1. THE MANY FACES OF Q – ROCK MASS CHARACTERIZATION FOR TUNNELS, CAVERNS, SLOPES, TBM PROGNOSIS, DEFORMABILITY, SHEAR STRENGTH, SEISMIC VELOCITY, PERMEABILITY

An introduction to the Q-system of rock mass characterization by the originator, with numerous examples of the method and its application in support selection for single-shell drill-and-blast tunnels and caverns. Since development in 1974 the method has been extended into several areas, including TBM prognosis (Q_{TBM}), and rock slope safe-angle selection (Q_{SLOPE}). It has also been correlated with seismic velocity V_P (using Q_c= Q x UCS/100), and with permeability (using Q_{H2O}). The lecture is of a general introductory interest-generating nature, with examples of dramatic collapses and lessons learned. There is also numerical modelling commentary and some examples.

CONTENTS of LECTURE

Lecture in two parts: Part 1: 1 hour. Part 2: 1 hour

2. SHEAR STRENGTH of ROCK, ROCK JOINTS and ROCK MASSES: PROBLEMS and SOME SOLUTIONS

An introduction to the shear strength components of rock masses: the intact rock (also up to very high stress), the rock joints, and the clay-filled discontinuities. The shear strength of rockfill and interfaces is also briefly covered. Attempts are made to suggest a logical approach to the shear strength of the combined strength components in a rock mass, such that progressive failure can also be understood. The main focus will be the shear strength of rock joints (and fresh fractures), obtaining and using the parameters JRC and JCS, and how they are scaled for larger block sizes. The discrete, deterministic approach will be contrasted to the continuum approach of Hoek and Brown and GSI.

Content of Lecture

1. INTACT ROCK – CRITICAL STATE – A NEW CRITERION
2. ROCK JOINTS – NO COHESION – TESTING PROBLEM
3. SCALE EFFECTS for ROCK JOINTS
4. STRESS TRANSFORMATION ERRORS: NO DILATION
5. ROCK MASSES – displacement-and-process dependent
6. CANNOT ADD ‘c’ and ‘σn tan φ’ – NOT COINCIDENT
7. A SIMPLE (-minded) ALTERNATIVE TO H-B/GSI: SPLIT QC
8. CONCLUSIONS

3. USING DEEP TUNNELS, CLIFFS, MOUNTAIN WALLS, MODELS AND MOUNTAINS: *TO EXPLORE FAILURE MODES* IN ROCK AND ROCK MASSES

This third lecture of the series combines some aspects of failure in tunnels due to high stress (and strain) levels, with what we have seen of the shear strength of rock masses. Topics are combined in an unusual way as the maximum height of cliffs in weak rock, and mountain walls in strong rock are each addressed, and a new method is introduced involving Poisson-ratio induced extension failure, the weakest link when near a free face, as proposed for tunnels by Baotang Shen, the developer of the FRACOD code. Finally the limiting height of mountains is addressed, again requiring the weakest link, in this case the critical state maximum shear strength.

CONTENT of LECTURE

1. **FAILURE MODES IN DEEP TUNNELS: STRESS/STRENGTH? CRITICAL STRAIN?**
2. **CLIFF FAILURES IN ROCK – CAN WE USE 'SOIL MECHANICS METHODS'?**
3. **CRITICAL TENSILE STRAIN APPROACH FOR CLIFFS AND MOUNTAIN WALLS**
4. **COMBINED FAILURE MODES. CCSS: Crack!! Crunch! Scrape! Swoosh!! M-C?**
5. **IS PREKESTOLEN (the 'Pulpit') SAFE TO STAND ON, 600m over LYSEFJORD?**
6. **BLOCK-ROTATION FAILURE MODES, AND STEAM!**
7. **THE HIGHEST MOUNTAINS ARE 'ONLY' 8 to 9 km HIGH – WHY IS THIS?**
8. **CRITICAL STATE SHEAR STRENGTH CURVATURE IS RELATED TO UCS**

4. TBM PERFORMANCE: CASE RECORD ANALYSIS including FAULTS, AND RECENT Qtbm PROGNOSIS

This fourth lecture is also anchored in case record analysis as a basis for understanding, in particular, why ulilization of TBM is time- and tunnel-length dependent. There is too much emphasis on penetration rate prognosis in the literature, when the reality, for tunnel completion, is the advance rate over time. Examples of open-gripper, double-shield and world-record performances are given, plus a rich selection of delays in fault zones. Q-value related reasons for delays are also treated with three ultra-simple equations AR = PR x U, $U = T^m$, and T = L/AR. The deceleration gradient (-m) depends on Q-values when rock mass conditions are poor (Q<1). Finally the Q_{TBM} prognosis model is explained and demonstrated.

CONTENT of LECTURE

1. SOME IMPORTANT ELEMENTS RELATED TO TBM PERFORMANCE

2. CUTTER FORCE VERSUS ROCK MASS STRENGTH

3. CASE-RECORDS OF OPEN-GRIPPER, DOUBLE-SHIELD TBM

4. WORLD-RECORD TBM PERFORMANCES

5. TBM DELAYS IN FAULT ZONES – EXAMPLES FROM SIX COUNTRIES

6. DECELERATION (-m) ACCENTUATED IN FAULT ZONES

7. IS IT CORRECT TO USE TBM: 'BECAUSE TUNNEL IS SO LONG'?

8. TBM THROUGH MOUNTAINS: HIGH STRESS CLOSE TO TUNNEL WALL

9. TBM PROGNOSIS : Q with MACHINE-ROCK INTERACTIONS

10. *QTBM* PROGNOSIS: EXAMPLE OF JOINTED-ROCK-WITH-FAULTS