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DETERMINATION OF THE ANGLE OF INTERNAL FRICTION AND OF THE COHESION OF SOILS IN SITU BY MEANS OF DYNAMIC DRILLING

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by

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Translated by Mrs. Séverine Britt

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DETERMINATION OF THE ANGLE OF INTERNAL FRICTION AND OF THE COHESION OF SOILS IN SITU BY MEANS OF DYNAMIC DRILLING
(A translation)

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In many cases, construction of foundations is done without adequate background data because the time and resources necessary for the recovery and laboratory testing of undisturbed samples are not available. Furthermore, the expense of such tests frequently would not be justified by the degree of importance of the projected construction. It is not sufficient, however, to rely solely on the planner's estimation, made either with or without examination of the foundation site, of the characteristics of the various strata involved. One should at least be able to check the value of this appraisal.

A very light weight hand-drill (see figure 1) developed and patented by the author, now seems to offer an economical method of adequately investigating foundation conditions down to a depth of about 20 meters. This drill is based on the following principle: A small olive-shaped shoe of diameter d is fixed at the end of an extensible rod made in several sections which are connected by olive-shaped couplings of diameter d' (slightly smaller than d). This shoe is driven in the ground by the stroke of a calibrated head dropping from a constant height.

Due to the small diameter of the shoe and the fact that the soil has some coherence, the hole opened by the shoe will not close up behind it. As a result the drill-rod does not rub against the sides of the hole and its liability to bending is slight and limited to the clearance $\underline{d} - \underline{d}'$, because only the couplings are in contact, without pressure, with the walls of the drill-hole, which does not need to be cased. Evidently such a process can only be applied in soils which have some cohesion and which do not contain large stones. By plotting the number of blows required to drive the drill a given distance, the resistance of the soil at the level of the bit can be measured. This "diagram of percussion" also gives an idea of the properties of the different layers encountered. When a sample is desired, the olive-shaped shoe may be replaced by a small bit. Although such samples cannot be qualified as undisturbed, they do provide valuable qualitative information. The soil resistance (in Kg/cm^2) can also be determined from the diagram of percussion by using a dynamic formula corrected from the results of drillings made in soils of known properties. Thus each drill becomes a calibrated apparatus of measurement. Then, by applying the formulas of Caquot and Buisman, it is possible to obtain the values of the angle Ø1 of the cohesion, and of the coefficient of compressibility, all of which are necessary for the computation of foundation settlement.

The time necessary for drilling depends evidently upon the nature of the ground and upon the working speed of the head. In sand, for example, one must figure on approximately a quarter of an hour and a hundred blows of the drive-head per meter of penetration, plus the time required to make the measurements and to collect samples.

In the case of coherent or friable soils which are more or less impermeable the objection may be made that the dynamic formulas give erroneous results because the water does not have time to excape from the ground mass, and pore pressure is created. Under these conditions, the influence of the angle would be underestimated, and in clays, only the cohesion under a rather great speed of shearing would be measured.

This objection is valid, but in the present state of the technique of measurements in situ and of the theory of soil mechanics, it is not certain that it is a redhibitory difficulty or that it is possible to do better. In fact, the experience seems to show that, for foundations in saturated clayey soils, it is wise to disregard the angle ϕ and to base the plans on the hypothesis $\phi 1 = 0$, the cohesion alone being taken into account.

On the other hand, apart from this dynamic method of reconnaissance, only the method of so-called static reconnaissance, as it was developed in Holland and in Belgium, is known. This "static" method consists of measuring the resistance of the ground to the penetration of a cone driven by a more or less continuous force. Without intending to lessen the value of this method which has been recognized in practice, it seems that the speed of penetration and the prevailing pore pressures will affect the results just as in the dynamic method. There appears to be no reason why the dynamic method would not give results comparable to those of the static method, (1) if the average speed of penetration is the same in both cases; (2) if the frequency of the blows of the sinking-head is low enough not to set the ground in a state of vibration; and (3) if the sinking-head is light enough that the shoe does not penetrate ground whose structure is so disturbed that the conditions necessary for establishment of the formulas no longer obtain. By remaining within the reasonable limitations which are involved by hand-working, both methods should give similar results. Since the Dutch method is not yet commonly used in France, there was no opportunity to make comparative tests, which no doubt would be of interest.

Right now the drill described in this paper offers a means of investigation, of approximate measurement, and of sampling, which can remove many doubts on the quality of the foundations and which also indicates where further investigation is needed. The tests made of this method thus far, have given proof of its value. The facts that the drill weighs only 50 kgs. and that it requires only one log-recorder and one or two drillers give an idea of the small cost involved for such test-drilling.

In addition, theoretical research has been carried on in foreign laboratories. Particularly, the experiments made by Mr. Liang-Sheng-Chen under the direction of Professor Casagrande at Harvard University are of very great interest.

The few very brief tests made by the author, with makeshift equipment, on the resistance of anchoring plates, (an account of which was given in a previous report) led him to believe that the degree of interlocking between component grains of the foundation material was an essential datum of these problems. The results of Mr. Liang-Sheng-Chen's experiments confirm the author's view-point. In these experiments, sand samples, each of which differed in grain size, size distribution, roughness, and compactness of their component grains were systematically subjected to triaxial compression tests. With discretion and objectivity, Mr. Liang-Sheng-Chen merely published the very precise results of his measurements. An attempt will be made to draw some conclusions from these results.

It seems that apart from any question of chemical composition the apparent angle $\phi 1$ may vary between 26.5° and 51.5° according to the degree of compaction, granular homogeneousness, and roughness of the grains, the void ratio varying from 0.22 to 1.24.

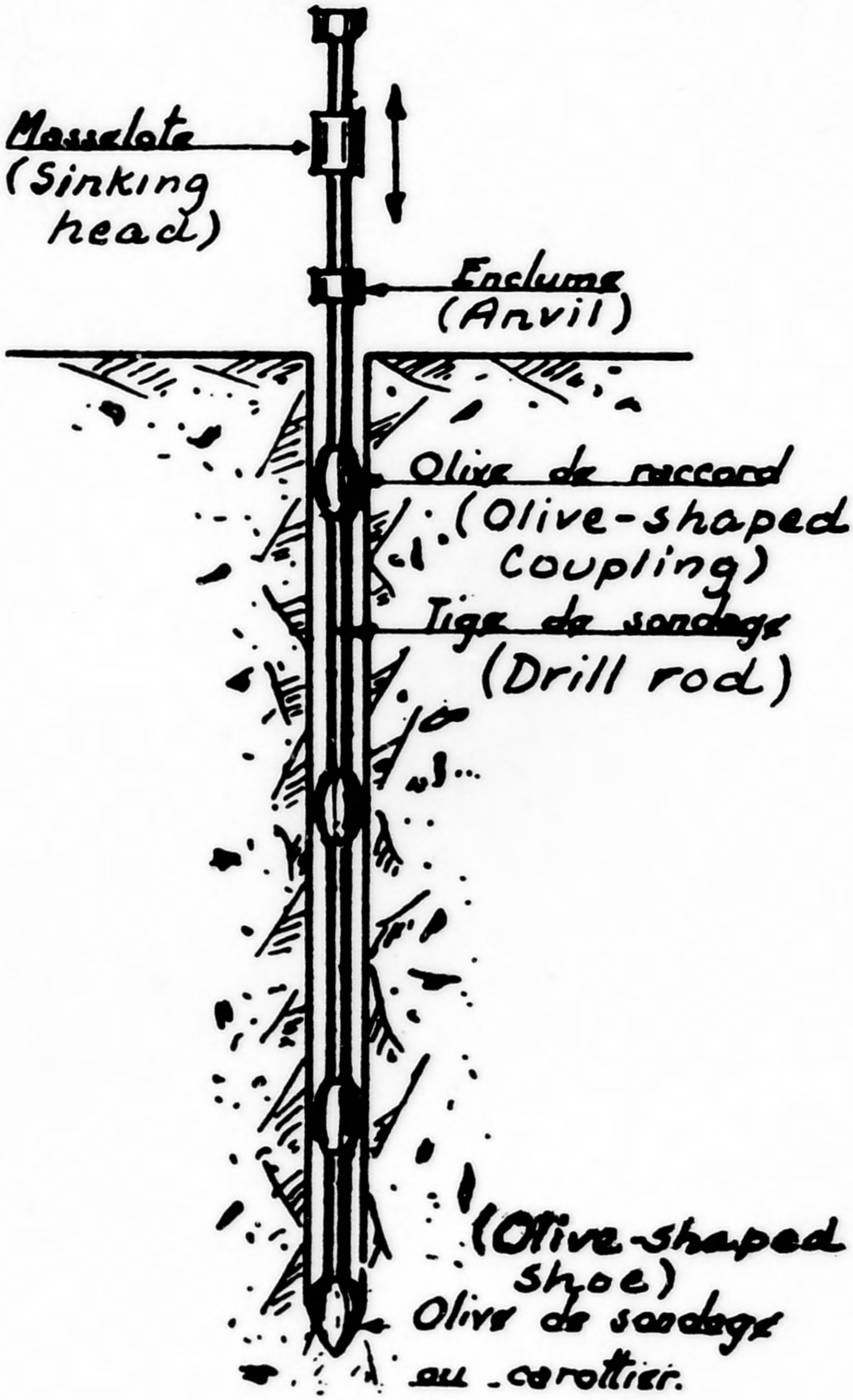
For one sample, under a uniform lateral stress of 1 kg/cm^2, the apparent angle ϕ varies perceptibly between the limits corresponding to Caquot's formula, $\tan \phi 1 = 1.57 \tan \phi$, and as a function of the degree of initial compaction.

At present, these tests seem to indicate that the practical results of measurements made in the laboratory on samples of fine-grained soils may be seriously questioned. Indeed, it is very difficult, if not impossible in actual practice, to obtain undisturbed samples whose compactness has not been altered by the processes of recovery and transportation, or by the unavoidable handling in the laboratory. It is also very optimistic to believe that these samples can be restored to their original state by means of artificial compaction, because this initial state is not known. Finally the small size of the testing apparatus make it necessary to eliminate the large fragments. As a result the granulometric composition may be considerably changed. Consequently an apparatus which makes it possible to measure soil properties in situ should be given favorable consideration since it avoids the causes of important errors, which cannot be eliminated from laboratory tests. If a comparison is made of the results obtained in the laboratory and in situ, it will, therefore, not be sound to assume the first as exact in order to appreciate the validity of the field tests.

Likewise, according to the degree of initial compaction, the failure of a soil occurs with decrease or increase of volume. In the laboratory, this failure is produced under constant lateral pressure, but in nature, these variations of volume necessarily bring about concomitant variations of lateral pressure, which entirely modify the conditions under which failure occurs. When there is a decrease of volume, the lateral pressure lessens and may even vanish, and if there is an increase of volume, the lateral pressure may increase in considerable proportions as a function of the compressibility of the soil. Considering these facts it seems that the measurements in the laboratory imply causes for systematic errors, which are avoided by the measurements in situ. Furthermore there appears to be no way in which the law of necessary variation of the lateral pressure corresponding to natural conditions could be determined in the laboratory.

It also seems that the notion of critical density is misleading and should be replaced by that of critical compaction since the variation of density is only a minor consequence. Critical compaction is a function of the grain size and of the degree of roughness of the grains. It corresponds to the amount that each grain can be moved without bringing about variations of volume in the mass and varies with the axial and lateral pressures. The behavior of a layer of sand will be very different according to its mode of formation and its history. In other words it will vary according to whether the initial compaction of the sand is higher or lower than the critical compaction which corresponds to natural pressures or to additional pressures produced by supplementary loads. The difficulty of taking undisturbed samples can be seen when the act of merely driving a core-drill unavoidably modifies the compaction. Measurements in situ, in this case also, seem "a priori" to be more true, since they simply show the actual resistance of the ground. They also seem to be more accurate than laboratory methods in the conclusions to which they lead. The characteristic values for the resistance of laboratory samples are obtained by the aid of formulae; then, these same values are reintroduced into the formulae from an opposite approach in order to find by extrapolation what the resistance would be under similar natural conditions. Consequently, systematical errors cancel each other automatically.

In order to define fine grained soils practically and to deduce their behavior in nature from measurement of samples the laboratory soil should be described by its index of roughness, its volume of voids or index of compaction, and its granulometric coefficient, which could be its Hazen's index. The normal continuation of the research and experiments of Mr. Liang-Sheng-Chen would be the study of (1) the influence of each of these parameters, taken separately, on the angle of friction and the compressibility of fine-grained soils, (2) the variations of these parameters as a function of the stresses in order to obtain a formula which would make it possible to forecast their values from these variables. Thus extrapolation from measurements on disturbed samples would be possible without too great errors, providing that such extrapolation be kept in line with the probable natural conditions to which the ground will be subjected. The index of roughness which, to the author's knowledge, has never been the object of a tentative definition, could be defined by the angle ϕ obtained for fixed arbitrary values of the other parameters. It is the author's hope that a French laboratory will become interested in these problems and succeed in bringing some precision in this field.



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