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SPT and Relative Density in Coarse Sands[a] 2138

and

Drill Rod Influence on Standard Penetration Test[b] 2141

Discussion by Victor F. B. de Mello,[4] M. ASCE

The subject of interpretations and correlations based on the Standard Penetration Test (SPT) is justly receiving added attention. The two contributions represent significant additional data for the profession to digest. In the face of the really important problems at stake (e.g., assessing liquefaction potentialities under nuclear plants and dams founded on sands), the writer (de Mello) would recommend guarding against dangerous generalizations unaccompanied by supporting theoretical and statistical bases.

In the paper under discussion, whereas in truth Marcuson and Bieganousky intended to test "several sands," they seem to have tested only four apparently very similar sands (rather summarily described for the purpose), and under well-controlled laboratory conditions within the very limited depth (rod length) range of 1.5 m–3.4 m. Marcuson and Bieganousky are highly commended for having concluded and emphasized that the relationship between SPT and overburden pressure and relative density cannot be generalized, the risk would have been of accepting the correlation as a generalizable working hypothesis.

On the other hand, the dominant fact of the Technical Note is the typically very heterogeneous alluvial deposit, such as described by Peck (24), although the standard deviations of SPT values at the different depths range as high as 20%–60% of the respective average values, the "average" values within specific depth ranges are compared, to postulate that rod type is not relevant. The conclusion is offered as extendable to all conditions, although when the dispersion of the statistical universe is big, there should be little hope of detecting any systematic but much smaller trend of possible variation. Absence of evidence is not evidence of absence. Schmertmann (16) in investigating an intended q_c/SPT ratio gathers data that "show considerable variation for the different hammer-rod combinations," thus indicating that differences may be significant only in the upper 10 m–12 m. The writer emphasized (20) the concern over appreciable variabilities within the top few meters, since at the time (1970) the only prescription in widespread use concerned shallow footing allowable bearing pressures. It is of interest to note that wave equation analyses either support the importance of rod length (23) or deny it (19), but the greater variability at very shallow

[a]November, 1977, by William F. Marcuson III and Wayne A. Bieganousky (Proc. Paper 13350).

[b]November, 1977, by Ralph E. Brown (Proc. Paper 13313).

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depths continues to interfere with the principal uses and research on SPT hitherto reported.

Generally, the engineer is not satisfied with proving the lack of a general relationship, and will either adopt a generalized working hypothesis, or seek in another direction, hopefully more fruitful. The writer (de Mello) thus repeats the suggestion that SPT is predominantly a function of in-situ shear resistance (20), and wonders why the renewed research neither pursues nor permits pursuing the hypothesis.

The first question that needs to be cleared, under controlled laboratory conditions, is whether or not the fundamental dependence of the SPT is on D_r and $\bar{\sigma}_v$, or on a nominal shear resistance of the sand in situ. It seems to the writer (de Mello) that the data collected in Fig. 14 of Ref. 20 have since only been supported and improved [see, for comparison, Schultze (25) and Koerner (22)]; there is no single consistent and practically useful relationship between D_r and the friction angle of sands, as hoped when the relative density concept was introduced. Therefore, if several sands are to be investigated as representing distinct cases, they should be sought not on the basis of names or of apparently dissimilar grainsize curves, but under the specific condition of configurating widely different ϕ' versus D_r functions. It is regretted that Marcuson and Bieganousky did not investigate and do not furnish the relevant descriptor of the sands for such research, i.e., their relationships of ϕ' versus D_r.

Moreover, the writer (de Mello) would point to a fundamental fallacy in the very definition of D_r, notwithstanding the intuitively reasonable concept. In a deterministic reasoning there are definite values of maximum and minimum densities for each soil, and nothing more reasonable than to establish these values at the limits of the scale for 0% and 100%. (Note however that variations of most parameters within the range would not be linear but exponential.) A similar concept led to the Consistency Index between the Plastic and Liquid Limits.

In a statistical realm, however, there can only be frustration in trying to deal with such extreme values, and, as pointed out in his Rankine Lecture (21) the writer (de Mello) would recommend that the engineer seek satisfactory working solutions by shying away from extreme-value statistics. One routine method is by arbitrarily but "completely" standardizing a procedure yielding reproducible values, close enough to the extreme ones but definitive: the test definition of the Liquid Limit wisely shied away from the "zero" strength condition and chanced upon roughly 25 g/cm^2 by the Atterberg-Casagrande test. Another subtle way out is represented by the frequent suggestion (e.g., Tavenas and others) to employ the averages of 10 test determinations for each extreme value.

The writer (de Mello) notes that "the extreme values obtained were used to compute relative densities" by Marcuson and Bieganousky, and hopes that the early recognition of the fundamental statistical fallacy may minimize the discrepancies and frustrations in such important research. In fact, along with the difficulties associated with SPT, with the present "definition" of D_r, and with the inapplicability of its standardized tests except to pure near-uniform alluvial sands, one source of future frustration may be that liquefaction of specimens is likely to be an extreme value condition of little consequence to big sand masses (21), naturally heterogeneous (24).

Having set aside extreme-value statistics, one must yet qualify the uses of "statistics at random." The writer (de Mello) showed (20) that if one adopted an idealized pile point resistance equation as the basis for regressions on the USBR data (which excluded holing and rod-length effects), one could arrive at a satisfactory relation for SPT $= f(\phi', \bar{\sigma}_v)$. There was no intention of establishing with such restrictive and few data a relationship for use by the profession, but merely to call for recognition of a defendable concept, which could yield theoretically supported statistical regressions. Recent work by Schmertmann and others shows that the dominant resistance against penetration of the spoon is rather the lateral friction: regressions could be redetermined with reference to such improved theorization. In either case it follows obviously that the overconsolidation ratio OCR affecting in-situ horizontal stresses would affect SPT values (20) through theoretically definable functions; it is gratifying that Marcuson and Bieganousky data have confirmed some influence. It is regrettable, however, that instead of seeking theoretically supportable generalizable regressions of SPT with (ϕ', OCR, $\bar{\sigma}_v$), Marcuson and Bieganousky chose to deduce "regressions at random" with (D_r, OCR, $\bar{\sigma}_v$). The regression herein requested should have a greater chance of generalization for widely different sands, and one hopes that the authors may yet extend their contribution to cover this hypothesis.

Incidentally, experience indicates that a noticeable added effect may derive as a function of time of permanence of the overconsolidating stress, affecting the comparisons of laboratory and in-situ investigations.

Appendix.—References

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