Program of SHORT COURSE

Rock engineering for tunnels (drill-and-blast and tbm), pre-grouting, caverns, dam abutments, rock slopes and rockfill
(All these topics to be addressed with relevant parts of the Q-system, Q_{TBM}, Q_{SLOPE} and the Barton-Bandis strength criterion)

Zagreb, Croatia, June 02-04, 2011

Lecturer: Dr. Nick Barton

Dr. Nick Barton was educated in the University of London from 1963 to 1970, and has a B.Sc. in civil engineering from King's College, and a Ph.D. on rock slope stability from Imperial College. He worked for two periods in the Norwegian Geotechnical Institute, Oslo, eventually as Division Director, then Technical Advisor, and was also four years in the USA, becoming Manager of Geomechanics in Terra Tek, now Schlumberger. Since 2001 he has had his own international rock engineering consultancy, registered as Nick Barton & Associates in Oslo, and also has an office in São Paulo. He has consulted on projects in 34 countries, and published widely (260 papers, and two text books). He has five international awards and was elected a Doctor honoris causa in Argentina. Recently he was selected for the 6th Mueller Award of ISRM, a lecture to be given in Beijing 2011.

This two and half-days short course will cover some key elements of the lecturer's internationally applied developments in rock mechanics and rock engineering. The course will start with a thorough treatment of the Q-system of rock mass classification and its many site-interpretation and tunnel-design aspects.

International experiences will be reflected in numerous case record examples using rock joint characterization techniques and rock mass *Q-system* application, for site investigation, for preliminary support design of tunnels and large caverns, and for follow-up and support modification during construction. The links between Q and seismic velocity will be explained. Mapping techniques, core logging interpretation, and so-called 'histogram-logging' will be emphasized.

Fundamentals of rock joint characterization, coupled behaviour involving permeability, shear strength, stiffness, and links to the strength of rockfill will also be covered, and a new *Q-slope* method will also be introduced, for estimating safe slope angles in jointed rock masses. Reinforcement of slopes in relation to shear strength will be emphasised. Most recently the shear strength of rock masses has also been linked to Q, and modelling using 'c then tan φ' degradation /mobilization is suggested as a more realistic method than conventional practice.

Time	02.06.2011. (Thursday)	Time	03.06.2011. (Friday)	04.06.2011. (Saturday)
09:00-10:30	**INTRODUCTION TO THE Q-SYSTEM OF ROCK MASS CHARACTERIZATION** ➢ Background, motivation, characteristics of Q. ➢ The six Q-parameters explained with numerous examples, including Q-roughness Jr-parameter links to the more sophisticated JRC. ➢ Q-RMR comparison and useful link-plots. ➢ Q-histogram logging. ➢ Q-Tables and general logging advice.	09:00-09:30	**SHEAR STRENGTH OF ROCKFILL-EMBANKMENTS, INTERFACES AND ROCK JOINTS, AND THEIR POINTS OF CONTACT** Due to a common situation of 'points-of-contact' under high stress, the shear strengths of these three 'geotechnical materials' are very similar. Large-scale test methods for accepting full-size rockfill are demonstrated. JRC-controlled, and R-controlled behaviour are differentiated in dam foundation scenarios.	09:00-14:00 A 1/2 day trip to a quarry for to practice Q-histogram logging in small groups at various exposures.
		09:30-10:30	**COMBINING BOREHOLE CHARACTERIZATION AND VARIOUS SEISMIC MEASUREMENTS IN TUNNELLING AND DAM FOUNDATION WORKS** An illustration of a variety of seismic measurements for characterizing civil engineering sites such as dam foundations, bridge foundations, tunnels and caverns. Cross-correlation between rock quality, velocity, permeability and deformability may be compromised by an EDZ with shear deformation.	
10:30-11:00	Coffee break/Questions	10:30-11:00	Coffee break/Questions	
11:00-12:00	**LINKING Q TO USEFUL PARAMETERS FOR DESIGN** ➢ Core logging examples, including faulted and weathered rock. ➢ Rock mass strength estimation from Q (CC and FC). ➢ P-wave velocity, and effects of	11:00-12:00	**INVESTIGATIONS AND DESIGN OF THE LARGEST CAVERN EVER BUILT, WITH CONTRAST TO A HYDROPOWER CAVERN IN SEVERELY FAULTED ROCK** The largest cavern ever built for use by the public, effectively doubling the previous largest span, was built in jointed gneiss in Norway, for initial use in the 1994 Winter Olympic Games. Q-logging site investigation, cross-hole tomography, stress	

	weathering and depth on velocity, and the links to Q. ➢ Deformation modulus estimation at depth, from seismic velocity or from Q. ➢ Tunnel and cavern convergence estimation from empirical Q formulae.		measurement and numerical UDEC-BB modelling and NMT-style permanent support design for this 62 m span cavern are described, including follow-up mapping and monitoring. The 'Class A' predictions of performance proved to be very accurate. A hydropower cavern in faulted rock in Taiwan with special support measures emphasises the range of problems.	
12:00-13:00	Lunch break	12:00-13:00	Lunch break	
13:00-14:30	**TUNNEL SUPPORT SELECTION FROM Q CLASSIFICATION, AND SUPPORT ELEMENT PROPERTIES** ➢ Historical development of Q for B+S(mr) mesh-based support. ➢ NMT tunnel support philosophy. ➢ Tunnel support design with B+S(fr) fibre-reinforced shotcrete support. ➢ Temporary or permanent support. ➢ Physical performance of S(fr) and bolting. ➢ Reinforced RRS arches for bad ground. ➢ Cost versus Q and tunnel size.	13:00-14:30	**SLOPE STABILITY PRINCIPLES AND Q_{SLOPE} METHOD OF CHARACTERISING ROCK SLOPES FOR DECIDING ON SAFE SLOPE ANGLES** A slight modification of the Q-system for collecting information on slope-related Q-parameters, including 'wedges' made of two different joint sets, and extreme rainfall. Safe slope angles for road cuttings or benches, using core characterization, and/or seismic refraction, and/or pilot-slope logging. Rock reinforcement based on shear strength for slopes that have to be over-steepened, as at dam and spillway sites. Some aspects of coupled behavior involving water pressure and permeability.	
14:30-15:00	Coffee break/Questions	14:30-15:00	Coffee break/Questions	

15:00-16:30	**TBM PROGNOSES THROUGH HARD ROCK, HIGH STRESS, OR WEAKNESS ZONES, USING QTBM METHODS WITH OPEN-GRIPPER OR DOUBLE-SHIELD TBM** ➢ Open-gripper and double-shield TBM ➢ Case record analysis and Q TBM development ➢ TBM prognosis in hard abrasive rock - case study ➢ TBM problems in fault zones - case examples ➢ TBM problems with high stress - case examples	15:00-16:30	**PRE-GROUTING AND WATER CONTROL** ➢ Water control methods in tunnels. ➢ Simplified interpretation of Lugeon tests for pre-grout design. ➢ Comparing joint aperture estimates with available particle sizes. ➢ High-pressure injection concepts and pressure decline. ➢ Some performance and volumetric data from pre-injected tunnels. ➢ Rock quality/parameter improvement by pre-injection.	
16:30-17:30	Discussion and questions	16:30-17:30	Discussion and questions	