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Priority concerns in geotechnical engineering for dams

For technical journals of broad coverage and merited repute, one must favour the periodic production of special issues on specific topics. This provides for the efficient storage and retrieval of selected technical information, but much greater merits accrue. One begins by commending the present issue, representing such an initiative. The occasion seems appropriate for submitting some comments regarding the deeper sense of needs and opportunities, hoping to stimulate greater intensity of focus. This issue concentrates on embankment dams, with cases that touch on four problems of great moment; possibly one might develop each issue with distinct contributions to each individual problem.

At the 2nd International Conference of the Soil Mechanics Society, Zurich, Switzerland, 1953, Terzaghi synthesized the early steps of his breakthrough as having included a short interlude of theorization (mathematical and deterministic), followed by the observation of case histories, an important call to which he rallied all geotechnicians. His emphasis of "keen" observation and "intelligently digested experience" was blurred, while circumstances favoured a proliferation of publications on individual cases, mostly descriptive, even when clothed in the results of tests and computations.

About 40 years later, a pause for reflection seems imperative, not only to minimize generating theories of single cases, but also to foster consciousness of the major intervening currents.

Two conflicting factors continue to be irreconcilable, that:

- in geographical and dam engineering, no two cases are entirely alike: one must focus keen attention on the detection of the difference and peculiarity, and on handling this with relish and sagacity;
- "laws of behaviour" are indispensable to theorization, computations and predictions, which are implicit in design (that is intention). Such laws are statistical, based on averages and confidence limits, requiring groups of sufficiently analogous cases (statistical universes) to permit the judgement of developments and progressive elaborations on the basis of inherent engineering criteria of benefit/cost. These are coupled with the scientific criterion of incalculable benefit to the improved cognizance of progressive "truth".

If there is a difference perceived, it is with regard to something, a presumed statistical truth of a specific time, region, and so on. Engineering must decide and act, with a sufficient factor of safety (that is, insurance against ignorance and dispersions), but minimized for economy, to achieve the project's benefit. It is as simple as that.

Yet the thousands of independent papers published through the decades have led to a loss of perspective (both in general and also in relation to geotechnique of embankment dams) in the same way that a person entering a forest loses awareness of it, becoming absorbed in seeing the tree trunks.

Broad trends

An unfortunate lack of cost data, deprives engineering of one of its parents (technology + economics). Very few authors have such information, and the publish-or-perish inclination can lead to misconceptions because of generalized cost overruns that are even making Society antagonize engineering. The figures that generally are mentioned, ironically, are cost increments, because of law suits (extreme conditions). How can a technology and profession grow on such scattered data when base costs are suppressed, and the partial information pertains to statistics of extremes?

Although the basic engineering process is that of technico-economic comparisons of alternative solutions, almost no case presents any such background comparison, so that its solution seems to be predestined (irrespective of the studies which precede it). Thereupon, the lauded principle of engineering decision by precedent becomes a traitor, and an obstacle to rational progress.

The fantastic development of computational ability is rightly acclaimed as a great boon, having broken the shackles of analytical mathematics. However, the computer specialist's ease of dialoguing with his respondent pet has made that an end in itself, with sterile elaborations, decades ahead of capacities to generate data (start) and decisions (end-product). The geotechnical engineer has been divorced from the fact that the first step of engineering is always physics (geomechanics, and so on) together with common sense, and only the second step is submission to the need to generate a hypothetical model for the computation of rationalized assessment.

Age-old traditions on failures, responsibilities and risks (never applied to professions such as medicine, law, economics) and the inherited absurdities of determinism (tests, calculations) and the never-fail syndrome, have systematically barred the advance of statistics. In principle, no technical paper should ever be published without dispersion bands around the presumed line correlation: yet, so far, the dogma that a value determined by test or computation is "true" (to whatever decimal place) dominates almost all publications.

Geotechnique of embankment dams

There have been good advances in the taking account of applied geology, of primordial importance to foundation problems. Communication problems persist, because of the tremendous differences of scales, of time and micro-effects per year; the geologist, generally facing indeterminations analogous to multiplying zero by infinity, mostly has to fall back on descriptions and a posteriori justifications.

The advent and advance of rock mechanics, with emphasis on discontinuities and their behaviour, constitutes an important complement to conventional geotechnics of continua. Problems of water retention by dams are mostly problems of discontinuities.

Adverse behaviour and failures are mostly generated in foundations. Inherited practices have amazingly clouded, in design, the tremendous differences in confidence levels of well constructed and inspected superstructures, and the ever-insufficiently investigated in-situ foundation quality

COMMENT

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and its erratic nature. Compensations derive principally from the fact that most in-situ test results are highly conservative, because of damage to samples, (a trend that is being consciously "corrected") leading to prospects of unpleasant surprises if routine practices of design by pseudo-precedent are not critically reconsidered.

Rockfills, of very varied qualities, mostly spread-compacted in shallow lifts (though some dumped, especially in major cofferdams, underwater) have become the dominant construction material. But the modelling of soils as a granular material consisting of different grain sizes has inhibited the understanding of rockfill behaviour. For instance, the inspection testing, which is cumbersome and erratic, is directed at densities. This is a grossly indirect index, insensitive to dominant factors of crushing of point contacts, and of grain size curves not distinguishing between interlocking and mere filling of voids. The promising breakthrough for immediate adoption is the roller equipped for automatic recording of dynamic moduli from the vibrations as picked-up at the rear wheels. Compaction precompressions, residual stresses, and anisotropies of stresses-strains, associated with revised significant tests on crushable quarried materials, are the recognized challenge for progress based on "intelligently digested experience". The simplicity and widespread success of compacted rockfill construction has permitted postponement of attempts at theorization, indispensable for true engineering.

Classification and index tests, developed from and for sedimentary soils, have proved to be hardly applicable to unsaturated, tropical lateritic and saprolitic horizons, both as foundations and as borrow pits. Confusions have persisted, but been rendered secondary by the "experience" that dominant compaction mostly discards index test variabilities. Yet, there have been failures by overcompaction, and by behaviours such as erodibility, and so on, not covered by the conventional identification indices.

Availability of powerful construction plant (in rich countries, to the detriment of technology of struggling economies) has pushed embankment dam design-construction-behaviour into rigidities and stringent serviceability criteria of micro-strains. Ironically, therefore, differential deformations lead to tensile cracks, hydraulic fracturing, often with the associated phantom of internal erosion (two-fold extreme value statistics). Numerous are the FEM analyses of damaging stress-strain behaviours, but until now they merit questioning, because of neglect of initial residual stresses. Claims of similar computer versus monitored data possibly benefit from: compensations of zero initial stress coupled with low moduli, whereas real microstrain moduli are much higher; and, similarity of quantities that tend to zero, when variations of data and criteria become secondary.

"Minor geologic effects" and all "execution effects", always rightly emphasized, continue under the umbrella of subjective "experience", begging for submission to technological approaches. — *Professor Victor F.B. de Mello, São Paulo, Brazil.*