Geophysical examination by reference to curves of boring wattage

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Geophysical Examination by Reference to Curves of Boring Wattage.

Bodenphysikalische Untersuchungen mit Hilfe von Bohrversuch=Wattkurven.

Etude géophysique basée sur les courbes wattmétriques obtenues dans l'essai de forage.

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There are two practical ways of carrying out tests of the ground:

I. examination at the site, and

II. examination of samples in the laboratory.

I. Examination at the site.

The readiest form of examination at the site is by means of loading tests, but this does not give the dependable results[1] because a loading test continues for only a short time by comparison with the loading to be imposed by the structure itself, while moreover such a load is of a special kind and of quite special geometrical shape and size. In the absence of any special law of similarity in regard to these influences the results are not, therefore, immediately applicable to an actual structure.[2] Moreover a loading test supplies only a single geophysical constant and as a rule this is not enough to allow of settlement of the ground being reliably predicted. From the work of *Terzaghi*[1] instances are known in which a loading test showed a sinkage of 1 cm and the actual settlement of the structures when built amounted to 1 m. The loading test by itself is therefore unacceptable, because unreliable, as a means of forecasting the settlement to be expected in a structure, for purposes of design or of control during construction.

In order correctly to forecast the settlement or the future stresses in the ground below a foundation, it is necessary that several geophysical constants should be determined. On the site it is possible to secure undamaged samples of the ground at any desired depth by simple means, but laboratory experiments suffer from the disadvantage that it is only too easy for such samples to suffer disturbance or alteration during transport as regards humidity, pore content, etc.

The best known methods of ground exploration on the site hitherto recorded in the literature are the following: —

1) The Swedish cone test.

2) The Sondbore process.

3) *Kögler*'s method.

4. *Hertwig*'s dynamical method of testing.

1) The cone test can be used only as a rough test of the suitability of the ground and can be applied only where the latter is of very finely divided texture, for if the grains are coarse the cone is immediately upset.[3] On large sites the cylinder pressure test has been tried, using a cylinder compression machine to determine the strength and deformation value of samples taken from different points on the site and from different strata. In this way expensive and complicated investigations can be avoided, but the method is not suitable for examinations carried out on the site.

2) The Sondbore method[4] consists in introducing a spiral boring bit into the ground at the end of a large number of rods. The whole length of rodding is loaded with a constant load capable of measurement up to 100 kg, and the method provides a combination of the boring and loading tests. Measurements are taken of the number of turns, the magnitude of the load and the depth of penetration. Errors may easily arise through the buckling and bending of the rods and through the apparatus being out of plumb; consequently this method again does not provide reliable results, and is really of use only for the purporse of affording a rough test of the ground. On the other hand it is well adapted for checking the stratification as regards depth, and for determining the humidity, the degree of weathering, and the level of the subsoil water.

3) *Kögler* in his tests makes use of two apparatus, namely a triangular press with filler blocks and a rubber apparatus subject to pneumatic pressure, exerting in each case a horizontal pressure. The functional connection between the vertical and horizontal components of pressure has hitherto not been very fully investigated.

4) A more accurate picture of the geophysical conditions of the ground is provided by the dynamical method of Hertwig,[5] and the numerous co-efficients which here arise can be determined at different frequencies and intensities. Since, moreover, the tests may be carried out in any desired direction and depth a considerably larger part of the ground is brought within its scope than is the case with the statical loading test. In order to adapt this method to practical applications it is necessary to have available a very large body of experimental results, and these are not yet forthcoming. *Hertwig*'s assumption that a simple functional relationship exists between the elastic constants and the depth of penetration (or the carrying capacity) would appear to be established. Moreover, the dynamical method, provided it is correctly carried out, gives much more accurate results than the statical method as the deformations are considerably larger (for instance, as much as 80 times as great).

II. The examination of ground samples in the laboratory.

The first essential for the examination of the soils in the laboratory is that the samples should be undamaged. They must have been obtained from all points and all depths in the site at which it is required to know of the geophysical constants. The work at the site is therefore limited to a systematic and careful collection of samples from the ground, to the making of site sketches and of longitudinal and cross sections, and to the provision of shafts and bore holes for ascertaining the depth of the strata and the level of the subsoil water. In the laboratory, the determination of the geophysical constants will then correspond to the examination of building materials as practised in testing laboratories.

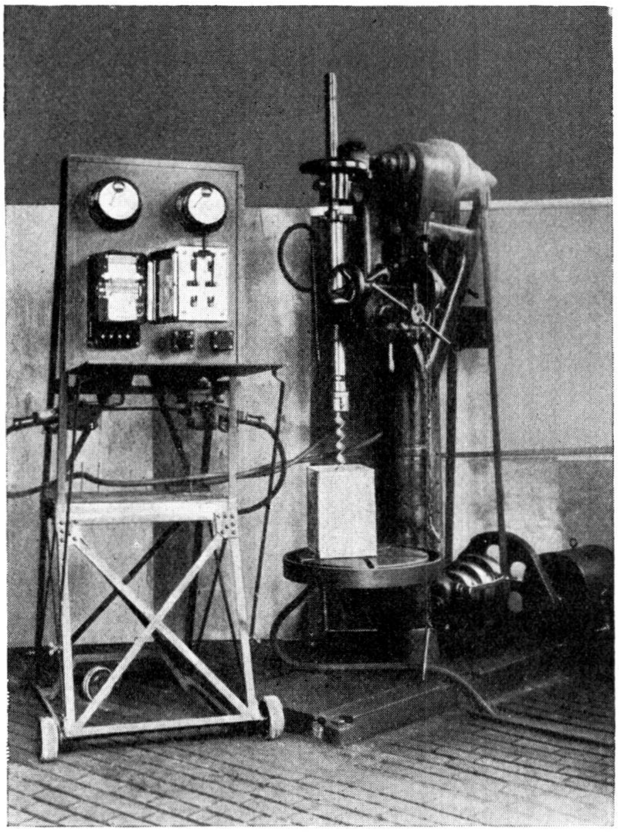

Fig. 1.

From among the methods, as already described, whereby the geophysical constants can be determined, the author selected the boring test. In research connected with agricultural machinery it has been sought to obtain a relationship between the shape of implement and the ground constants.[6] In the author's experiments the emphasis was laid on the determination of the geophysical constants, not only for the upper layers of the ground, but for all depths affecting the question. The experimental apparatus adopted was a vertical boring machine with single drive, fitted with transportable measuring instruments which included a voltmeter, an ammeter and a selfrecording wattmeter (Fig. 1). The boring machine was one intended for metal working and could be operated at 40, 46 and 254 r. p. m. with rates of feed of $\frac{27.5}{254}$ and $\frac{72}{254}$. Cylindrical drills of different diameters as used for metal, spiral augers as used for wood work, and various types of earth borers were all tried. The boring experiments were carried out partly on the site and partly in the laboratory. Undamaged samples of the ground, as described below, contained in wooden boxes $10 \times 10 \times 30$ cm, served as the experimental material:

a) Natural samples of the soil taken from the site to represent different kinds of ground: sand (sprinkled, shaken, dry and damp, pre-loaded under different pressures); loams containing various admixtures of sand of varying elasticity and initial loading.
b) Artificially prepared samples consisting of both sandy and loamy layers.

During the progress of the boring operation a wattage curve was obtained with the recording wattmeter, the abscissae being proportional to the power absorbed and the ordinates proportional to the speed. From a great number of experiments the following results have been deduced:

1) Each kind of ground tested with the same boring machine, the same rate of revolution and the same rate of feed shows a characteristic curve of wattage depending on its humidity and plasticity (Fig. 2).
2) When the porosity is changed the wattage curve also changes.
3) When the rate of revolution is small the effect of porosity and plasticity is greater than when the rate of revolution is higher.

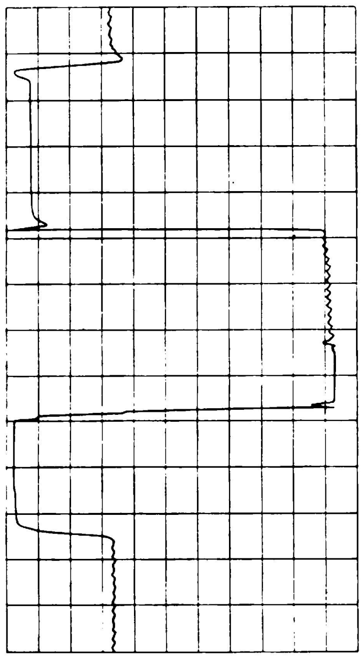

Fig. 2.
Wattage curves obtained in boring tests through ground containing strata of varying density and porosity.

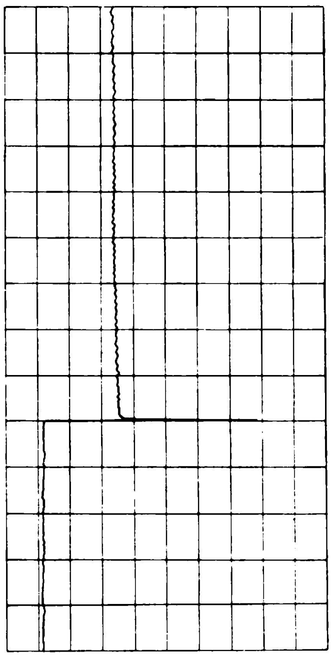

Fig. 3.
Wattage curves obtained in boring tests through strata of varying humidity.

4) Alteration in the degree of humidity exerts a greater influence in the case of the earth borer (plate borer) than in that of the spiral or cylindrical borer (Fig. 3).
5) In sandy ground the wattage curve is steady when using the plate borer, in plastic ground it rises steeply at a slope which is inversely proportional to the plasticity (Fig. 4).
6) The shorter the boring tool the more accurately does the wattage curve reflect the local conditions. It might, therefore, be advisable to make the boring apparatus as small as desired with a view to rendering the examination of the geophysical relationship as accurate as the case demands.
7) The more uniform the character of the ground the better the results obtained (but in the case of sand and gravel errors easily arise) (Figs. 5 and 6).

8) Where tests are being made on the site, special attention must be paid to the rod on which the boring tool is mounted. In order to reach great depths a long rod must be used and this entails a risk of buckling which is liable to throw the boring gear out of plumb. If this occurs the sharp rise in the wattage curve gives an incorrect picture.

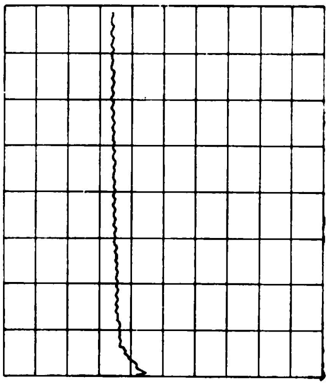

Fig. 4.
Wattage curves obtained in boring tests through loam using a post auger.

9) The determination of each of the geophysical constants should be made by means of whatever boring tool is the most sensitive to the particular geophysical property in question, and in the same way there is a particular rate of rotation and of feed which is the most effective in each case. The boring tool, rate of revolution and feed likely to give the best results in any given instance can be determined only on the basis of numerous experiments. At the same time it can be deduced from the experiments already carried out by the author that certain kinds of boring tools act particularly well in regard to certain geophysical properties to which other sorts of boring apparatus are almost insensitive.

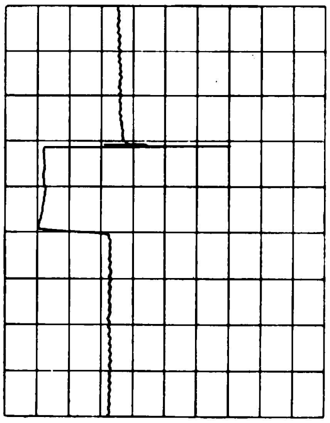

Fig. 5.
Wattage curves obtained in boring tests through strata of loam, turf and sand.

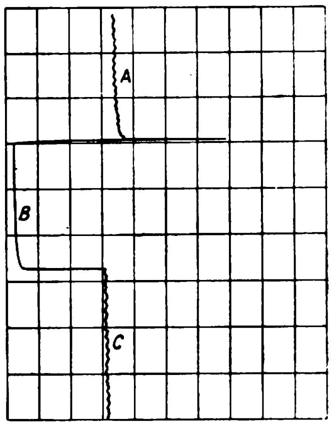

Fig. 6.
Wattage curve:
A — artificially consolidated sand.
B — artificially loosened sand.
C — sand in natural condition.

10. In order to free the result of the experiment from errors due to the frictional resistance of the boring rod, the boring apparatus should be dismantled

after each boring test and the boring rod allowed to run without any tool, as a means of ascertaining the no-load wattage curve with a view to taking this into account when interpreting the wattage curve obtained from the actual boring test.

The author's experiments indicate definitely and clearly that this method is suitable for determining the geophysical constants at the site. In order to obtain a reliable basis for interpreting the wattage curve from the boring tests a large number of parallel experiments are to be undertaken in the laboratory and samples are to be tested for comparison by geophysical methods other than boring.

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