Guest Editorial

EXTENDING THE BOUNDARIES IN THE HIMALAYAS

During two recent trips to India, the first to the September 2008 ITA Congress in Agra, the second to hold a three-days short course in New Dehli in December, the undersigned was impressed by two things in particular (leaving aside, of course, the incomparable Taj Mahal, admired equally on any occasion).

While more Indian engineering geologists may now be utilizing the Q-system in large hydroelectric projects in India and surrounding countries, the limitations in certain extreme conditions are not to be ignored. Taking one 'boundary' first, the writer was informed that beyond Q=5, the Q-system had' little application' in the northern foothill regions of the continent.

While this point is taken as a *possible generality*, it was questioned by others with more experience, and my personal experiences at Dul Hasti suggest that Q as high as 500, giving only 1 m/hr TBM penetration rate, and only 5 to 20 m drill-bit life in the same massive quartzites, does require flexibility of the classification method, which soon may show Q < 0.01, or worse, in an adjacent shear zone, or in the alternating beds of over-excavating, low stand-up-time, sheared and talcy phyllites. These layers, following disturbance, may resemble dry bars of soap – and are more difficult to climb than a sandhill – following their collapse to the floor of a big tunnel.

Dramatic descriptions of some of the conditions at the Tala Project in Bhutan, and an ITA congress author suggesting that '*Q<0.001*' is needed for exceptional inrush/burst and tunnel drowning, is certainly correct. The Q-system, without additional engineering advice, can also not tackle the recent case of an Indian TBM machine-and-tunnel burial, simply from the remarkably high pressure (100 bars?) 'production' of water, mud, silt and sand from a single pilot hole.

A personal experience from a difficult sub-sea TBM project in Hong Kong, where the undersigned was consultant to Skanska, is a useful illustration of the message to be focussed on in this guest editorial. On the second visit to this 3.3 m diameter sewage tunnel, to verify the continuing difficulties, the contractor had commissioned a 720 m horizontal drill-core, drilled back-wards towards the TBM, from the tunnel-completion-shaft on Stonecutter Island (now part of one of the world's largest container ports). The TBM had yet to approach and penetrate a regional fault zone in the last 900 m, a wide zone which was mostly missed during sub-sea seismic, due to 'impossble' ship-traffic conditions for the seismic exploration vessel.

The interesting lesson from this case is that, despite three attempts at drill-hole deviation, only some 4 to 5 m of core (and clay) recovery was possible from the (untreated) side of the fault zone. Yet the 50-times larger diameter TBM could subsequently penetrate all of this wide fault zone, without exceptional delays, *because it was penetrating through pre-injected ground*. This permanent measure for making progress was forced on the contractor by the number of fault zones and water inflows, one 15 m fault requiring hand-mining, and 85 days delayed tunnelling. The contractor was using an ‘inherited’ TBM from the previous contract with French contractors, who were eventually replaced by several contractors-for-completion. All the new contractors also had great difficulties, and could not conform to the still optimistic owner-consultant schedule for completion.

Case record data from Q-system designed final support of a large rail tunnel in Norway, has shown a twelve-fold increase in tunnelling cost and a ten-fold increase in tunnelling time, over the range of Q from 10 to < 0.01. The steep curve seen in the middle of these measured trends, where 0.01<Q<1.0 are areas where pre-injection can improve bad ground, actually raising the quality of most or all of the six Q-parameters, by (high-pressure) penetration into one or more of the joint sets. Deformation modulus, wall deformation, velocity and permeability, and support needs, are each benefited by the grouting, if high enough pressures are used. The delay for pre-injection is payed-back handsomely, in the form of a more uniform steady advance rate, with shorter delays.

When confronted with an (unknown) water-and-mud burst, the first hours, days, or weeks of drainage is an essential fore-runner of better conditions, assuming that pre-injection, with quadruple-packers and pumps capable of > 100 bars, cannot be achieved to pre-empt such in-rushes. Eventual recovery with massive amounts of pumped concrete, then ‘post-injection’ might be one way forward into improved territory.

It was encouraging to see among exhibitors of TBM at Agra ITA, a dedicated approach to pre-injection needs, with pre-fabricated holes around the front shield, for less troublesome drilling-ahead and umbrella pre-grouting. Although perhaps not admitting it in public, TBM manufacturers may have accepted that *there are limits* to TBM progress, unless really bad ground ahead is improved. A theo-empirical equation from the Q_{TBM} prognosis model, now in use in several countries also by others, says it all. Delay will be ‘infinite’ (buried machine, new contract, D+B form other end) unless the deceleration gradient (-m) seen with ‘unexpected events’ can be raised by pre-injection of this ‘unexpected’ low-Q ground. Raising Q by pre-injection can also save lives.

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