Correlations Between Cone Penetration Resistance and Standard Penetration of some New Zealand Volcanic and Alluvial Deposits

Alaa S Ahmed-Zeki and Peter B C Bosselmann
Foundation Engineering, Auckland, New Zealand

Summary: The results of cone and standard penetration tests carried out in Tauranga volcanic soils and in Whangarei alluvial soils are graphically correlated using normal arithmetic plots. The linear least square equation relating the cone tip resistance, q_c, and the standard penetration N value is in the form $q_c = k * N$, where k is a constant. The ratio q_c/N is then used to establish correlations with the type of soil and the results are compared to international findings.

1 INTRODUCTION

CPT-SPT correlations are useful for the conversion of available field test data into the form appropriate for various foundation analyses and design. It is attempted here to prepare correlations on local materials which should lead to better results than others based on internationally collected data. It has frequently been emphasised that it is imperative to rely on locally prepared correlations (eg. Pender, 1998). A new evidence on the significance of deriving correlations on local soils comes from the finding that cone penetration resistance of pumiceous sand is not an indicator of relative density (Wesley *et al.*, 1998). Additionally interesting is the conclusion arrived at by Marks and Larkin (1998) that the low strain shear modulus of the pumice sand is significantly lower than that of quartz sand at similar relative densities and confining pressures. Pranjoto and Larkin (1995) have suggested the grain softness of pumice sand and the high void ratio as being substantially responsible for its different behaviour in comparison to quartz sand. Nonetheless, it is worthwhile mentioning that Takesue *et al.* (1995) have shown that CPT-SPT correlations as well as pile design values for a volcanic soil distributed in southern Kyushu-Japan and locally known as Shirasu) were consistent with quartz sand values.

2 GEOLOGY

Tauranga Basin where the field tests covered by this study were undertaken, is a Pleistocene, predominantly fluvial/estuarine basin which was partially infilled during a period of rapid subsidence after the eruption of the Waiteariki Ignimbrite (Briggs *et al.*, 1996). The infill in the basin is comprised of terrestrial and estuarine volcaniclastic sediments and non-welded or partially welded distal ignimbrites and airfall tephras (Pahoia Tephras), generally covered by a sequence of younger airfall tephra (eg. Hamilton Ash and Rotoehu Ash). These were reworked via fluvial, lacustrine and estuarine processes (Matua Subgroup), and re-deposited in sequences interbedded with the primary volcanic units.

In Whangarei, the field tests were carried out in a low lying area consisting of undifferentiated riverbed and flood plain alluvium (Thompson, 1961; Markham, 1981). These soils typically consist of thinly to very thinly bedded, very loose to loose, unconsolidated sands, gravels, clays and silts with occasional lenses of black humus rich peat.

3 FIELD TEST PROCEDURES

3.1 Standard Penetration Test

SPTs consist of driving a 50mm outer diameter split spoon sampler into the soil using 64 kg hammer free falling through 0.75 metres. The number of blows required to drive the split spoon sampler a distance of 300mm, after an initial penetration of 150mm is referred to as the SPT "N" value. The test is used mainly to assess the density of non-cohesive soils, but may also give an indication of the relative strengths of cohesive soils. It has the advantages of being simple and rapid, allowing a large number of tests to be undertaken at a relatively low cost, supplemented by a large database. It is a common practice not to record a blow count exceeding 50.

Patterson-Kan and North (1986) stated that due to the fact that mechanical drop hammers as used in New Zealand deliver a much greater energy per blow than the American rope and capstan method, the locally performed tests consequently give numerically lower SPT values. Therefore they suggested that the SPT results may be factored up to 20 to 25% before application to the correlation charts prepared in North America. However, the writers of this article are unaware of anybody applying this procedure in New Zealand.

3.2 Cone Penetration Test

In these tests, a 35mm diameter rod with a cone tipped end is pushed continuously into the soil at a rate of approximately 20mm/second by a hydraulic jacking system.

Measurements are made of the end bearing resistance on the cone (the actual end bearing force divided by the cross-sectional area) and friction resistance on a separate 130mm long sleeve (the frictional force on the sleeve divided by its surface area), immediately behind the cone. A 200 kN load cell was used in Tauranga soils tests while the capacity of the load cell in Whangarei alluvials was 100 kN. As penetration occurs the information is recorded digitally, processed and plotted once testing is finished.

4 ANALYSIS AND DISCUSSION

The depths to the recorded SPT N values were considered to be at the mid points of the 300mm penetration of the sampler. At these depths the corresponding q_c values were recorded. An alternative procedure would have been to calculate average values of N and q_c along the 300mm penetration of the SPT sampler. No correction for overburden pressure was applied. The correlations were carried out for every two adjacent CPT and SPT at the sites. At one location within the volcanic soils, two CPTs were performed adjacent to an SPT location; here the q_c values were averaged at the assigned depths.

A direct q_c versus N relationship was established in the form of;

$$q_c = k * N$$

where *k* is a constant. The results are presented in Figures 1 and 2 which show that the correlations within the volcanic soils demonstrate a much larger scatter. In Figure 2, setting the trendline's intercept on the vertical axis to zero resulted in a negative value for correlation coefficient, so the dashed trendline representing a non-restricted linear best fit relationship is plotted to demonstrate the close comparison in magnitude for the q_c versus N values under consideration.

Power (1982) reported values for *k* of 0.3, 0.5 and 0.7 for a range of Chalk types, while Chang (1988) observed values of 0.18, 0.2 and 0.23 for Singapore residual soils with a well-defined correlation.

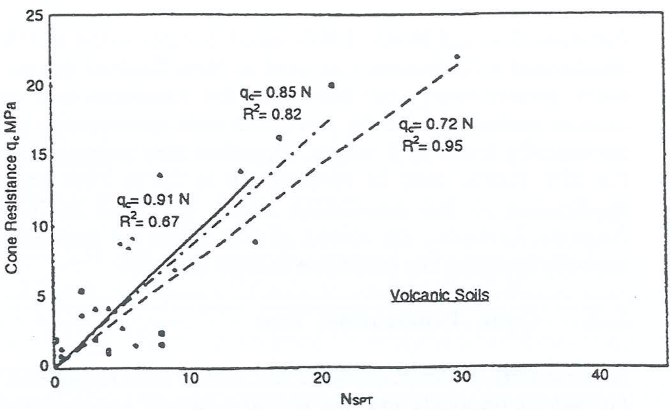


Figure 1 CPT-SPT correlations for volcanic soils. Different symbols denote pairs of CPT-SPTs at different locations of the site.

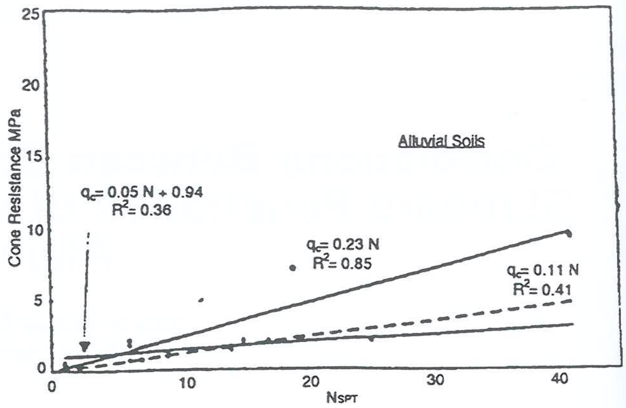


Figure 2 CPT-SPT correlations for alluvial soils. Different symbols denote pairs of CPT-SPTs at different locations of the site

To correlate the findings of these field tests with the type of soil penetrated, Figures 3 and 4 were plotted on normal scales. No grain size analyses were available for incorporation into the current work, so the soil descriptions presented in the borehole records were used. As can be seen, the plots for the volcanic soils show a very significant scatter. Figure 4 for the alluvial soils, however, shows a somewhat better relationship for the two parameters and the q_c/N values here range between 80 and 500 for the adopted units.

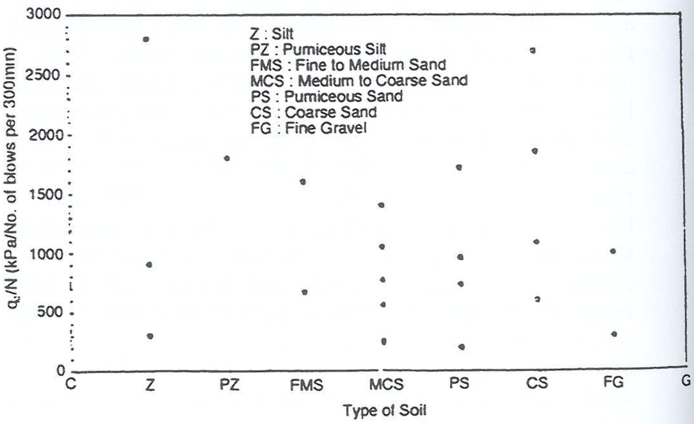


Figure 3 Correlation of q_c/N ratio versus soil type (volcanic soils)

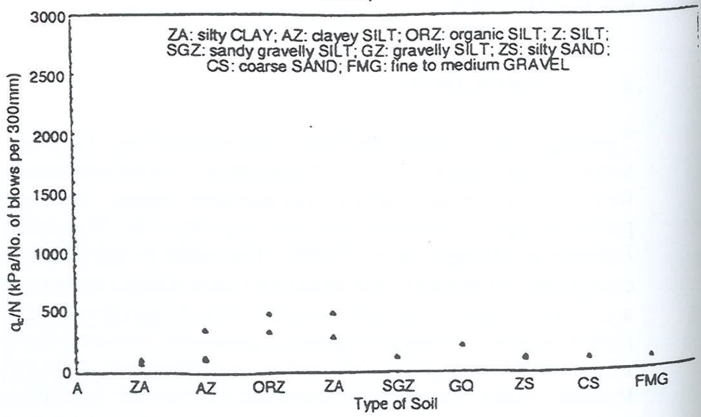
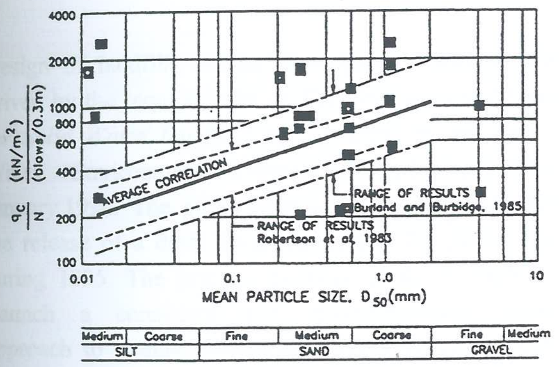


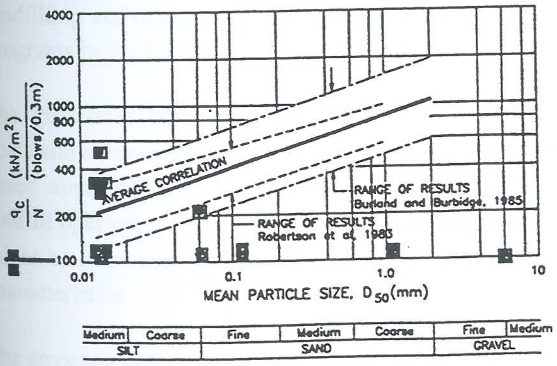
Figure 4 Correlation of q_c/N ratio versus soil type (alluvial soils)

In an attempt to compare parameters from local soils to those published in geotechnical literature overseas, the q_c/N ratio against soil type was plotted as shown in Figure 5 (a) and (b). Extremely high values, which are believed to be due to the sensitivity of the materials to disturbance where SPT N values approach zero, were discarded. The limitation on using the bore log description still applies for these figure, albeit it can be observed that finer tuning to plot the points within any soil group does not seem to alter the general picture.

It is clear on Figure 5 (a) that points of q_c/N ratio versus soil type for the volcanic soils fall far beyond the outer limits observed by Burland and Burbidge (1985) or Robertson *et al.* (1983), regardless of the soil's particle size distribution. The corresponding relationship for the alluvial soils as shown in Figure 5 (b) compares reasonably closely to the published relationships in the fine-grain region, but significantly lower for the sand and gravel sized soils and so it does not show dependence on the grain size distribution. For both volcanic and alluvial soils, the increasing trend of the q_c/N ratio is not visible.



(a)



(b)

Figure 5 Relative locations of q_c/N ratio versus "as-logged" soil type points for (a) volcanic soils and (b) alluvial soils, plotted on a pre-prepared figure of the variation of q_c/N ratio with the mean grain size of soil. The dashed lines show the upper and lower limits of observations by the relevant researchers.

(Figure originally printed in the Canadian Foundation Engineering Manual, 3rd edition, 1992, page 52, and is reprinted with the permission of the Canadian Geotechnical Society)

5 CONCLUSION

This study was an attempt to make use of some available data in formalising corrections for the cone resistance and standard penetration in local geological formations. No doubt, more data should improve the results and refine the observations.

Linear least square equations have been presented relating CPT cone resistance, q_c and the standard penetration N value for volcanic and alluvial deposits found at two sites in Tauranga and Whangarei respectively.

However, rather than succeeding in observing well pronounced relationships, a substantial data scatter was observed, especially with the volcanic soils, when plotting q_c/N values against the type of soil. This could indicate either that correlation relationships are difficult to obtain because of inherent variabilities in the two types of field tests, or that the effect of a soil property other than grain size distribution is influential.

In comparison to the observations published overseas, the trend of increasing q_c/N values against increasing soil particle size was absent in this study. Certainly, this study has presented new evidence for the inappropriateness of the direct application of imported correlations for design purposes.

6 ACKNOWLEDGMENTS

The writers are grateful to Prof. Michael J. Pender and Dr. Laurence D. Wesley for reviewing and commenting on this article. The assistance of Mr. Rodney Melville-Smith, Managing Director of Foundation Engineering Consultants in providing access to the company's database is highly appreciated. Also due thanks are forwarded to Mr. Barry Coker, Foundation Engineering Consultants for the valuable discussions on computer spreadsheeting.

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