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

## व्यापक परिचालन मसौदा

**हमारा संदर्भ: सीईडी 48/टी-31** **29 मई 2024**
**तकनीकी समिति**: रॉक मैकेनिक्स विषय समिति, सीईडी 48

**प्राप्तकर्ता :**

क) सिविल इंजीनियरी विभाग परिषद, सीईडीसी के सभी सदस्य
ख) सीईडी 48 के सभी सदस्य
ग) रूचि रखने वाले अन्य निकाय

प्रिय महोदय/महोदया,

निम्नलिखित भारतीय मानक का मसौदा संलग्न है:

| प्रलेख संख्या | शीर्षक |
|---|---|
| **सीईडी 48 (25742)WC** | **शैल संहति का मात्रात्मक वर्गीकरण तंत्र — दिशानिर्देश सिद्धांत भाग 1 इंजीनियरिंग गुणधर्मो के निर्धारण के लिए शैल संहति रेटिंग (आर एम आर) का भारतीय मानक मसौदा** [ IS 13365 (भाग 1) का *पहला पुनरीक्षण*] ICS 93.020 |

कृपया इस मानक के मसौदे का अवलोकन करें और अपनी सम्मतियॉ यह बताते हुए भेजे कि यदि यह मानक के रूप में प्रकाशित हो तो इस पर अमल करने में आपके व्यवसाय अथवा कारोबार में क्या कठिनाइयाँ आ सकती हैं ।

सम्मतियाँ भेजने की अंतिम तिथि : **30 जून 2024**

सम्मति यदि कोई हो तो कृपया अधोहस्ताक्षरी को उपरिलिखित पते पर संलग्न फोर्मेट में भेजें या manoj@bis.gov.in पर ईमेल कर दें ।

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यह प्रलेख भारतीय मानक ब्यूरो की वैबसाइट www.bis.gov.in पर भी उपलब्ध हैं।

धन्यवाद ।

भवदीय,

**( द्वैपायन भद्र )**
**प्रमुख (सिविल इंजीनियरी)**

संलग्नक : उपरिलिखित

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

# DRAFT IN WIDE CIRCULATION

**Our Ref: CED 48/T-31** **29 May 2024**

**TECHNICAL COMMITTEE:** Rock Mechanics
Sectional Committee, CED 48

**ADDRESSED TO:**

a) All Members of Civil Engineering Division Council, CEDC
b) All Members of CED 48
c) All others interests.

Dear Sir/Madam,

Please find enclosed the following document:

| Doc No. | Title |
|---|---|
| **CED 48(25742)WC** | **Draft Indian Standard**<br>**Quantitative Classification Systems of Rock Mass — Guidelines**<br>**Part 1 Rock Mass Rating (RMR) for Predicting Engineering Properties**<br>[ *First Revision* of IS 13365 (Part 1) ] ICS 93.020 |

Kindly examine the draft standard and forward your views stating any difficulties which you are likely to experience in your business or profession, if this is finally adopted as National Standard.

Last Date for comments**: 30 June 2024**

Comments if any, may please be made in the attached format and mailed to the undersigned at the above address or preferably through e-mail to manoj@bis.gov.in.

In case no comments are received or comments received are of editorial nature, you may kindly permit us to presume your approval for the above document as finalized. However, in case of comments of technical in nature are received then it may be finalized either in consultation with the Chairman, Sectional Committee or referred to the Sectional Committee for further necessary action if so desired by the Chairman, Sectional Committee.

The document is also hosted on BIS website www.bis.gov.in.

Thanking you,

Yours faithfully,

**( Dwaipayan Bhadra )**
**Head (Civil Engineering)**

Encl: As above

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**Doc. No.: CED 48(25742)WC**

**Title:** **Draft Indian Standard Quantitative Classification Systems of Rock Mass — Guidelines**
**Part 1 Rock Mass Rating (RMR) for Predicting Engineering Properties**
[ *First Revision* of IS 13365 (Part 1) ] ICS 93.020

LAST DATE OF COMMENT: **30 June 2024**

*NAME OF THE COMMENTATOR/ORGANIZATION*: ___________________________

| Sl. No. | Clause/Para/Table/ Figure No. Commented | Comments/Modified Wordings | Justification of the Proposed Change |
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*Draft Indian Standard*

**QUANTITATIVE CLASSIFICATION SYSTEMS OF ROCK MASS — GUIDELINES PART 1 ROCK MASS RATING (RMR) FOR PREDICTING ENGINEERING PROPERTIES**

[ *First Revision* of IS 13365 (Part 1) ]
ICS 93.020

| Rock Mechanics Sectional Committee, CED 48 | Last date of Comments **30 June 2024** |
| --- | --- |

FOREWORD

(*Formal clauses will be added later*)

Quantitative classification of rock masses has many advantages. It provides a basis for understanding characteristics of different groups. It also provides a common basis for communication besides yielding quantitative data for designs for feasibility studies of project. This is the reason why quantitative classifications have become very popular all over the world.

Rigorous approaches of designs based on various parameters could lead to uncertain results because of uncertainties in obtaining the correct value of input parameters at a given site of tunnelling. Rock mass classifications which do not involve uncertain parameters are following the philosophy of reducing uncertainties.

This standard (Part 1) covers the procedure for determining the class of rock mass based on geomechanics classification system, which is also called the Rock Mass Rating (RMR) system. The classification can be used for estimating the unsupported span, the stand-up time and the support pressures of an underground opening. It can also be used for selecting a method of excavation and permanent support system. Further, cohesion, angle of internal friction and elastic modulus of the rock mass can be estimated. Modified RMR can also be used for predicting the ground conditions for tunnelling.

This standard has been published in four parts. The other parts in the series are:

- Part 2 Rock mass quality for prediction of support pressure, support system and engineering properties in underground openings
- Part 3 Determination of slope mass rating
- Part 4 Geological strength index (GSI)

This standard (Part 1) was first published in 1998. This revision of the standard has been brought out based on the experience gained in use of the standard since its last revision. In this revision, the following major modifications have been mode:

a) Minimum value of RQD has been clarified,
b) Equation for support pressure has been improved,
c) SI unit system has been implemented, and
d) Reference of various Indian standard has been updated.

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.

*Draft Indian Standard*

# QUANTITATIVE CLASSIFICATION SYSTEMS OF ROCK MASS — GUIDELINES PART 1 ROCK MASS RATING (RMR) FOR PREDICTING ENGINEERING PROPERTIES

*( First Revision )*

## 1 SCOPE

This standard (Part 1) covers the procedure for determining the class of rock mass based on geomechanics classification system, which is also called the Rock Mass Rating (RMR) system. The classification can be used for estimating the unsupported span, the stand-up time and the support pressures of an underground opening. It can also be used for selecting a method of excavation and permanent support system. Further, cohesion, angle of internal friction and elastic modulus of the rock mass can be estimated. Modified RMR can also be used for predicting the ground conditions for tunnelling.

It is emphasized that recommended correlations should be used for feasibility studies and preliminary designs only. *In-situ* tests are essential for final design of important structures.

## 2 REFERENCES

The standards listed in Annex A contain provisions which through reference in this 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 the standards indicated in Annex A.

## 3 PROCEDURE

To apply the geomechanics classification system, a given site should be divided into a number of geological structural units in such a way that each type of rock mass present in the area is covered. The following geological parameters are determined for each structural unit:

a) Uniaxial compressive strength of intact rock material (IS 8764),
b) Orientation of discontinuities [IS 11315 (Part 1)],
c) Spacing of discontinuities [IS 11315 (Part 2)],
d) Condition of discontinuities [IS 11315 (Part 4)],
e) Ground water condition [IS 11315 (Part 8)], and
f) Rock quality designation [IS 11315 (Part 11)].

### 3.1 Collection of Field Data

Various geological and other parameters given in **3.1.1** to **3.1.6** should be collected and recorded in data sheet shown in Annex B.

**3.1.1** *Uniaxial Compressive Strength of Intact Rock Material ($q_c$)*

The strength of the intact rock material should be obtained from rock cores in accordance with IS 9143 or IS 8764 as applicable based on site conditions. The ratings based on uniaxial compressive strength and point load strength are given in Annex B (Item I). However, the use of uniaxial compressive strength is preferred over that of point load index strength.

**3.1.2** *Rock Quality Designation (RQD)*

Rock quality designation (RQD*)* should be determined as specified in IS 11315 (Part 11). The details of rating are given in Annex B (Item II).

Where the rock cores are not available, RQD can be determined with the help of following formula:

$$\begin{aligned} \text{RQD} &= 115 - 3.3\,J_\text{v} \\ &= 100 \text{ for } J_\text{v} < 4.5 \end{aligned}$$

where

$J_\text{v}$ = number of joints per metre cube.

Minimum value of RQD is taken as 10 percent even if it is zero.

**3.1.3** *Spacing of Discontinuities*

The term discontinuity covers joints, beddings or foliations shear zones, minor faults, or other surfaces of weakness. The linear distance between two adjacent discontinuities should be measured for all sets of discontinuities. The details of ratings are given in Annex B (Item III).

**3.1.4** *Condition of Discontinuities*

This parameter includes roughness of discontinuity surfaces, their separation, length or continuity, weathering of the wall rock or the planes of weakness and in filling (gauge) material. The details of rating are given in Annex B (Item IV). The description of the term used in the classification is given in IS 11315 (Part 4) and IS 11315 (Part 5).

**3.1.5** *Ground Water Condition*

In the case of tunnels, the rate of inflow of ground water in litre per minute per 10 m length of the tunnel should be determined, or a general condition can be described as completely dry, damp, wet, dripping, and flowing. If actual water pressure data are available, these should be stated and expressed in terms of the ratio of the water pressure to the major principal stress. The latter should be either measured from the depth below the surface (vertical stress increases with depth at 0.027 $MN/m^2$ per metre of the depth below surface). The details are given in Annex B (Item V).

Rating of above five parameters (*see* **3.1.1** to **3.1.5**) is added to obtain what is called the basic rock mass rating ($\text{RMR}_\text{basic}$).

**3.1.6** *Orientation of Discontinuities*

Orientation of discontinuities means the strike and dip of discontinuities. The strike should be recorded with reference to magnetic north. The dip angle is the angle between the horizontal and the discontinuity plane taken in a direction in which the plane dips. The value of the dip and the strike should be recorded as shown in Annex B (Item VI) for each joint set of particular importance that are unfavourable to the structure. In addition, the orientation of tunnel axis or slope face or foundation alignment should also be recorded.

The influence of the strike and the dip of the discontinuities is considered with respect to the orientation of tunnel axis or slope face or foundation alignment. To facilitate the decision whether the strike and dip are favourable or not, reference should be made to Annex C, Tables C1 and C2, which give assessment of joint favourability for tunnels and dams foundations respectively. Once favourability of critical discontinuity is known, adjustment for orientation of discontinuities is applied as per Item VII of Annex B in earlier obtained basic rock mass rating to obtain RMR.

## 4 ESTIMATION OF ROCK MASS RATING (RMR)

**4.1** The rock mass rating should be determined as an algebraic sum of ratings for all the parameters given in Items I to VI after adjustments for orientation of discontinuities given in item VII of Annex B. The sum of Items II to V is called Rock Condition Rating (RCR), which discounts the effect of compressive strength of intact rock material and orientation of joints. This is also called as the modified RMR.

**4.2** On the basis of RMR values for a given engineering structure, the rock mass should be classified as very good (rating 100 to 81), good (80 to 61), fair (60 to 41), poor (40 to 21) and very poor (< 20) rock mass.

**4.3** RCR may also be obtained from ($Q.\mathrm{SRF}$) value as follows:

$$\mathrm{RCR} = 8\, l_{\mathrm{n}}(Q.\mathrm{SRF}) + 30$$

$Q.\mathrm{SRF}$ has been named as rock mass number and denoted by $N$. By doing so, the uncertainties in obtaining correct rating of SRF is eliminated as explained below:

$$Q = (\mathrm{RQD}/J_{\mathrm{n}})(J_{\mathrm{r}}/J_{\mathrm{a}})(J_{\mathrm{w}}/\mathrm{SRF})$$

or

$$N = Q.\mathrm{SRF} = (\mathrm{RQD}/J_{\mathrm{n}})(J_{\mathrm{r}}/J_{\mathrm{a}})\,J_{\mathrm{w}}$$

It can be seen in above equation that $N$ is free from SRF. The RQD, $J_{\mathrm{n}}$, $J_{\mathrm{r}}$, $J_{\mathrm{a}}$ and $J_{\mathrm{w}}$ are parameters as defined in IS 13365 (Part 2).

**4.4** In the case of larger tunnels and caverns, RMR may be somewhat less than obtained from drifts. In drifts, one may miss intrusions of other rocks and joint sets.

**4.5** Separate RMR shall be obtained for different orientation of tunnels after taking into account the orientation of tunnel axis with respect to the critical joint set (Item VI, Annex B).

**4.6** Wherever possible, the undamaged face should be used to estimate the value of RMR, since the overall aim is to determine the properties of the undisturbed rock mass. Severe blast damage may be accounted for by increasing RMR and $\mathrm{RMR}_{\mathrm{basic}}$ by 10 to get the RMR value of undisturbed rock mass.

## 5 ENGINEERING PROPERTIES OF ROCK MASSES

**5.1** The engineering properties of rock masses can be obtained from this classification as given in Table 1 based on assumptions given in **5.1.1** to **5.1.3.** If the rock mass rating lies within a given range, the value of engineering properties may be interpreted between the recommended range of properties.

**5.1.1** *Average Stand-up Time*

The stand-up time depends upon effective span of the opening which is defined as size of the opening or the distance between tunnel face and the adjoining tunnel support, whichever is minimum (*see* Fig. 1). For arched openings the stand-up time would be significantly higher than that for flat roof openings. Controlled blasting will further increase the stand-up time as damage to the rock mass is decreased.

**5.1.2** *Cohesion and Angle of Internal Friction*

Assuming that a rock mass follows Coulomb criterion, its shear strength will depend upon cohesion and angle of internal friction. Usually, the strength parameters are different for peak failure and residual failure conditions.

The values of cohesion for dry rock masses of slopes are likely to be significantly higher.

For underground openings, the values of cohesion will still be higher (*see* **5.1.5** and **5.1.6**) due to more confinement.

**5.1.3** *Modulus of Deformation*

There are three correlations for determining deformation modulus of rock mass.

**5.1.3.1** Figure 2 gives correlations between rock mass rating (RMR) and modulus reduction factor (MRF), which defined as ratio of modulus of deformation of rock mass ($E_\mathrm{d}$) to elastic modulus of rock core (*see* IS 9221). Thus, modulus of deformation of rock mass be determined as product of modulus of elasticity of rock core ($E_\mathrm{r}$) and modulus reduction factor corresponding to rock mass rating from the equation below (for hard jointed rock).

$$E_\mathrm{d} = E_\mathrm{r}.\,\mathrm{MRF}$$

The correlation for MRF is shown in Fig. 2.

**5.1.3.2** There is an approximate correlation between modulus of deformation and rock mass rating for hard rock masses ($q_\mathrm{c} \geq 50$ MPa).

$$E_\mathrm{d} = 2 \times \mathrm{RMR} - 100\text{, in GPa}$$

or

$$E_\mathrm{d} = 10^{(\mathrm{RMR}-10)/40}\text{, in GPa (for all values of RMR)}$$

These correlations are shown in Fig.3.

For dry soft rock masses ($q_c < 50$ MPa) modulus of deformation is dependent upon confining pressure due to overburden.

$E_{\mathrm{d}}$ = $0.3z^{\alpha}10^{(\mathrm{RMR}-20)/38}$, in GPa;
$\alpha$ = 0.16 to 0.30 (higher for poor rocks); and
$z$ = depth of location under consideration below ground surface in metres (for depths 50 m).

The modulus of deformation of poor rock masses with water sensitive minerals decreases significantly after saturation and with passage of time after excavation. For design of dam foundations, it is recommended that uniaxial jacking tests with bore hole extensometers, wherever feasible, should be conducted very carefully soon after the excavation of drifts particularly for poor rock masses in saturated condition.

**5.1.4** *Allowable Bearing Pressure*

Allowable bearing pressure is also related to RMR and may be estimated as per IS 12070.

**5.1.5** In stability analysis of rock slopes, strength parameters are needed in cases of rotational slides. The same may be obtained from RMR parameters which is sum of rating of Items I to IV of Annex B. The seepage condition should be considered in the analysis. The same strength parameters are also applicable in case of wedge sliding along discontinuous joint sets (*see* **5.1.6** and Table 2). However, it would be better if strength parameters are obtained from back analysis of distressed slopes in similar rock conditions near the site.

**5.1.6** *Shear Strength of Jointed Rock Masses*

$$\tau_{\mathrm{n}} = A\,(\sigma_{\mathrm{n}} + T)^{B}$$
$$= 0 \text{ if } \sigma_{\mathrm{n}} < 0$$

where

$\tau_{\mathrm{n}}$ = $\tau/q_{\mathrm{c}}$,
$\sigma_{\mathrm{n}}$ = $\sigma/q_{\mathrm{c}}$,
$q_{\mathrm{c}}$ = mean uniaxial compressive strength of intact rock material, and
$A, T, B$ = constants.

In case of underground openings, the increase in strength occurs due to limited freedom of fracture propagation in openings than that in block shear test. Another reason for strength enhancement is that the *in-situ* stress along the axis of tunnels and caverns prestresses rock wedges both in roof and walls. The mobilised uniaxial compressive strength of rock mass may be estimated from the following correlations for tunnels and caverns:

$$q_{\mathrm{c\,mass}} = 7\gamma\, Q^{1/3} \text{in MPa} \;;\; Q \leq 10 \;;\; J_{\mathrm{w}} = 1; q_{\mathrm{c}} < 100 \text{ MPa}$$
$$\tan \emptyset = J_{\mathrm{r}}/J_{\mathrm{a}} \leq 1.5$$

**Table 1 Engineering Properties of Rock Mass**
(*Clause* 5.1)

| **Item** | **Rock Mass Rating** | **100 to 81** | **80 to 61** | **60 to 41** | **40 to 21** | **< 20** |
|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| 1 | Class | I | II | III | IV | V |
| 2 | Classification of rock mass | Very good | Good | Fair | Poor | Very Poor |
| 3 | Average stand-up time | 10 years for 15 m span | 6 months for 8 m span | 1 week for 5 m span | 10 h for 2.5 m span | 30 min for 1 m span |
| 4 | Cohesion of rock mass[1)] (MPa) | > 0.4 | 0.3 to 0.4 | 0.2 to 0.3 | 0.1 to 0.2 | < 0.1 |
| 5 | Angle of internal friction of rock mass[1)] | > 45° | 35 to 45° | 25 to 35° | 15 to 25° | 15° |

[1)] Values are also applicable for saturated rock masses in slopes

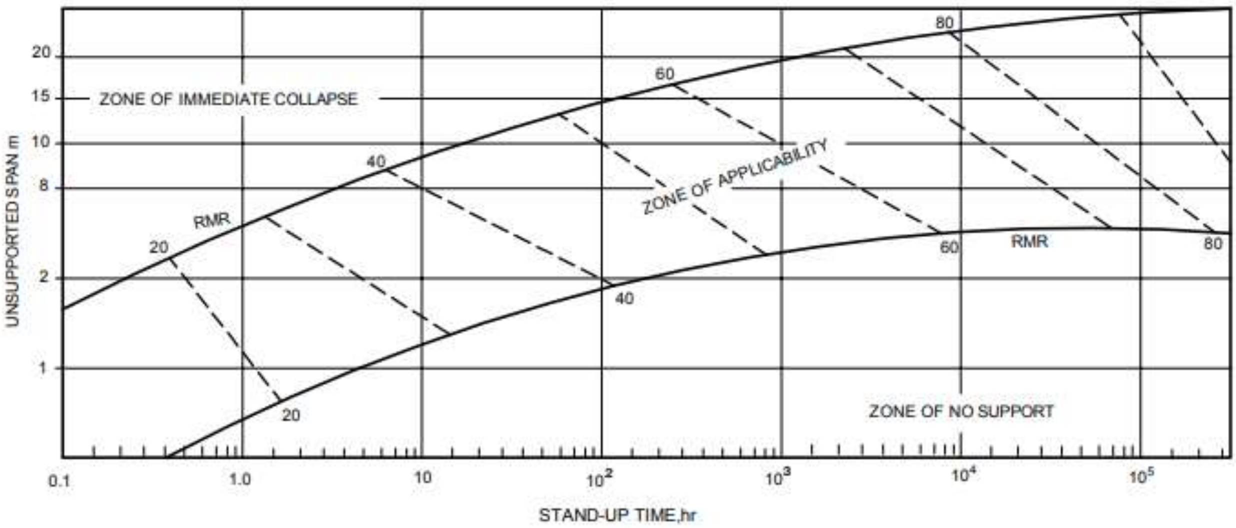


FIG. 1 STAND-UP TIME V/S UNSUPPORTED SPAN AS PER ROCK MASS RATING

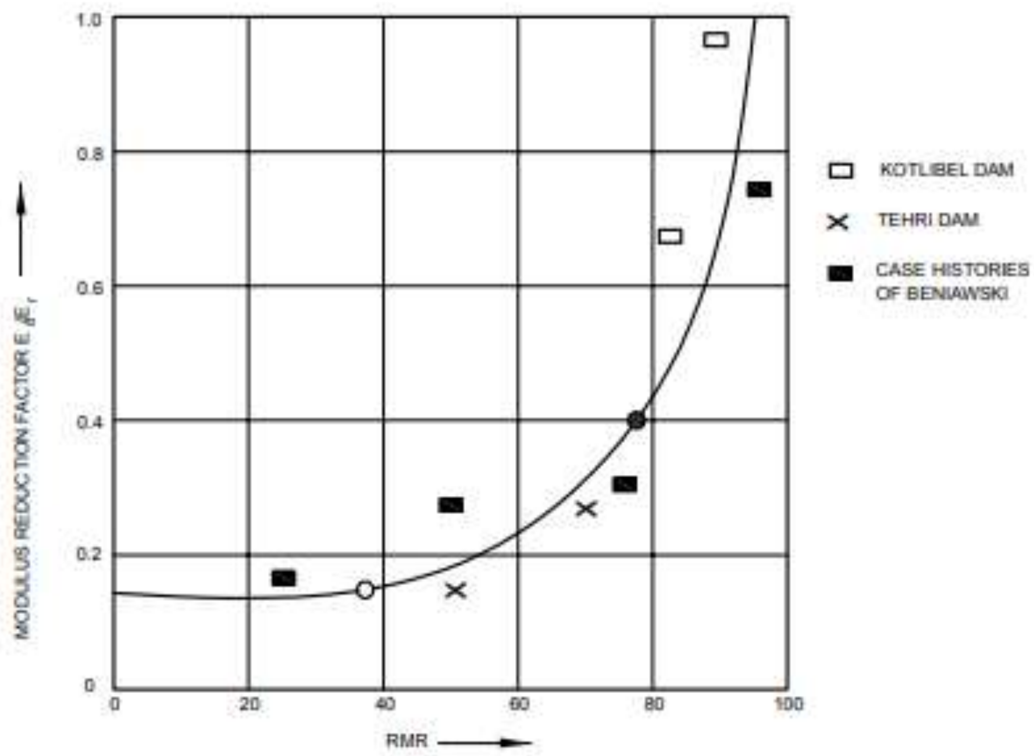


FIG. 2 RELATIONSHIP BETWEEN RMR AND MODULUS REDUCTION FACTOR

where

$\gamma$ = unit weight of rock mass in g/cc,
$Q$ = rock mass quality [IS 13365 (Part 2)],
$J_r$ = joint roughness number, and
$J_a$ = joint alteration number.

**5.1.7** *Estimation of Support Pressure*

The short-term support pressures for arched underground openings in both squeezing and non-squeezing ground conditions may be estimated from the following empirical correlation in the case of tunnelling by conventional blasting method using steel rib supports:

$$P_{roof} = 7.5\ B^{0.1}\ H^{0.5} - \mathrm{RMR}/20\ \mathrm{RMR}, \text{in MPa}$$

where

$B$ = span of opening in metres,
$H$ = overburden or tunnel depth in metres ($> 50$ m), and
$P_{roof}$ = short term roof support pressure in MPa.

The support pressures estimated from Q-system [IS 13365 (Part 2)] are more reliable if Stress Reduction Factor (SRF) is correctly obtained.

**5.1.8** *Prediction of Tunnelling Conditions*

Ground conditions for tunnelling can be predicted by using the following correlations (*see* Fig. 4):

| Sl No. | Ground Condition | Correlations |
|---|---|---|
| (1) | (2) | (3) |
| i) | Self-supporting | $H < 23.4\ N^{0.88}.B^{-0.1}$ and $1\ 000\ B^{-0.1}$ |
| ii) | Non-squeezing | $23.4\ N^{0.88}\ B^{-0.1} < H < 275\ N^{0.33} B^{-0.1}$ |
| iii) | Mild squeezing | $275\ N^{0.33}\ B^{-0.1} < H < 450\ N^{0.33} B^{-0.1}$ |
| iv) | Moderate squeezing | $450\ N^{0.33} B^{-0.1} < H < 630\ N^{0.33} B^{-0.1}$ |
| v) | High squeezing | $H > 630\ N^{0.33}\ B^{-0.1}$ |

In the above correlations, $N$ is the rock mass number, as defined in **4.3**. $H$ is the overburden in metres and $B$ is the tunnel width in metres.

## 6 PRECAUTIONS

It must be ensured that double accounting for parameters should not be done in analysis of rock structures and rating of rock mass. If pore water pressure is being considered in analysis of rock structures, it should not be accounted for in RMR. Similarly, if orientation of joint sets is considered in stability analysis of rock structures, the same should not be accounted for in RMR.

NOTE – For the purpose of eliminating doubts due to individual judgements, the rating for different parameters should be given a range in preference to a single value.

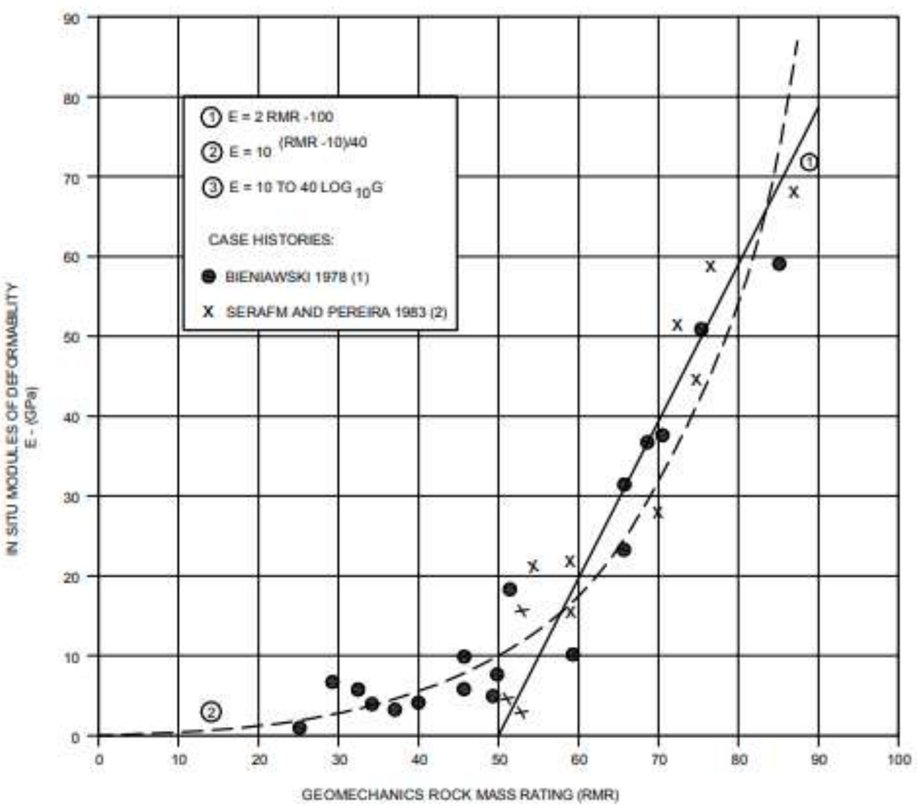


FIG. 3 CORRELATION BETWEEN THE *IN-SITU* MODULUS OF DEFORMATION AND THE GEOMECHANICS CLASSIFICATION (ROCK MASS RATING (RMR) FOR HARD ROCKS (1 GPa = 10 000 kg/cm$^2$).

**Table 2 Recommended Mohr Envelops for Joined Rock Masses**
(*Clause* 5.1.5)

$$\tau_n = \frac{\tau}{q_c}, \sigma_n = \frac{\sigma}{q_c}; \sigma \text{ in kg/cm}^2; \tau = 0 \text{ if } \sigma < 0$$

$S$ = degree of saturation [average value of degree of saturation is shown by $S_{av}$]
= l, for completely saturated rock mass

| Rock Type Quality | Limestone | Slate, Xenolith, Phyllite | Sandstone, Quartzite | Trap, Metabasic |
|---|---|---|---|---|
| Good Rock Mass<br>RMR = 61 to 80<br>$Q$ = 10 to 40 | $\tau_{n\,(nmc)} = 0.38\ (\sigma_n + 0.005)^{0.669}$<br>$\tau_{n\,(sat)} = 0.35\ (\sigma_n + 0.004)^{0.669}$<br>$[S = 1]$ | $\tau_{n\,(nmc)} = 0.42\ (\sigma_n + 0.004)^{0.683}$<br>$\tau_{n\,(sat)} = 0.38\ (\sigma_n + 0.003)^{0.683}$<br>$[S = 1]$ | $\tau_{n\,(nmc)} = 0.44\ (\sigma_n + 0.003)^{0.683}$<br>$\tau_{n\,(sat)} = 0.43\ (\sigma_n + 0.002)^{0.695}$<br>$[S = 1]$ | $\tau_{n\,(nmc)} = 0.50\ (\sigma_n + 0.003)^{0.698}$<br>$[S_{av} = 0.30]$<br>$\tau_{n\,(sat)} = 0.49\ (\sigma_n + 0.002)^{0.698}$<br>$[S = 1]$ |
| Fair Rock Mass<br>RMR = 41 to 60<br>$Q$ = 2 to 10 | $\tau_{n\,(nmc)} = 2.60\ (\sigma + 1.25)^{0.662}$<br>$[S = 1]$<br>$\tau_{n\,(sat)} = 1.95\ (\sigma + 1.20)^{0.662}$<br>$[S = 1]$ | $\tau_{n\,(nmc)} = 2.75\ (\sigma + 1.15)^{0.675}$<br>$[S_{av} = 0.25]$<br>$\tau_{n\,(sat)} = 2.15\ (\sigma + 1.10)^{0.675}$<br>$[S = 1]$ | $\tau_{n\,(sat)} = 2.85\ (\sigma + 1.10)^{0.688}$<br>$[S_{av} = 0.15]$<br>$\tau_{n\,(sat)} = 2.25\ (\sigma + 1.05)^{0.688}$<br>$[S = 1]$ | $\tau_{n\,(nmc)} = 3.05(\sigma + 1.00)^{0.691}$<br>$[S_{av} = 0.35]$<br>$\tau_{n\,(sat)} = 2.45\ (\sigma + 0.95)^{0.691}$<br>$[S = 1]$ |
| Poor Rock Mass<br>RMR = 21 to 40<br>$Q$ = 0.5 to 2 | $\tau_{n\,(nmc)} = 2.50\ (\sigma + 0.80)^{0.646}$<br>$[S_{av} = 0.20]$<br>$\tau_{n\,(sat)} = 1.50\ (\sigma + 0.75)^{0.646}$<br>$[S = 1]$ | $\tau_{n\,(nmc)} = 2.65\ (\sigma + 0.75)^{0.655}$<br>$[S_{av} = 0.40]$<br>$\tau_{n\,(sat)} = 1.75\ (\sigma + 0.70)^{0.655}$<br>$[S = 1]$ | $\tau_{n\,(nmc)} = 2.85\ (\sigma + 0.70)^{0.672}$<br>$[S_{av} = 0.25]$<br>$\tau_{n\,(sat)} = 2.00\ (\sigma + 0.65)^{0.672}$<br>$[S = 1]$ | $\tau_{n\,(nmc)} = 3.00\ (\sigma + 0.65)^{0.676}$<br>$[S_{av} = 0.15]$<br>$\tau_{n\,(sat)} = 2.25\ (\sigma + 0.50)^{0.676}$<br>$[S = 1]$ |
| Very Poor Rock Mass<br>RMR < 21<br>$Q$ = < 0.5 | $\tau_{n\,(nmc)} = 2.25\ (\sigma + 0.65)^{0.534}$<br>$\tau_{n\,(sat)} = 0.80\ (\sigma)^{0.534}$<br>$[S = 1]$ | $\tau_{n\,(nmc)} = 2.45\ (\sigma + 0.60)^{0.539}$<br>$\tau_{n\,(sat)} = 0.95\ (\sigma)^{0.539}$<br>$[S = 1]$ | $\tau_{n\,(nmc)} = 2.65\ (\sigma + 0.55)^{0.546}$<br>$\tau_{n\,(sat)} = 1.05\ (\sigma)^{0.546}$<br>$[S = 1]$ | $\tau_{n\,(nmc)} = 2.90\ (\sigma + 0.50)^{0.548}$<br>$\tau_{n\,(sat)} = 1.25\ (\sigma)^{0.548}$<br>$[S = 1]$ |

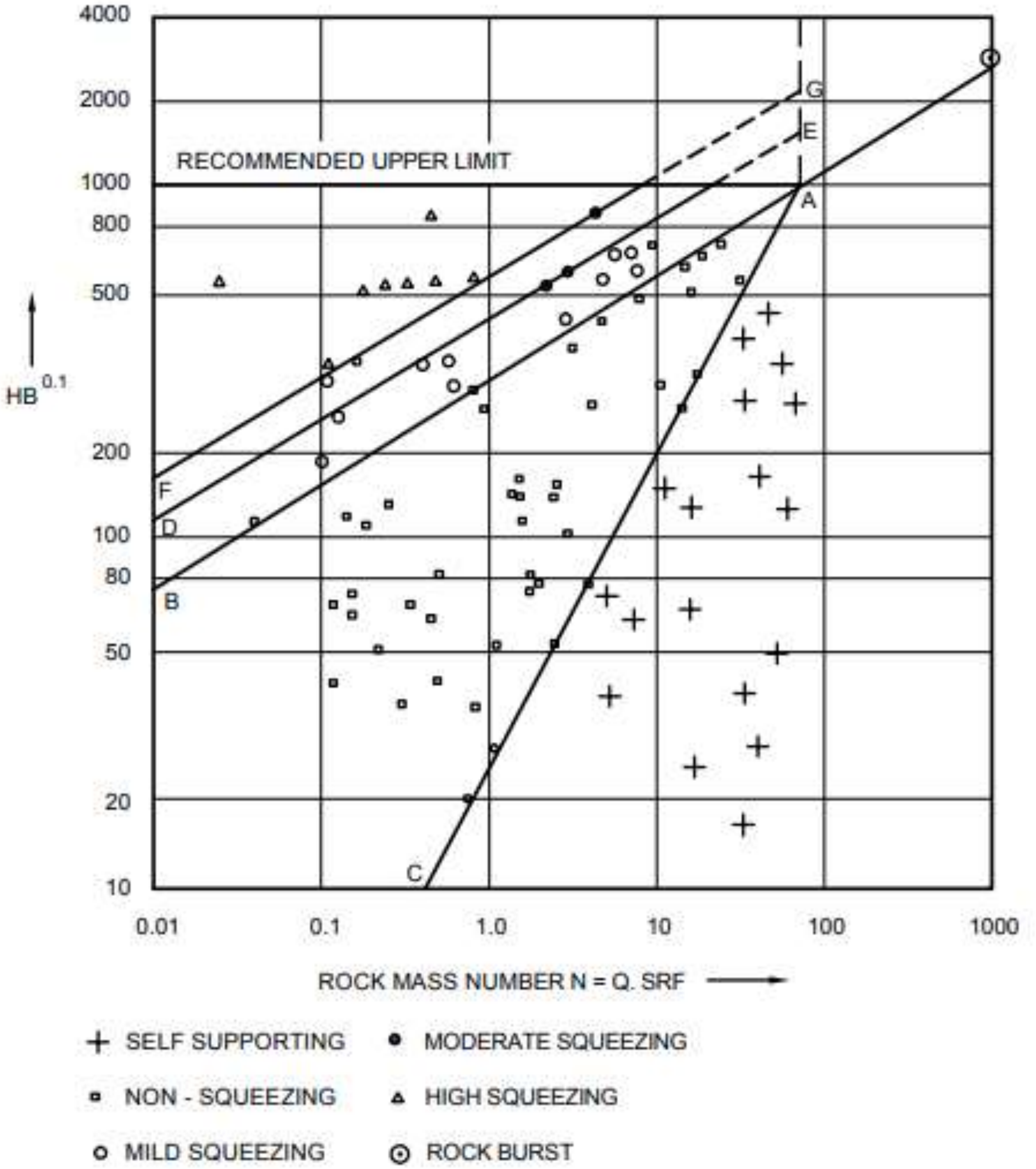


FIG. 4 CRITERIA FOR PREDICTING GROUND CONDITIONS USING ROCK NUMBER, TUNNEL DEPTH AND TUNNEL WIDTH.

**ANNEX A**
(*Clause* 2)

## LIST OF REFERRED INDIAN STANDARDS

| *IS No.* | *Title* |
|---|---|
| IS 8764 : 1998 | Method of determination of point load strength index of rocks (*first revision*) |
| IS 9143 : 1979 | Method for the determination of unconfined compressive strength of rock material |
| IS 9221 : 1979 | Method for the determination of modulus of elasticity and Poisson's ratio of rock materials in uniaxial compression |
| IS 11315 | Method for the quantitative description of discontinuities in rock mass: |
| (Part 1) : 2023 | Orientation (*first revision*) |
| (Part 2) : 2023 | Spacing (*first revision*) |
| (Part 4) : 2023 | Roughness (*first revision*) |
| (Part 5) : 2023 | Wall strength (*first revision*) |
| (Part 8) : 2023 | Seepage (*first revision*) |
| (Part 11) : 2023 | Core recovery and rock quality designation (*first revision*) |
| IS 12070 : 1987 | Code of practice for design and construction of shallow foundation on rocks |
| IS 13365 (Part 2) : 2019 | Quantitative classification systems of rock mass – Guidelines: Part 2 Rock mass quality for prediction of support pressure, support system and engineering properties in underground openings (*first revision*) |

**ANNEX B**
(*Clauses* 3.1, 4.1 *and* 5.1.5)

## DATA SHEET FOR GEOMECHANICAL CLASSIFICATION OF ROCK MASSES (RMR)

Name of project ……………… Location of site …………………
Survey conducted by ……….. Date …………………………….
Type of rock mass unit ……… Origin of rock mass…………….

The appreciate rating may be encircled as per site conditions.

### I STRENGTH OF INTACT ROCK MATERIAL (MPa)

| | *Compressive Strength* | *Point Load Strength* | *Rating* |
|---|---|---|---|
| Exceptionally strong | > 250 | > 8 | 15 |
| Very strong | 100 to 250 | 4 to 8 | 12 |
| Strong | 50 to 100 | 2 to 4 | 7 |
| Average | 25 to 50 | 1 to 2 | 4 |
| Weak | 10 to 25 | Use of uniaxial compressive | 2 |
| Very weak | 2 to 10 | strength is preferred | 1 |
| Extremely weak | < 2 | | 0 |

### II ROCK QUALITY DESIGNATION (RQD)

| | RQD | Rating |
|---|---|---|
| Excellent | 90 to 100 | 20 |
| Good | 75 to 90 | 17 |
| Fair | 50 to 75 | 13 |
| Poor | 25 to 50 | 8 |
| Very Poor | 0 to 25 | 3 |

### III SPACING OF DISCONTINUITIES

| | *Spacing*, m | *Rating* |
|---|---|---|
| Very wide | > 2 | 20 |
| Wide | 0.6 to 2 | 15 |
| Moderate | 0.2 to 0.6 | 10 |
| Close | 0.06 to 0.2 | 8 |
| Very close | < 0.06 | 5 |

NOTE – If more than one set of discontinuity are present and the Spacing of discontinuities of each set varies, consider the set with lowest rating.

### IV CONDITION OF DISCONTINUITIES

| Very rough and un-weathered wall rock, tight and discontinuous, no separation | Rough and slightly weathered wall rock surface, separation < 1 mm | Slightly rough and moderately to highly weathered wall rock surface, separation < 1 mm | Slickensided wall rock surface or 1-5 mm thick gauge or 1-5 mm wide opening, continuous discontinuity | 5 mm thick soft gauge 5 mm wide continuous discontinuity |
|---|---|---|---|---|
| **Rating** 30 | 25 | 20 | 10 | 0 |

## V GROUND WATER CONDITION

| | | | | | |
|---|---|---|---|---|---|
| Inflow per 10 m tunnel length, (litre/min) | none | < 10 | 10-25 | 25-125 | > 125 |
| Joint water pressure/major principal stress | 0 | 0-0.1 | 0.1-0.2 | 0.2-0.5 | > 0.5 |
| General description | Completely dry | Damp | Wet | Dripping | Flowing |
| **Rating** | 15 | 10 | 7 | 4 | 0 |

## VI ORIENTATION OF DISCONTINUTIES

Orientation of tunnel/slope/foundation axis….

Set 1 Average strike ………. (from….. to…..) Dip……..
Set 2 Average strike ………. (from….. to…..) Dip……..
Set 3 Average strike ………. (from….. to…..) Dip……..

## VII ADJUSTMENT FOR JOINT ORIENTATION *(see Annex C)*

| *Strike and dip orientation of joints for* | *Very favourable* | *Favourable* | *Fair* | *Unfavourable* | *Very unfavourable* |
|---|---|---|---|---|---|
| Tunnels | 0 | – 2 | – 5 | – 10 | – 12 |
| Raft foundation slopes | 0 | – 2 | – 7 | – 15 | – 35 |
| Slopes | Use slope mass rating ($SMR$) as per IS 13365 (Part 3) | | | | |

# ANNEX C
(*Clause* 3.1.6)

## ASSESSMENT OF JOINT FAVOURABILITY FOR TUNNELS AND DAMS FOUNDATIONS

### Table C1 Assessment of Joint Orientation Favourability in Tunnels (Dips are Apparent Dips along Tunnel Axis)
(*Clause* 3.1.6)

| **Strike Perpendicular to Tunnel Axis** | | | | **Strike Parallel to Tunnel Axis** | | **Irrespective or Strike** |
|---|---|---|---|---|---|---|
| *Drive with Dip* | | *Drive Against Dip* | | | | |
| Dip45°-90<br>Very favourable | Dip 20°-45<br>Favourable | Dip 45°-90<br>Fair | Dip 20°-45<br>Unfavourable | Dip 20°-45°<br>Fair | Dip 45°-90°<br>Very unfavourable | Dip 0°- 20°<br>Fair |

### Table C2 Assessment of Joint Orientation Favourability for Stability or Raft Foundation
(*Clause* 3.1.6)

| **Dip** | | | | |
|---|---|---|---|---|
| **0° -10°** | **10°-30°**<br>Dip Direction | | **30°- 60°** | **60°- 90°** |
| | Upstream | Downstream | | |
| Very favourable | Unfavourable | Fair | Favourable | Very unfavourable |