House, A-8, Mohan Co-operative Industrial Estate, Mathura Road, New Delhi - 110044*)	SHRI SHARIQUE KHAN
In Personal Capacity (*Jal Vidyut Apts, Sector 21-C, Faridabad - 121001*)	SHRI IMRAN SAYEED
In Personal Capacity (*A-125. Prodhyagiki Apartment, Sector-3, Dwarka, New Delhi - 110059*)	DR RAJBAL SINGH
In Personal Capacity (*C-1004, Park View City-2, Sector - 49, Gurugram - 122018*)	DR MANOJ VERMAN
BIS Directorate General	SHRI ARUNKUMAR S., SCIENTIST 'E'/DIRECTOR AND HEAD (CIVIL ENGINEERING) [REPRESENTING DIRECTOR GENERAL (*Ex-officio*)]

Member Secretary
DR MANOJ KUMAR RAJAK
SCIENTIST 'D'/JOINT DIRECTOR
(CIVIL ENGINEERING), BIS

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act*, 2016 to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the website-www.bis.gov.in or www.standardsbis.in.

This Indian Standard has been developed from Doc No.: CED 48 (20399).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones: 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.gov.in

Regional Offices:		*Telephones*
Central	: 601/A, Konnectus Tower -1, 6th Floor, DMRC Building, Bhavbhuti Marg, New Delhi 110002	2323 7617
Eastern	: 8th Floor, Plot No 7/7 & 7/8, CP Block, Sector V, Salt Lake, Kolkata, West Bengal 700091	2367 0012 2320 9474
Northern	: Plot No. 4-A, Sector 27-B, Madhya Marg, Chandigarh 160019	265 9930
Southern	: C.I.T. Campus, IV Cross Road, Taramani, Chennai 600113	2254 1442 2254 1216
Western	: Plot No. E-9, Road No.-8, MIDC, Andheri (East), Mumbai 400093	2821 8093

Branches : AHMEDABAD. BENGALURU. BHOPAL. BHUBANESHWAR. CHANDIGARH. CHENNAI. COIMBATORE. DEHRADUN. DELHI. FARIDABAD. GHAZIABAD. GUWAHATI. HIMACHAL PRADESH. HUBLI. HYDERABAD. JAIPUR. JAMMU & KASHMIR. JAMSHEDPUR. KOCHI. KOLKATA. LUCKNOW. MADURAI. MUMBAI. NAGPUR. NOIDA. PANIPAT. PATNA. PUNE. RAIPUR. RAJKOT. SURAT. VISAKHAPATNAM.

Published by BIS, New Delhi