SHORT COURSE,
ROCK ENGINEERING FOR TUNNELS (DRILL-AND-BLAST AND TBM), PRE-GROUTING, CAVERNS, DAM ABUTMENTS, ROCK SLOPES AND ROCKFILL
DR. NICK BURTON
ZAGREB, 2-4.06.211.

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 weathering and depth on velocity, and the links to Q.	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 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	

	➢ Deformation modulus estimation at depth, from seismic velocity or from Q. ➢ Tunnel and cavern convergence estimation from empirical Q formulae.		'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	