Tunneling in difficult ground
Uncertainties and decisions. Attention to the Himalayan range

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The growth of infrastructure needs has increased the demands for the excavation of tunnels in poor ground or varying geological conditions. The assessment of ground for design has to be based on a sound understanding of the regional geological rules and the establishment of a geological model, where data and conditions are translated into an engineering description. A series of geological models for a variety of rocks associated with different structural conditions in various tectonic environments, based on the geological history are presented. Site investigation is an important factor for the establishment of the geological model and it must be based on a sound geological understanding of regional geology, otherwise it is likely not to find much of value. Examples and cases from both mountain and urban tunnels under complex or difficult geological conditions are discussed.

Going from the geological model to the ground model, the design requires knowledge on the quality of the material in which the tunnel will be constructed. Engineering design requires numbers and the lecture explores and discusses methods that can be used to assess the geological factors that have an impact on this quality. These mainly are the quality of the intact rock, the fabric of the mass, the quality of discontinuities. Since the attempt of Terzaghi, in 1946, to correlate the characteristics of a rock masses for the tunnel design, a number of rock mass classifications have been developed and play an important role providing input data on strength and deformation properties of the ground for numerical models. A discussion on this issue is presented, with the field of application of this quantitative characterization of the rock masses and its limitations. Together with the rock mass properties, the in situ stresses field has to be estimated or measured and this is one of the most difficult tasks.

Although the role of engineering geology has been extended into the area of defining the design parameters, the idealization process, in the form of numerical analysis, should be driven by sound geologic reasoning in order idealization does not misinterpret reality. In this context the understanding of the real behaviour is indeed absolutely necessary before any calculation is attempted. Thus, the engineering geological “I.D” of the geomaterial and the stress environment define this ground behaviour such us: brittle failure, gravitational falling or sliding or “chimney” type failure, or ravelling, or formation of a “plastic” zone by shear failure with deformation problems and squeezing, or swelling.

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Mechanizing tunnelling is discussed in relation with the geological conditions in complex mountain ranges and particularly the use of the appropriate type of TBM to face either rock bursting phenomena or squeezing ground.

Along the lecture geological uncertainties and decisions, in the design and construction are discussed. These relate to:

-spatial changes of the geological formations with particularities in their borders, some time with chaotic structure.
-variability of properties of the ground and its behaviour
-in situ stresses, with some particular and extreme cases
-specific geological features, such as fault zones, thrusts
-hydrogeologic conditions with special emphasis to karst

Examples from a number of tunnels from around the world illustrate the design and construction procedures. Attention is specified to tunnels in the Himalayan range.