From Palmström A.: RMi – a rock mass characterization system for rock engineering purposes. PhD thesis, Oslo University, Norway, 1995, 400 p.

APPENDIX 10

SYMBOLS USED

1. General

γ	weight per unit volume
n	porosity
v	Poisson's ratio
μ	friction coefficient (= tan φ)
E	Young's modulus
V	deformation modulus
φ	friction angle
c	cohesion

2. Rock properties

w	water content, dry weight basis
d	the diameter (in mm) of the actual specimen
σ_c	uniaxial compressive strength of intact rock material
$\sigma_{c\,90}$	uniaxial compressive strength measured at right angle to the schistocity or
σ_{c50}	uniaxial compressive strength for 50 mm diameter sample size
R_c	strength anisotropy ($\sigma_{c\,max}/\sigma_{c\,min}$)
$Ia_{(50)}$	strength anisotropy index
Is	point load strength index
$Is_{(50)}$	point load strength measured on standard 50 mm thick sample
k	correlation factor between compressive and point load strength ($k = \sigma_c/Is$)
k_{50}	correlation factor related to 50 mm thick samples ($k_{50} = \sigma_{c50}/Is_{50}$)
Fi	rock foliation index, as given in Table A3-I.
fA	rock anisotropy factor
fW	rock weathering and alteration factor
c	the content of platy and prismatic minerals in %

3. Jointing and block characteristics

i	dilation angle for a joint plane
φ_j	friction angle for a joint
S_j	shear strength intercept ('cohesion') for a joint
JRC	joint roughness coefficient
JCS	the joint wall compressive strength (for fresh (unweathered) rocks JCS = σ_c)
u	undulation of joint plane
L_1	direct measured length along a joint surface (Turk and Dearman, 1982)
L_2	the trace length measured on joint surface (Turk and Dearman, 1982)

γ	angle between joint sets
S	spacing of joints within a set
S_a	average joint spacing
S1, S2, S3	spacing in various joint sets
$\alpha 2$	ratio between medium joint spacing and minimum spacing (S2/S1)
$\alpha 3$	ratio between maximum joint spacing and minimum spacing (S3/S1)
a3	length of the block
a1	thickness of the block.
β	block shape factor
β_e	estimated block shape factor from $\beta_e = \beta_o + 7(\alpha 3 - 1) = 27 + 7(a3/a1 - 1)$
β_o	the lowest value of β, i.e. $\beta = 27$ for a cubical (equidimensional) blocks
Jv	volumetric joint count (= the number of joints per m^3)
wJd	weighted joint density
Ib	block size index (eq. block diameter) introduced by ISRM (1978).
Db	block diameter applied in rock support assessments (= $\sqrt[3]{\underline{Vb}}$)
Db_e	eq. block diameter
Vb	block volume
Vb_o	block volume delimited by 3 joint sets intersecting at right angles
A	the size of the observation area (in m^2, see Fig. A3-27)
na	number of joints on an observation area with length L_i
na*	number of joints adjusted for the length and size of observation area (see eq. (A3-32a))
Na	2-D joint frequency, i.e. the number of joints in a defined area, Na = na/A
Nl	1-D joint frequency, i.e. the number of joints intersecting a defined length along a line or borehole
Nr	the number of random joints in the observation area
N_α	number of joints intersected at an angle α
N_{90}	the number of joints with the same orientation which would have been observed at an intersection angle of 90^o
n_j	the rating for joint sets applied in eq. (A3-20 and (A3-21)
ka	correlation factor from 2-D frequency measurement to 3-D (volume) (see Fig. A3-25c and eq. (A3-32b))
kl	correlation factor from 1-D frequency measurement to 3-D (volume) (see Fig. A3-26 and eq. (A3-33))
ca	1/ka for 2-D observations on rock surfaces
cl	1/kl for 1-D observations of scanlines or drill cores
L	length of the measured section along core or line, see Fig. A3-27
δ	the angle between the observation plane (or drill core) and the individual joint, which is used in the weighted joint density method
f_i	factor for the angle between joint and observation plane (or $(1/\sin\delta_i)$ used in the weighted joint density measurement, as given in Table A3-31

4. Stresses and related parameters

σ_o	initial stress
$\sigma_1, \sigma_2, \sigma_3$	principal stresses; $\sigma_1 > \sigma_2 > \sigma_3$
σ_{min}	minimal principal stress
σ_{max}	maximum principal stress
σ_1'	the major principal effective stress at failure.

σ_3'	the minor principal effective stress
σ_n	normal stress
p_z or p_v	vertical stress
p_h	horizontal stress
p_0	in situ hydrostatic rock stress
σ_θ	tangential stress around underground openings
σ_r	radial stress around underground openings
$\sigma_{\theta w}$	tangential wall stress
$\sigma_{\theta r}$	tangential roof stress
τ	shear stress at failure
Φ_i'	instantaneous friction angle
c	cohesion
c_i'	instantaneous cohesive strength
k	ratio of horizontal and vertical stresses (p_h / p_v)
f	the gradient of line in the $-\varepsilon_3^p$, ε_1^p diagram (Fig. 8-4)

5. Refraction seismic properties and features

V_p	longitudinal (compressional) wave velocity
V_s	shear wave velocity
V_l	sonic velocity in water
V_f	longitudinal sonic velocitiy measured in the field
V_l	longitudinal sonic velocity measured in the laboratory
$V_\parallel$, $V_\perp$	wave propagation parallel and across layers/schistocity
v	seismic velocity measured in the field
V_0	basic seismic velocity (km/s) for intact rock under the same stress level as in the field (measured in the laboratory)
V_n	maximum or 'natural' velocity in crack- and joint-free rock under the same stress level as in the field. Natural velocities for some fresh rocks measured in the laboratory are shown in Table A3-33
a, b	constants related to the local ground conditions (rock material, stress condition, jointing features etc.)for in-situ seismic velocities
ks	factor representing in-situ conditions in seismic velocity assessments
Nl_1, v_1 and Nl_2, v_2	corresponding values of joints/m and in-situ longitudinal velocity, respectively, for two pairs of measurements
SVR	'seismic velocity ratio' (SVR = V_f / V_l)
VI	sonic velocity index (VI = SVR^2)

6. Rock mass properties and features

σ_{cm}	the compressive strength the rock mass,
m	undisturbed material constant in the original Hoek-Brown failure criterion
m	disturbed material constant in the original Hoek-Brown failure criterion
m_r	material constants in the Hoek-Brown failure criterion for *broken* rock mass
m_i	material constants in the Hoek-Brown failure criterion for intact rock
m_b	constant in the modified Hoek-Brown failure criterion (1992)
s	undisturbed material constant in the original Hoek-Brown failure criterion
s	disturbed material constant in the original Hoek-Brown failure criterion

s_r material constants in the Hoek-Brown failure criterion for *broken* rock mass
a constant in the modified Hoek-Brown failure criterio (1992)
C_g the reduction factor which Hansagi named 'gefüge-factor' (joint factor) being "*representative for the jointed effect of a rock mass*".

6.1 Classification systems and parameters

RSR rock structure rating
RMR rock mass rating in the Geomechanics classification system
RQD rock quality designation
Q rock mass quality value in the Q classification system
Jn factor for joint set number in the Q-system
Jr factor for joint roughness in the Q-system
Ja factor for joint alteration and filling in the Q-system
Jw factor for joint water pressure or inflow in the Q-system
SRF stress reduction factor in the Q-system
ESR excavation support ratio in the Q-system

6.2 Parameters and features in the Rock Mass index (RMi)

jR joint roughness factor, representing the small and large scale unevenness of the joint surface (jR = jw × js)
js joint smoothness factor (small scale evenness of joint surface)
jw joint waviness factor (large scale planarity of joint wall)
jA joint alteration factor, characterizing the strength of the joint surface
jL joint length and continuity (joint termination) factor
jC joint condition factor (combination of jR, jA and jL)
JP jointing parameter (i.e. combination of jC and Vb)
D factor in eq. (4-4) to calculate the jointing parameter [JP (D = $0.37 \times jC^{-0.2}$)]

7. Parameters in the RMi rock support method

z the depth of the actual location below surface
Db equivalent block diameter
CF continuity factor for the rock mass (CF = tunnel size/block size)
Cg competency factor for continuous ground (Cg = RMi /σ_c)
Gc ground condition factor for discontinuous ground (Gc = JP × SL)
SL stress level factor used for discontinuous ground
Sr size ratio (Sr = CF × Co)
Co orientation factor for joints and zones
C gravity adjustment factor (of Gc) for tunnel walls (Milne and Potvin, 1992)
α the strike between tunnel surface and discontinuity
β the dip between tunnel roof (or floor) and discontinuity
Tz the width (thickness) of weakness zone
Ts the width (thickness) of singularity
σ_{cz} compressive strength of rock material in weakness zone
JP_a the jointing parameter of the rock masses adjacent to the weakness zone
Gc_z the ground condition factor for zones with $Tz < JP_a \times \sigma_{cz}$

Sr_z	size ratio ($Sr_z = Co \times Tz / Db$) for weakness zones for Tz < Wt or Tz < Wt
Gc_s	the ground condition for singularities
B	rock bolt
S	shotcrete
F	fibrecrete
Wt	width (span) of tunnel
Ht (or Hw)	height of tunnel (or wall height)
r_i	internal tunnel radius
A	roof factor for various excavation shapes (used by Hoek and Brown, 1980)
B	wall factor for various excavation shapes (used by Hoek and Brown, 1980)

8. Parameters and features applied in the method for TBM penetration assessment

E	factor for various groups of rocks
k_s	a TBM jointing factor (applied in the NTH method)
c_o	factor representing orientation of the main joint set relative to the tunnel axis
k_{eq}	'equivalent TBM jointing factor' (applied in the NTH method)
k_{DRI}	adjustment factor of k_s to arrive at $k_{eq} = k_s \cdot k_{DRI}$ (applied in the NTH method)
M_{eq}	equivalent thrust per cutter (also applied in the NTH method)
M_B	thrust capacity per disc (also applied in the NTH method)
k_d	correction factor for cutter diameter in Fig. 7-7 (also applied in the NTH method)
k_a	correction factor for cutter spacing given in Fig. 7-8 (also applied in the NTH method)
I	TBM advance rate (m/h)
i_o	TBM penetration rate in mm per revolution $i_o = F \times k_{eq}^{G}$
F	a factor in the expression for TBM penetration ($F = 0.0015\ M_{eq}^{1.5}$)
G	an exponent in the expression for i_o ($G = 30\ k_{eq}^{-0.5} \times M_{eq}^{-0.8}$ for $k_{eq} < 3.5$)