2.5 Q-tables AND LOGGING ADVICE
for
HISTOGRAM LOGS

$$Q = \frac{RQD}{J_n} \times \frac{J_r}{J_a} \times \frac{J_w}{SRF}$$

Jn = the rating for the number of joint sets (9 for 3 sets, 4 for 2 sets etc.) In the same domain
Jr = the rating for the roughness of the least favourable of these joint sets or filled discontinuities
Ja = the rating for the degree of alteration or clay filling of the least favourable joint set or filled discontinuity
Jw = the rating for the water inflow and pressure effects, which may cause outwash of discontinuity infillings
SRF = the rating for faulting, for strength/stress ratios in hard massive rocks, for squeezing or for swelling

RQD / Jn = relative block size (useful for distinguishing massive, rock-burst-prone rock)
Jr / Ja = relative frictional strength (of the least favourable joint set or filled discontinuity)
Jw / SRF = relative effects of water, faulting, strength/stress ratio, squeezing or swelling (an 'active stress' term)

An alternative combination of these three quotients in two groups only, has been found to give fundamental properties for describing the shear strength of rock masses – something close to ***the product of 'c' and 'tan φ'***. By implication Q (and in particular Qc) have units resembling ***MPa.***

Footnotes at the bottom of the tables that follow, also give advice for site characterization ratings for the case of Jw and SRF, which must not be set to 1.0 and 1.0, as some authors have suggested. This destroys the intended multi-purposes of the Q-system, which has an entirely different structure compared to RMR.

1. Rock Quality Designation		**RQD (%)**
A	Very poor	0-25
B	Poor	25-50
C	Fair	50-75
D	Good	75-90
E	Excellent	90-100

Notes:

i) Where RQD is reported or measured as $\leq$ 10 (including 0), a nominal value of 10 is used to evaluate Q.

ii) RQD intervals of 5, i.e., 100, 95, 90, etc., are sufficiently accurate.

2.	Joint set number	J_n
A	Massive, no or few joints	0.5-1
B	One joint set	2
C	One joint set plus random joints	3
D	Two joint sets	4
E	Two joint sets plus random joints	6
F	Three joint sets	9
G	Three joint sets plus random joints	12
H	Four or more joint sets, random, heavily jointed, 'sugar-cube', etc.	15
J	Crushed rock, earthlike	20

Notes:

i) For tunnel intersections, use ($3.0 \times Jn$).

ii) For portals use ($2.0 \times Jn$).

3. Joint roughness number		J_r
a) Rock-wall contact, and b) Rock-wall contact before 10 cm shear		
A	Discontinuous joints	4
B	Rough or irregular, undulating	3
C	Smooth, undulating	2
D	Slickensided, undulating	1.5
E	Rough or irregular, planar	1.5
F	Smooth, planar	1.0
G	Slickensided, planar	0.5
Notes: **i)** Descriptions refer to small-scale features and intermediate scale features, in that order.		

4.	Joint alteration number	Φ_r approx.	J_a
	a) Rock-wall contact (no mineral fillings, only coatings)		
A	Tightly healed, hard, non-softening, impermeable filling, i.e., quartz or epidote.	--	0.75
B	Unaltered joint walls, surface staining only.	25-35°	1.0
C	Slightly altered joint walls. Non-softening mineral coatings, sandy particles, clay-free disintegrated rock, etc.	25-30°	2.0
D	Silty- or sandy-clay coatings, small clay fraction (non-softening).	20-25°	3.0
E	Softening or low friction clay mineral coatings, i.e., kaolinite or mica. Also chlorite, talc, gypsum, graphite, etc., and small quantities of swelling clays.	8-16°	4.0
	b) Rock-wall contact before 10 cm shear (thin mineral fillings).		
F	Sandy particles, clay-free disintegrated rock, etc.	25-30°	4.0
G	Strongly over-consolidated non-softening clay mineral fillings (continuous, but < 5 mm thickness).	16-24°	6.0
H	Medium or low over-consolidation, softening, clay mineral fillings (continuous, but < 5 mm thickness).	12-16°	8.0
J	Swelling-clay fillings, i.e., montmorillonite (continuous, but < 5 mm thickness). Value of J_a depends on per cent of swelling clay-size particles, and access to water, etc.	6-12°	8-12
	c) No rock-wall contact when sheared (thick mineral fillings)		
KL M	Zones or bands of disintegrated or crushed rock and clay (see G, H, J for description of clay condition).	6-24°	6, 8, or 8-12
N	Zones or bands of silty- or sandy-clay, small clay fraction (non-softening).	---	5.0
OP R	Thick, continuous zones or bands of clay (see G, H, J for description of clay condition).	6-24°	10, 13, or 13-20

5.	Joint water reduction factor	approx. water pres. (kg/cm^2)	J_w
A	Dry excavations or minor inflow, i.e., < 5 l/min locally.	< 1	1.0
B	Medium inflow or pressure, occasional outwash of joint fillings.	1-2.5	0.66
C	Large inflow or high pressure in competent rock with unfilled joints.	2.5-10	0.5
D	Large inflow or high pressure, considerable outwash of joint fillings.	2.5-10	0.33
E	Exceptionally high inflow or water pressure at blasting, decaying with time.	> 10	0.2-0.1
F	Exceptionally high inflow or water pressure continuing without noticeable decay.	> 10	0.1-0.05

Notes:

- **i)** Factors C to F are crude estimates. Increase Jw if drainage measures are installed.
- **ii)** Special problems caused by ice formation are not considered.
- **iii)** For general characterization of rock masses distant from excavation influences, the use of Jw = 1.0, 0.66, 0.5, 0.33 etc. as depth increases from say 0-5m, 5-25m, 25-250m to >250m is recommended, assuming that RQD /Jn is low enough (e.g. 0.5-25) for good hydraulic connectivity. This will help to adjust Q for some of the effective stress and water softening effects, in combination with appropriate characterization values of SRF. Correlations with depth-dependent static deformation modulus and seismic velocity will then follow the practice used when these were developed.

6. **Stress Reduction Factor**		
a) Weakness zones intersecting excavation, which may cause loosening of rock mass when tunnel is excavated		**SRF**
A	Multiple occurrences of weakness zones containing **clay** or chemically disintegrated rock, very loose surrounding rock (any depth).	10
B	Single weakness zones containing **clay** or chemically disintegrated rock (depth of excavation ≤ 50 m).	5
C	Single weakness zones containing **clay** or chemically disintegrated rock (depth of excavation > 50 m).	2.5
D	Multiple shear zones in competent rock (**clay-free**), loose surrounding rock (any depth).	7.5
E	Single shear zones in competent rock (**clay-free**), (depth of excavation ≤ 50 m).	5.0
F	Single shear zones in competent rock (**clay-free**), (depth of excavation > 50 m).	2.5
G	Loose, open joints, heavily jointed or 'sugar cube', etc. (any depth)	5.0
Note: **i)** Reduce these values of SRF by 25-50% if the relevant shear zones only influence but do not intersect the excavation. This will also be relevant for characterization.		

6. Stress Reduction Factor

	b) Competent rock, rock stress problems	σ_c / σ_1	$\sigma_\varphi / \sigma_c$	SRF
H	Low stress, near surface, open joints.	> 200	< 0.01	2.5
J	Medium stress, favourable stress condition.	200-10	0.01-0.3	1
K	High stress, very tight structure. Usually favourable to stability, may be unfavourable for wall stability.	10-5	0.3-0.4	0.5-2
L	Moderate slabbing after > 1 hour in **massive** rock.	5-3	0.5-0.65	5-50
M	Slabbing and rock burst after a few minutes in **massive** rock.	3-2	0.65-1	50-200
N	Heavy rock burst (strain-burst) and immediate dynamic deformations in **massive** rock.	< 2	> 1	200-400

Notes:

ii) For strongly anisotropic virgin stress field (if measured): When $5 \leq \sigma1 / \sigma3 \leq 10$, reduce σc to $0.75\ \sigma c$. When $\sigma1 / \sigma3 > 10$, reduce σc to $0.5\ \sigma c$, where σc = unconfined compression strength, $\sigma1$ and $\sigma3$ are the major and minor principal stresses, and $\sigma\theta$ = maximum tangential stress (estimated from elastic theory).

iii) Few case records available where depth of crown below surface is less than span width. Suggest an SRF increase from 2.5 to 5 for such cases (see H).

iv) Cases L, M, and N are usually most relevant for support design of deep tunnel excavations in hard massive rock masses, with RQD /Jn ratios from about 50 to 200.

v) For general characterization of rock masses distant from excavation influences, the use of SRF = 5, 2.5, 1.0, and 0.5 is recommended as depth increases from say 0-5m, 5-25m, 25-250m to >250m. This will help to adjust Q for some of the effective stress effects, in combination with appropriate characterization values of Jw. Correlations with depth - dependent static deformation modulus and seismic velocity will then follow the practice used when these were developed.

6. **Stress Reduction Factor**			
c) Squeezing rock: plastic flow of incompetent rock under the influence of high rock pressure		$\sigma_\varphi / \sigma_c$	**SRF**
O	Mild squeezing rock pressure	1-5	5-10
P	Heavy squeezing rock pressure	> 5	10-20

Note:

vi) Cases of squeezing rock may occur for depth H > 350 $Q^{1/3}$ according to Singh 1993. Rock mass compression strength can be estimated from SIGMA $_{cm} \approx 5 \gamma Q_c^{1/3}$ (MPa) where γ = rock density in t /m^3, and Q_c = Q x σ_c /100, Barton, 2000.

d) Swelling rock: chemical swelling activity depending on presence of water		**SRF**
R	Mild swelling rock pressure	5-10
S	Heavy swelling rock pressure	10-15

NOTES ON Q-METHOD OF ROCK MASS CLASSIFICATION

1) The tables contain all the ratings necessary for *classifying* the Q-value of a rock mass. The ratings form the basis for the Q, Qc and Qo estimates of rock mass quality (Qc needing only multiplication of Q by σc /100, and Qo the use of a specifically oriented RQD, termed RQDo relevant to a loading or measurement direction). All the *classification* ratings needed for tunnel and cavern design are given in the six tables, where Q only would usually apply.

2) **For correlation to engineering parameters, use Qc (multiplication of Q by σc / 100). For specific loading or measurement directions in anisotropically jointed rock masses use RQDo in place of RQD in the Q estimate. This means that an *oriented* Qc value should contain a correctly *oriented* RQDo for better correlation to *oriented* engineering parameters.**

3) Q-parameters are most conveniently collected using *histogram logging*. Besides space for recording the usual variability of parameters, for structural domain 1, domain 2 etc., it contains reminders of the tabulated ratings at the base of each histogram. Space for presentation of results for selected (or all) domains at the top of the diagram, includes *typical range, weighted mean and most frequent* (Q-parameters, and Q-values).

4) During **field logging**, allocate running numbers to the structural domains, or core boxes, or tunnel sections, e.g. 1 = D1, 2 = D2 etc. and write the numbers in the allotted histogram columns, using a regular spacing for each observation such as 11, 113, 2245, 6689 etc. In this way the histograms will give the correct visual frequency of all the assembled observations, in each histogram column. Besides this, it will be easy to find the relevant Q-parameters for a particular domain, core box or section of tunnel, for separate analysis and reporting. Overall frequencies of observations of each rating (or selected sets of data) can be given as numbers on separate logging sheets. Large data sets can be computerised when returning from the field.

NOTES ON Q-METHOD OF ROCK MASS CLASSIFICATION, Cont.

5) **It is convenient and correct to record rock mass variability. Therefore allow as many as *five* observations of each parameter, for instance in a 10m length of tunnel. If all observations are the same, great uniformity of character is implied, if variable – this is important information. At 'the end of the day' the histograms will give a correct record of variability, or otherwise.**

6) Remember that logged RQD of < 10, including 0, are set to a nominal 10 when calculating Q. In view of the log scale of Q, the histograms of RQD in the logging sheet will be sufficiently accurate if given mean values, from left to right, of 10, 15, 25, 35……85, 95, 100. The log scale of Q also suggests that decimal places should be used sparingly. The following is considered realistic 0.004, 0.07, 0.3, 6.7, 27, 240. Never report that Q = 6.73 or similar, since a false sense of accuracy will be given.

7) Footnotes below each table also give advice for site *characterization* ratings for the case of Jw and SRF, which **must not** be set to 1.0 and 1.0, as some authors have suggested. This destroys the intended multi-purposes of the Q-system, which has an entirely different structure compared to RMR.

Important:

Use all appropriate footnotes under the six tables. Some have been updated or added since the minor 1993/1994 updating of three SRF values for highly stressed massive rock, which were changed due to 'new' support techniques, namely B+S(fr).

Location: | Depth / chainage: | Date: | Page:

Numbers for domains, core boxes, tunnel lengths (under-line, or specify)

Q (typical range) = ( )x( )x( )

Q (mean) = ( )x( )x( )

Q (most freq.) = ( )x( )x( )

BLOCK SIZES

RQD % (Core pieces ≥ 10 cm)

Very Poor		Poor		Fair		Good		Exc.	
0	10	20	30	40	50	60	70	80	90	100	100

J_n (Number of joint sets)

Earth	Four		Three		Two		One		None
20	15	12	9	6	4	3	2	1	0.5

1=

2=

3=

4=

5=

6=

7=

8=

9=

FRICTION

J_r (Joint roughness - least favourable)

Fills	Planar			Undulating			Disc.
1.0	0.5	1	1.5	1.5	2	3	4

J_a (Joint alteration - least favourable)

Thick Fills							Thin Fills				Coated		Unfilled		Heal
20	13	12	10	8	6	5	12	8	6	4	4	3	2	1	0.75

ACTIVE STRESS

J_w (Joint water pressure)

Exc. Inflows		High Press			Wet	Dry
0.05	0.1	0.2	0.33	0.5	0.66	1

$\frac{RQD}{J_a}$ =

$\frac{J_r}{J_a}$ = (most freq.)

SRF (Stress reduction factor)

Squeeze				Swell				Faults				Stress/Strength							
20	15	10	5	20	15	10	5	10	7.5	5	2.5	100	50	20	5	2	0.5	1	2.5

Photos

or Sketch