Draft Indian Standard

QUANTITATIVE CLASSIFICATION SYSTEM OF ROCK MASS – GUIDELINES
PART 3 DETERMINATION OF SLOPE MASS RATING

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.

Slope mass rating (SMR) is a measure of degree of stability of rock slopes. The determination of slope mass rating is very easy and yet reliable. This method is recommended for landslide hazard zonation for feasibility studies in the hilly areas where rock is exposed.

Slope mass rating takes into account orientation of joints, seepage forces, fracture spacing, degree of weathering and method of excavation. It also considers mode of failures; for example, planar slide, wedge slide and toppling failure.

Detailed study of rock slopes is needed, if SMR is found to be less than 60 or slope appears to be in distress.

Technical Committee responsible for the formulation of this standard is given in Annex A.

In reporting the results 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) : 'Rules for rounding off numerical values (revised)'.

Draft Indian Standard

QUANTITATIVE CLASSIFICATION SYSTEM OF ROCK MASS – GUIDELINES PART 3 DETERMINATION OF SLOPE MASS RATING

1 SCOPE

1.1 This standard (Part 3) covers the procedures for obtaining the value of slope mass rating (SMR) for preliminary assessment of the stability of rock slopes. The approach is based on modification of RMR system using adjustment factors related to discontinuity orientation with reference to slope as well as failure mode and slope excavation methods.

2 REFERENCES

The Indian Standards given below contain provisions which through reference in this text, constitute provision 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 these standards are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
8764:1978	Method of determination of point-load strength index of rocks
11315	Method for quantitative description of discontinuities in rock mass
(Part 1) : 1987	Orientation
(Part 2) : 1987	Spacing
(Part 4) : 1987	Roughness
(Part 8): 1987	Seepage
(Part 11):1987	Core recovery and rock quality designation
13365 (Part 1):1087	Quantitative classification systems of rock mass - Guidelines: Part 1 Rock mass rating (RMR) for predicting engineering properties

3 PROCEDURE

3.1 Estimation of Rock Mass Rating (RMR basic)

The geomechanical properties of rock mass shall be evaluated by RMR system. The RMR basic shall be determined by adding the rating values for the following five parameters as given in Table 1. The procedure has been elaborated in detail in IS 13365 (Part 1).

a) Uniaxial compressive strength of intact material (*see* IS 8764)
b) Rock quality designation (RQD) (*see* IS 11315 (Part 11)]
c) Spacing of discontinuities (*see* IS 11315 (Part 2)]
d) Condition of discontinuities (*see* IS 11315 (Part 4)
e) Ground water conditions (see IS 11315 (Part 8)

3.2 Determination of Failure Modes in Rock Slopes

The slope failures in rock mass are governed by geological discontinuities and movement occurs along surfaces formed by one or several sets of geological discontinuities. Basic modes of failures are given in IS 11315 (Part 1) and summarised below.

3.2.1 *Plane Failure (Plain Wedge Slide)*

Plane failure takes place along continuous joints dipping towards the slope or valley with strike nearly parallel to the slope face [Fig. 1(a)]. The instability conditions occur if critical joint dips less than slope, and the mobilised shear strength along the joint is not enough for stability.

3.2.2 *Wedge Failure (3D Wedge Slide)*

Wedge failure takes place along two geological discontinuities of different sets, whose line of inter-section is towards the slope or valley, but the plunge is less than the inclination of the slope [Fig. 1(b)]. It is generally more frequent than the planer slides.

It may be noted that plane failure is a special case of wedge failure.

Table 1 RMR$_{basic}$ Rating

(*Clause* 3.1)

	Parameter		**RANGES OF VALUES**				
1.	Strength of intact rock	Point load Strength Index	>10 MPa	4-10 MPa	2-4MPa	1-2MPa	<1 MPa for this low range, uniaxial compressive test is preferred
		Uniaxial Compressive Strength	> 250 MPa	100-250 MPa	50-100 MPa	25-50 MPa	5-25 MPa 1-5 MPa <1 MPa
	Rating		15	12	7	4	2 1 0
2.	Drill core quality	RQD	90-100%	75-90%	50-75%	25-50%	<25%
	Rating		20	17	13	8	3
3.	Spacing of discontinuities		>2 m	0.6-2 m	200-600 mm	60-200 mm	<60 mm
	Rating		20	15	10	8	5
4.	Condition of discontinuities		Very rough surfaces; Not continuous No separation Unweathered wall rock	Slightly rough Separation< 1mm Slightly weathered walls	Slightly rough surfaces Separation< 1mm Highly weathered walls	Slickensided surfaces or Gouge 5 mm thick or Separation 1 - 5 mm Continuous	Soft gouge> 5 mm or Separation> 5 mm continuous
	Rating		30	25	20	10	0
5.	Ground water condition		Completely dry	Damp	Wet	Dripping	Flowing
	Rating		15	10	7	4	0

3.2.3 *Toppling Failure*

Toppling failure takes place along a continuous set of joints which dips against the slope, and with strike nearly parallel to slope face [Fig. 1(c)]. Joints are generally weathered in these cases. In practice, two kinds of instability can happen, that is, minor toppling near the surface of slope, and deep toppling- which can produce large deformations. In both the cases the failures develop slowly, and are not prone to sudden rock falls.

3.2.4 *Collection of Field Data*

The determination of failure modes in rock slopes shall be done on the basis of graphical analysis of the geological discontinuities observed on the slope. Depending upon the structural complexity of the area, 100 to 500 readings of the geological discontinuities shall be taken, the poles shall be plotted in an equal area stereonet and contoured to get the maximas of pole concentrations. The failure modes can be identified from the pattern of maximas of pole concentrations [Fig.1 (a), (b) and (c)].

3.3 Determination of Adjustment Rating for Rock Slopes

The adjustment rating for joints in rock slopes is a product of the following three factors:

i) F_1 ~~Which is~~ depends on parallelism between the slope dip and the discontinuity dip direction;
ii) F_2 ~~Which is~~ depends on the dip of discontinuity; and
iii) F_3 ~~which is~~ depends on the relationship of dips of discontinuity and ~~inclination of~~ slope.

NOTES
1 Discontinuity refers to the planer discontinuity or the line of intersection of two planer discontinuities whichever is important from the point of view of instability of rock slopes.
2 The effect of ground water on the SMR has been considered indirectly by RMR_{basic}
3 The SMR shall not be applicable where length of joints along dip direction is less than 5 percent of affected slope height.

Table 2 gives rating for F_1, F_2 and F_3. The notations are as follows:

a_s = dip direction or inclination direction of the slope face,
β_s = dip or inclination of slope face,
a_j = dip direction of discontinuity in the case of planer slide,
= plunge or dip-direction of line of intersection of the unstable wedge,
β_j = dip of discontinuity in the case of planer slide,
P = planer failure or wedge failure, and
T = toppling failure.

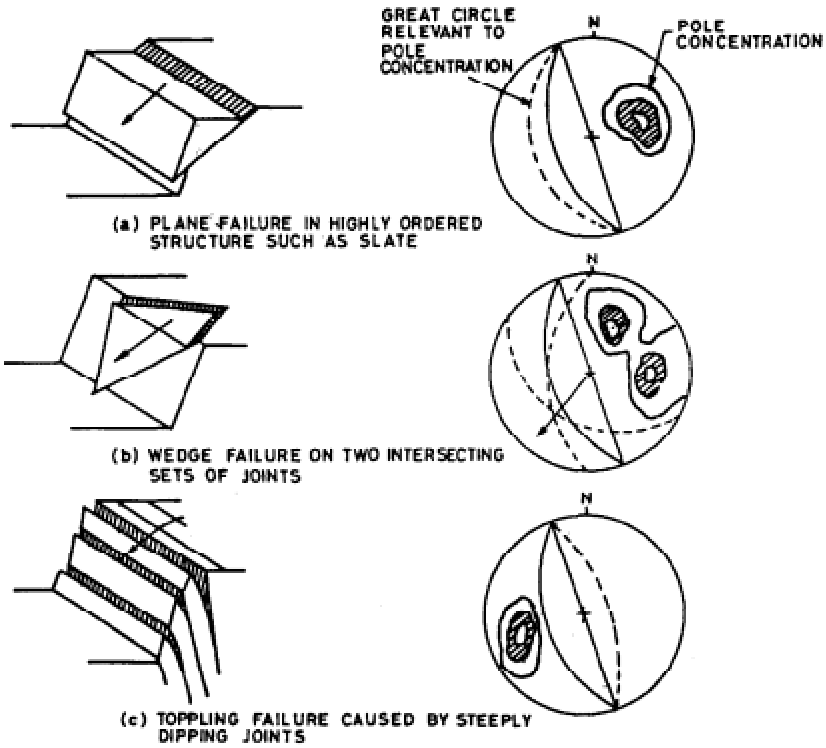

FIG. 1 REPRESENTATION OF STRUCTURAL DATA CONCERNING THREE POSSIBLE SLOPE FAILURE MODES IN ROCKS BASED ON STEREONET PLOITING.

Table 2 Adjustments Rating for Joints
(*Clauses* 3.3 and 3.6, and Note 3)

Case	Adjustment Factors	Very favour able	Favourable	Fair	Unfavourable	Very Unfavourable
P	$[a_j - a_s]$	>30°	30°-20°	20°-10°	10°-5°	< 5°
T	$[a_j - a_s\text{-}180°]$					
P or *T*	F_1	0.15	0.40	0.70	0.85	1.00
P or *T*	$[\beta_j]$	<20°	20°-30°	30°-35°	35°-45°	>45°
P	F_2	0.15	0.40	0.70	0.85	1.00
T	F_2	1	1	1	1	1
P	$\beta_j - \beta_s$	>10°	10°-0°	0°	0°-(-10°)	<-10°
T	$\beta_j + \beta_s$	<110°	110°-120°	>120°	–	--
P or *T*	F_3	0	-6	-25	-50	-60
P = plane failure; *T* = topping failure; a_s = slope dip direction; a_j = joint dip direction; β_j = dip of joint; β_s= dip of slope						

The adjustment rating F_4 for slope in a natural condition or excavated by pre-splitting blasting, smooth blasting, mechanical or poor excavation methods is given in Table 3.

Table 3 Adjustments Rating for Methods of Excavation of Slopes
(*Clause* 3.3)

Method	**Natural slope**	**Presplitting**	**Smooth blasting**	**Blasting or mechanical**	**Deficient blasting**
F_4	+15	+10	+8	0	-8
SMR = RMR_{basic}+ ($F_1 \times F_2 \times F_3$) +$F_4$					

3.4 Estimation of Slope Mass Rating

The product of F_1 , F_2 and F_3 shall be added to RMRbasic rating and add F_4 to obtain slope mass rating (SMR).

Slope mass rating (SMR) = RMR_{basic}+ ($F_1 \times F_2 \times F_3$) +$F_4$

On the basis of the values of slope mass rating, the stability of rock slopes should be classified as fully stable (81-100), stable (61-80), partially stable (41- 60), unstable (21-40) and very unstable (<20) as given in Table 4.

3.5 Remedial Measures

Accordingly the very unstable cut slope may require re-excavation, unstable slope may need extensive corrective measures, partially stable slopes may have to be supported with systematic supports such as rock bolts, and rock anchors and stable to fully stable slopes may need occasional to no supports.

3.6 Cut Slope Angle (Slope Height < ~~2°m~~ 20m)

Safe cut slope angle can be determined from Table 2 by varying slope angle β_s till SMR of cut slope is more than 60. In weaker rocks cut slope angle may be taken equal to or less than apparent dip/dip of discontinuity in planer slide or dip of line of intersection of unstable wedges wherever excavation is feasible.

Table 4 Tentative Description of SMR Classes

Class No	**V**	**IV**	**III**	**II**	**I**
SMR	0-20	21-40	41-60	61-80	81-100
Description	Very bad	Bad	Normal	Good	Very Good
Stability	Completely unstable	Unstable	Partially stable	Stable	Completely stable
Probable Type of Failure	Big planer or rotational	Planer or big wedge	Planer or many wedges	Blocks	None
Support	Re-excavation	Important corrective measures	Systematic supports	Occasional supports	None