DISCUSSION

THE DYNAMIC PENETRATION TEST: A STANDARD THAT IS NOT STANDARDIZED

(IRELAND, H. O., MORETTO, O. & VARGAS, M. (1970). *Géotechnique* **20**, No. 2, 185–192)

K. Drozd, Prague

In Czechoslovakia the geological conditions are not convenient for the method presented by the Authors. For some time we have been trying to introduce it but without much success mainly because of the problems mentioned in the Paper. In addition to these difficulties there are other problems.

One problem is how to measure the penetration for the first 150 mm (6 in.) for which the number of blows is not recorded. Should it start from the bit of the shoe or from the depth of penetration after the sampler's seating? As the soil resistance depends on the position of the sampler in the subsoil this first condition is important. Carrying out tests near the surface it is possible to check the contact of the sampler bit with the soil on the bottom of a borehole precisely, but at greater depth this is impossible. As the length of the first penetration depends among other things on the total weight of the equipment—the weight of the sampler, leading rods, dropping hammer and the cushion block—all these parts should be standardized. Another important condition is the ratio of borehole diameter to the sampler diameter. The resistance of soil in a more open borehole is lower; thus even the borehole diameter should be standardized.

In Czechoslovakia three different devices were used for an automatic release of dropping weight, one of them even for SPT tests below water level in the borehole. Different results were recorded because of the different weights of these devices.

As the standard penetration test results are used mostly for an evaluation of the density of granular soils, the problem of the influence of moisture content in sand on the standard penetration test results was studied (Drozd, 1965). It was found that different moisture contents in fine grained soils can cause the number of blows to be increased several times. From this point of view the applicability of standard penetration tests can be questionable.

REFERENCE

DROZD, K. (1965). The influence of variable moisture content in sand on the results of dynamic penetration tests. *Proc. 6th Int. Conf. Soil Mech., Montreal* **3**, 335–336.

* * *

U. W. Stoll, Ann Arbor, Michigan

Although very informative, the Paper reflects an evident and sharp divergence in outlook of the Authors. The writer is inclined towards Ireland's and Vargas's view that the wide use of the 2 in. standard core barrel is a *fait accompli* (at least in the U.S.) and hundreds of drilling contractors currently use this device. As regards the question of standardizing procedures, ASTM designation D 1586–67 describes the core barrel and appurtenances in detail, including general provisions for clearing the borehole, performing the penetration test, and recovering and handling the sample obtained.

Although this standard is concise and generally acceptable to practising American engineers, detailed descriptions of the techniques for advancing and casing the test hole are not defined in the ASTM standard. Consequently, the Authors' discussion of the pitfalls and precautions when working below the water table in granular soils is most welcome. Recently a group of practising soil engineers in Detroit, Michigan has prepared a manual *Recommended practice for soil borings* which includes a section describing methods and applicability of locally employed drilling techniques as shown here.

Drilling in soil

Soil borings shall be made by using any of the following drilling equipment, subject to the following limitations and procedures.

The continuous solid stem auger may be used under the following conditions.

(*a*) If caving or squeezing of the sides of the drill hole should occur, augering shall be discontinued forthwith, the depth noted and recorded, and the hollow stem auger or the wash casing used to complete this and subsequent test holes.

(*b*) If groundwater is encountered in granular soil, drilling by the solid stem auger shall be discontinued forthwith, the depth noted and recorded, and the wash casing method used to complete this hole. Provided that squeezing or caving does not occur, augers may be used to extend subsequent holes to a depth no closer than 3 ft to the anticipated water table, and the wash casing method shall be used to complete the test holes.

The hollow stem auger may be used under the following conditions.

(*a*) If there is heaving of the soil up into the bottom of the auger stem or if clays or saturated silt having an estimated unconfined compression strength of less than 1 ton/sq. ft are to be sampled as provided for later, hollow stem augering shall be discontinued forthwith, the depth noted and recorded, and the wash casing method used to complete this and subsequent holes.

(*b*) If groundwater is encountered in granular soil, provisions set forth under (*b*) for the continuous solid stem auger shall apply.

The wash casing method may be used under the following conditions.

(*a*) Soil borings shall be advanced by driving steel casing of not less than $2\frac{3}{8}$ in., nor more than 6 in. inside diameter, to such depth below ground surface as is required to maintain an open hole for sampling operations, but in no case shall less than five feet of casing be used. The casing shall be driven without the use of wash water, but the soil within the casing may be removed by the wash method to the depth at which the sample is to be taken.

(*b*) Drill water shall be forced down through the drill pipe and out through ports in the chopping bit to carry the cuttings up and out of the boring. The casing shall be driven closely following the chopping bit to exclude overlying soils from the hole.

(*c*) As the boring is advanced, special note shall be taken of the depth at which there is a loss or gain of water observed in the casing. This information shall be recorded in the field notes in addition to any subsequent water level or infiltration measurements which may be specified.

Standard penetration and split spoon sampling

At every change in soil stratification and at intervals not to exceed $2\frac{1}{2}$ ft in the upper 10 ft, and not to exceed 5 ft below 10 ft depth, advance of the boring shall be stopped and loose material removed from the hole. A 2 in. outer diameter split spoon sampler meeting the dimensional requirements outlined in ASTM designation D 1586–67 shall be lowered into the hole on the end of a threaded pipe extension and driven for 18 in. by a standard 140 lb hammer falling freely through a 30 in. drop. The number of blows required for each successive 6 in. of penetration shall be recorded.

The following requirements and precautions shall be observed in performing this sampling procedure.

(*a*) When casing or the hollow stemmed auger is used, measured comparison between embedded depth of casing and combined length of the sampler and pipe extension shall confirm that the casing is clear of soil to its tips and the spoon shall extend unobstructed to the bottom of the casing before sampling begins.

(*b*) Pipe extension to the spoon sampler shall be composed of securely coupled pipe sections, of between 1·6 and 1·8 in. outer diameter and weighing between 3·0 and 4·0 lb/ft.

(*c*) A spring type of sample retainer installed in the tip of the sampler shall be used only when necessary to prevent loss of the sample, and identified on the boring notes.

(*d*) When very soft cohesive or water-bearing cohesionless soils are encountered, the hole and casing must be maintained full of water, or driller mud or bentonite, if necessary, while advancing the hole during sampling and when removing the wash pipe and/or spoon sampler.

(*e*) So-called 'refusal' shall be defined as total penetration achieved when driving the standard split spoon totals less than 4 in. for 100 blows, and the actual penetration shall be recorded.

(*f*) Use of cable winch or any other winding reel device attached to the standard weight during the penetration test is expressly prohibited.

* * *

S. Frydman, Technion, Israel Institute of Technology

The Authors have correctly pointed out the non-standardized nature of the dynamic penetration test, and have mentioned some of the variations associated with the performance of the standard penetration test. This test, usually used to enable the estimation of the relative density of sand deposits, represents an efficient substitute for more costly and difficult density testing. Recent publications (Bazaraa, 1967; D'Appolonia *et al.*, 1968; Holtz and Gibbs, 1969) relating standard penetration resistance to relative density have different conclusions, and it is suspected that these may, at least in part, have been due to differences in test technique.

In Israel the standard penetration test is commonly used in site investigation for evaluating the relative density of granular layers. The test is carried out in accordance with ASTM designation D 1586–67, but it has been found that even this standard leaves room for interpretations which may lead to variations in the test procedure. Clause 2.3 of the standard requires that the drive weight assembly 'shall consist of a 140 lb (63·5 kg) weight, a driving head, and a guide permitting a free fall of 30 in. (0·76 m). Special precautions shall be taken to ensure that the energy of the falling weight is not reduced by friction between the drive weight and guides.'

The Authors have stated that one method of lifting the drop weight may consist of a manilla rope passing over a well-lubricated tripod supported sheave, wrapped around a 10 or 12 in. dia. winch head with about two turns. This rope is pulled at the standing end and friction lifts the drop weight which is then released by quickly throwing the rope slack.

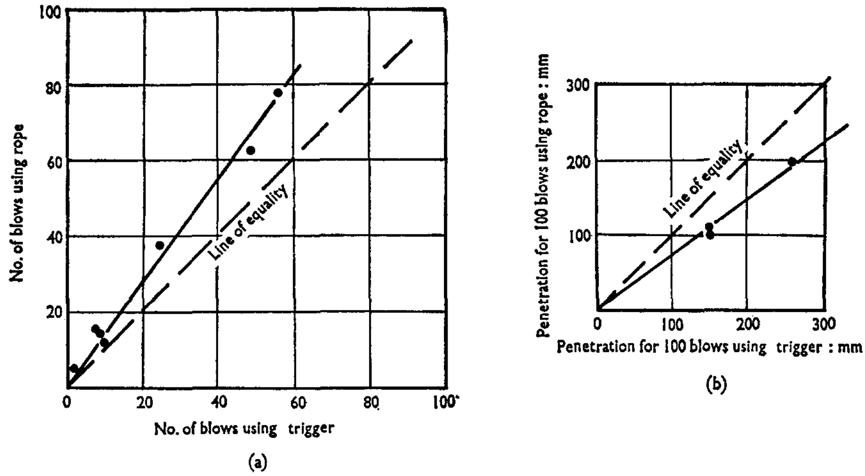

Fig. 1. Results of standard penetration tests performed in sandy soil using rope and trigger

Another possible method mentioned is the use of a trigger to release the raised weight in order to ensure a truly free fall.

In Israel until about one year ago it was common to use the former of these methods. A series of comparative tests was performed using both methods in sandy and gravelly sand layers because of suspicions that friction could not be completely released between the rope and the winch head. A test was carried out in boreholes using one of the methods at a particular depth. The hole was then drilled a further 200 mm below the bottom of the previous test, cleaned out, and a test performed using the alternate procedure. The order in which the methods were used was alternated. Fig. 1 shows the results of these tests: Fig. 1(a) shows results in which the full 300 mm were penetrated and Fig. 1(b) shows results of tests in which less than 300 mm were penetrated by 100 blows. The penetration resistance recorded using the rope was of the order of 1·4 times that obtained using the trigger mechanism. However, the question must be asked which method of ensuring 'free-fall' was used by those workers on whose correlative relationships common engineering designs depend.

REFERENCES

BAZARAA, A. R. S. (1967). Use of the standard penetration test for estimating settlements of shallow foundations on sand. Ph.D. thesis, University of Illinois.

D'APPOLONIA, D. J., D'APPOLONIA, E. & BRISETTE, R. F. (1968). Settlement of spread footings on sand. *J. Soil Mech. Fdns Div. Am. Soc. civ. Engrs* **94**, SM3, 735–760.

HOLTZ, W. G. & GIBBS, H. J. (1969). Discussion on settlement of spread footings on sand. *J. Soil Mech. Fdns Div. Am. Soc. civ. Engrs* **95**, SM3, 900–905.

* * *

E. J. Zegarra, Soil Testing Services, Inc., Northbrook, Illinois

I should like to make some remarks from my experience in having compiled and edited the final draft of the specification adopted by ASTM for performance of the test. As chairman of the section on sampling, Sub 2 of Soils Committee D 18, I was responsible for the preparation of standard methods satisfactory to the membership and the profession. It was the purpose of that standard to fix the methods, procedures and equipment used in the test and to prevent the intrusion of variables or modifications, worthy or desirable as they may be, that would confuse and obscure the results.

A simple method based on the energy used to drive a given body into the soil offers a temptation to correlate the results of the input of energy with useful parameters such as ultimate pile load, bearing capacity and even soil properties. As is well known the correlation is ineffectual but the temptation never dies. During the formulation of the specification, suggestions for changes were supported by strong opinions, detailed analyses and highly theoretical approaches but all had to be overcome in order to preserve the simple equipment and procedures of the method. Many attempts were made to include, as part of the specification, the interpretation of results not only as a measure of soil parameters but as correspondence to results of other sampling instruments, different weights, height of drop, dimensions and boring procedures. Admittedly the standard penetration test is a crude, pragmatic and empirical method whose origin, growth and development are the result of the need to explore economically the soils at the bottom of a boring and do it consistently.

It should be admitted that the split-tube is the cheapest and perhaps the most effective method of sampling sandy soils. Over the years accumulated experimental data have been used to relate the number of blows to the relative density of sands and sandy soils without pretence to theory or rigid analysis. Many attempts have been made to rationalize the method but to no avail. Without this test soil engineers would be seriously handicapped; modifications, substitutions and changes would create chaos. Hence the need for a standard specification which, in the U.S., gives it respectability.

A controversial feature introduced in 1956 was adopted: the number of blows required to effect the first 6 in. of penetration is not considered in recording the total number for a penetration of 12 in., i.e. the N value. This procedure eliminates from the count the effects of soil disturbance at the bottom of the hole and compensates for the presence of soil accidentally accumulated after cleaning out the boring before sampling. As De Mello *et al.* (1960) point out there may be a correlation between seating or not seating the sampler over the first six inches. The standard makes that correlation unnecessary. Brazilian engineers using samplers of different dimensions, other hammers and heights of drop have gained local experience. They can communicate among themselves but cannot translate their results to standard penetration test results. It is to facilitate a universal language that method D-1586 was standardized by ASTM in 1966.

Although the standard penetration test was originally devised to explore all types of soils and the results were used in a variety of ways to predict the type and behaviour of foundations, its present use is more modest. It is restricted primarily, and perhaps exclusively, to sample sands and sandy soils and to appraise their state of relative density. Other methods and devices are used to sample effectively cohesive soils.

As long as soil mechanics remains the art that it is, this simple and crude test will be an essential adjunct to the exercise of the few scientific facts that judgement and experience employ to decipher the properties of sand below ground surface.

REFERENCE

De Mello, V. F. B., Souto Silveira, E. B. & Quaresma, A. R. (1960). Some field correlations on dynamic penetration resistances in exploratory borings in Geotécnica, Brazil. *Proc. 1st Pan Am. Conf. Soil Mech., Mexico City.*

STRESSES AND DISPLACEMENTS IN A CROSS-ANISOTROPIC SOIL

(Barden, L. (1963). *Géotechnique* **13**, No. 3, 198–210)

G. P. Raymond, Queen's University, Ontario

This correspondence is concerned mainly with the undrained settlement of a cross-anisotropic soil. Unlike the Paper, however, no restriction is placed on the value of the independent