over a long period of time; however, it is considered that the selsyn type deflection gage adequately measures settlements over a period of time.

The flexible pavement test section at Marietta, Georgia, contained two groups each of four pressure cells. One group of cells was installed at various depths in a clay subgrade beneath a macadam base and asphaltic concrete pavement while the other group was placed similarly in a sand subgrade beneath a sand asphalt pavement. Deflection gage installations similar to that illustrated on figure 12 were made in triplicate in three macadam base pavements of different base thickness and in a sand-clay base item. These installations were for the purpose of obtaining deflections at the surface of the pavement and of the surface of the subgrade. Single deflection gage installations, to measure pavement surface deflections only, were made in triplicate in a pavement containing a telford base. Measurements of pressures and deflections were made beneath moving and standing wheel loads of B-24 and B-29 planes at three different wheel loads and with plane motors dead and running. A detailed report on this project is available as a part of the report entitled "Certain Requirements for Flexible Pavement Design for B-29 Planes" published by the Waterways Experiment Station.

Deflections and pressures are being measured by the Waterways Experiment Station at several depths in a test section beneath loads applied by flexible faced loading plates to simulate tire loadings. These tests are in progress at the time of writing of this paper, and it is contemplated that another paper entitled "Stresses and Displacements in a Homogeneous Soil" by W.J. Turnbull and S.M. Fergus will be presented at this conference describing them in greater detail. The selsyn type deflection gage is used to determine vertical deflection profiles beneath single and dual plate systems of several load magnitudes and different dual spacings representing hypothetical single and dual wheel plane loadings. WES cells were installed in horizontal, vertical and 45-degree positions to measure induced stresses on these planes under the previously-described conditions. This test section was constructed of a uniform clayey silt soil throughout for the purpose of furnishing stress-strain data in as nearly a homogeneous soil mass as it was practicable to construct.

WES pressure cells were installed in vertical, horizontal, and 45-degree positions in the Stockton No. 2 test section and subjected to moving and standing single wheel loads up to 200,000 lb. The cells were installed at several elevations in flexible pavement bases and subgrades of different soil types. A report on these tests is not available at the time this paper is written; however, it is anticipated that a paper covering these tests will be presented at this conference.

CONCLUSIONS

Experience with the test results derived from the use of the WES pressure cell and deflection gages described in this paper has indicated that these instruments furnish measurements of induced stresses and strains which are considered to be reasonably accurate and reliable. It is recognized that certain discontinuities result wherever foreign objects are placed in the soil mass but to date there are no known stress and strain measuring devices which obviate these discontinuities.

It is believed that a primary need exists at the present time for a pressure cell which will accurately measure residual soil pressures over long periods of time. Development of such a cell is included in a comprehensive research program now underway at the Experiment Station.

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TWO TYPES OF SOIL TESTING UNITS

RENE DEGUILLAUME

Membre de la Société des Ingénieurs Civils de France

SUMMARY OF THE FRENCH REPORT

Knowledge of a soil's characteristics enables the problem of foundations to be solved and only the specialised laboratory is qualified to specify them.

The engineer is therefore obliged to rely on the soils laboratory for any job that has to executed on an apparently compressible soil.

There are, however, all kinds of compressible soils just as there are jobs of varying degrees of difficulty.

Now, to set a laboratory in motion for a job of minor importance in a case where the soil is sound in appearance would be needless and expensive.

It is nevertheless necessary to reconcile stability and economy.

Hence the importance to the engineer of a simple and sufficiently accurate means of soil investigation in the field.

The two apparatus described below were designed with this object for a firm of contractors in Algiers at a time when there was not a soils laboratory in Algeria and only two processes for approximate evaluation of soil compressibility were known: these were the multiple or single foot loading plate and the driving of test piles which required a pile driver, and this limited the usefulness of the latter process.

The two units in question are:
a static device made in 1927 and a dynamic device made in 1929.

1. STATIC SOIL TESTING UNIT

This device (Diagram A.) is a load amplifier.

Its three superimposed plates, connected to a beam are based on Quintenz' principle.The beam however, is not set as in a typical Quintenz weighting machine but has been turned round 200 grades horizontally.

As a result any load C suspended at the free end of the beam is amplified when transmitted to the plate, the amplification being measured by the constant ratio $\frac{OA}{OB}$: OA being the effective length of the beam and OB the distance from the beam's rotation axis to the axis of the vertical lever of the loaded plate.

The effective length of the beam measured from its rotation axis to the weight suspension notch is (Fig.3): OA = 1.60 m.

The distance from the beam's rotation axis to the axis of the vertical lever BG of the loading plate is: OB = 0.04 m. x)

The amplification coefficient is derived from the system's equilibrium condition for Q = amplified load C transmitted to the loading plate.

$$\text{But } C = Q \cdot \frac{OB}{OA} \text{ therefore : } Q = \frac{1.60}{0.04} = 40\ C$$

The contrivance has been designed to carry at the end of the beam a 60 kg. weight of water or 220 kg. of lead shot.

The water is supplied from a tank with a controlled outflow; the lead shot is delivered from a hopper similar to the Michaélis device once used for the testing of concrete bricks.

The plate can therefore undergo a variable vertical impulsion Q which can attain,

$$Q = 60 \times 40 = 2400 \text{ kilograms}$$
$$\text{or } Q = 220 \times 40 = 8800 \text{ kilograms}$$

according to whether the load is composed of water of lead shot.

A cylindrical steel plunger P, 19 inches (50 cm) long is implanted normal to the under side of the loading plate.

It is known that the basis of Quintenx' principle is the maintenance of horizontality in the loading plate during its vertical displacements.

Therefore, the loading plate remaining horizontal during its vertical displacement transmits the vertical impulsion received to the cylindrical plunger which bears on the soil.

The sections adopted for the plungers are of 7.75, 15.5, 31, and 352 suare inches, (50, 100, 200 and 2270 sq.cm.). The plunger of 352 sq.in.(2270 sq.cm.) section - with a diameter of 21 inches (0.5376 meter) - is called the control plunger : it serves to check the safety of loads on doubtful soils and is very seldom used.

Tests: Three kinds of test can be made with this device:

The 'quick' test on easily identifiable soils where the job is of minor importance.

The 'more accurate' test, checked by a Rabut recorder on doubtful soils, or in the case of heavy works of constantly varying load such as culverts, reservoirs, warehouses,silos ......etc.

And the 'control' test to measure the effect of the safety load limit (when required) by means of the Rabut recorder.

For the two first tests the liquid load is used while for the third the load is of lead shot.

Fig. 2 of Diagram A represents the curve drawn by the Rabut recorder at a rotation speed of 13 minutes (ER fig.3)

This curve has three parts:

1) part α an oblique line. Its higher extremity gives the soil's apparent yield limit.

2) part β slightly incurved towards the top. This corresponds to highly accentuated soil deformation.

The soil is no longer elastic. The line of permanent deformation has been reached; the yield limit has been exceeded.

If the load is withdrawn a more or less accentuated imprint remains according to whether the unloading was effected near the beginning or towards the end of this part of the curve.

3) part γ still more curved inwards than the latter, with a tendency to, but unable to become vertical. The vertical cylindrical plunger has been driven into the soil: the driving-failure point has been reached.

The outline of the curve indicates clearly that the penetration is proportional to the load until the yield limit has been reached. Thenceforth the sinkings increase faster than the load.

The load applied at any given moment can be read on the penetration curve, as the flow of water or lead shot is constant (or very nearly so).

Taking the usual safety factor of 4 on the basis of the failure point the working load q per unit of surface measurement is, for a total failure load R :

$$q = \frac{0.25\ R}{\Omega} \quad \text{per square centimeter}$$

for Ω section of the vertical plunger used for the test.

The load R must be less than or at most equal to the load corresponding to the yield limit (extremety of part α of the curve) which should not be exceeded.

This device has proved very useful for the laying of very delicate foundations.

Its only drawback is its size which makes it inconvenient to use in narrow cuts.

It was replaced in 1929 by the dynamic device described below, which is still in use.

2. DYNAMIC SOIL TESTING UNIT

The principle of this percussion driven pile is derived from the French Army Engineer's test pile method explained in the Building Manual for pile bridges to bear heavy weights. (Manuel de Construction des ponts de pilots pour poids lourds. Livre de l'Officier. Edition 1918)

Nevertheless the ratio of hammer head weight to pile weight in the Dutch formula (which is the basis of the test pile method) has not been maintained.

The ratie $\frac{\text{hammer head weight}}{\text{pile weight}} = \frac{2}{3}$ has been replaced by a ratio of 4 because of the advantage to be obtained from the use of a steel pile and heavy hammer heads.

The half angle of the pile point, originally fixed at 20° was subsequently increased to 58°.

The safety factors used are those recommended by Benabenq, minimum 4, maximum 8.

The machine, (Diagram B) is composed of:

A steel tripod fitted with a universal joint suspended head.

A pile connecting rod, and

A metal hammer head.

The equipment is conposed of a set of five piles whereof the section varies from 0.8 to 2.52 sq.inches (5.167 to 16.25 sq.cm.).

The driving formula used is expressed:

$$R\,\Omega = \frac{P^2 H}{(P + p)h} + (P + p)$$

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x) Fig. 3 has been slightly distorted so as to be more explicit; the dimension OB is not true to scale.

Appareil statique d'essai des sols

Statics instrument of test of sols

Pl. A.

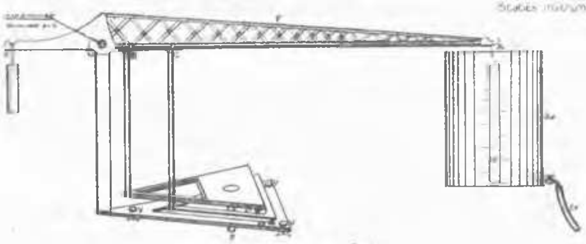


Fig 1

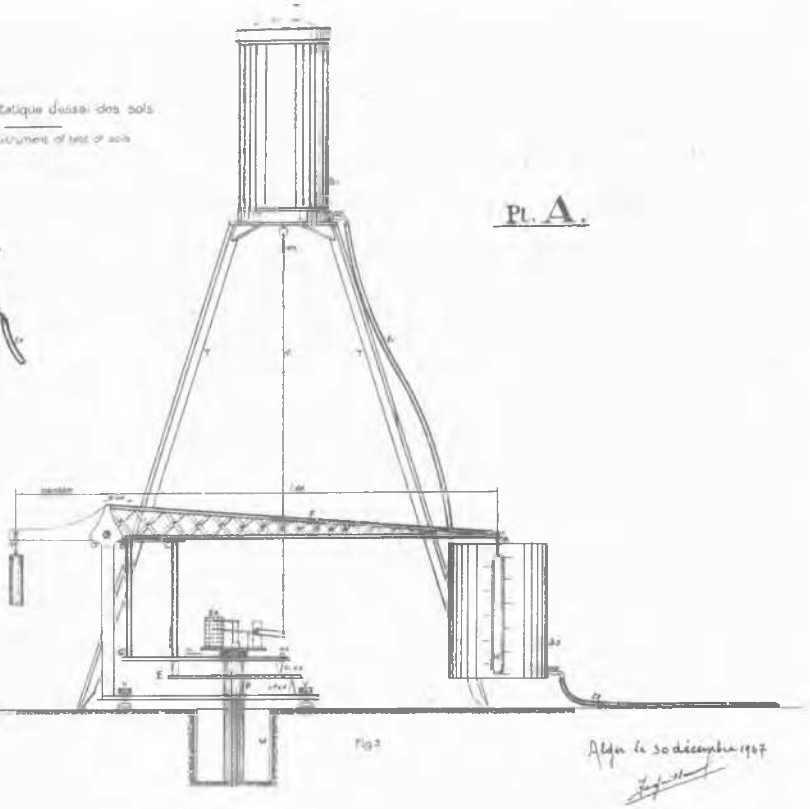


Fig 3

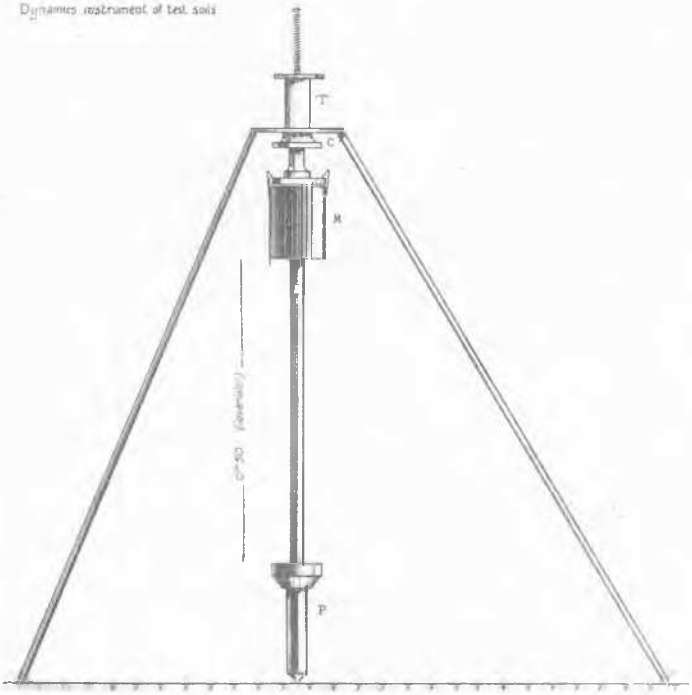
Courbe d'enfoncement en fonction du temps
Sinking graph in time function
(Enregistreur Rabut)

Fig 2

Alger le 30 décembre 1947

Appareil dynamique d'essai des sols

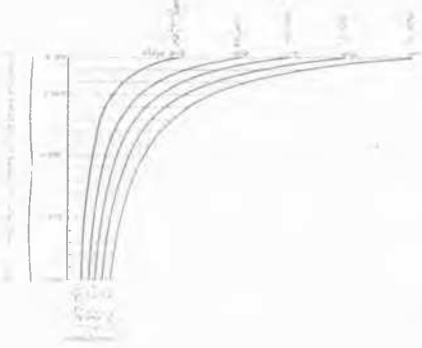
Dynamics instrument of test soils



Courbes des enfoncements et des resistances

Sinking and strengt graphic

Pl. B.



Pilot n° 3

Pile

Alger le 30 décembre 1947.

Where:

P = weight of hammer head in kg

p = weight of pile and connecting rod in kg.

H = height of drop constantly maintained at 0.50 meters.

h = perforation (in metres) caused by the pile as a result of ten blows.

Ω = pile section in square centimetres.

This gives R = soil strength in kg.per sq.cm. with a safety factor of 1.

The equation for the machine is :

$$R = \frac{3.512}{\Omega . h} + 10.975 \quad \text{(in kg. per sq.cm.)}$$

For variations of h between 0.01 m. and 0.10 m. in fractions of 5 mm. the soil strength is given by a table in kg/sq.cms. with a safety factor of 1. According to the margin of safety required, between 4 and 8, the value given by the table is divided by the value expressing the safety factor.

Fig. 2 of Diagram B gives the penetration and soil strength curves. These curves of hyperbolic outline show the regularity of expression in the equation for the unit.

The unit together with its accessories weights 46 lbs. (21 kg.) When the tripod is closed it is 45 inches (1.15 m.) long. It is therefore handy, relatively light and can be carried fairly comfortably in a private car. It can be carried about quickly from place to place for rapid prospection of all kinds of compressible soils: the test takes only a few minutes.

COMPARISON BETWEEN SOILS LABORATORY RESULTS AND THOSE OBTAINED BY THE DYNAMIC FIELD TEST UNIT.

It is only quite recently (Spring and Summer 1947) that data obtained with the dynamic field test unit were compared with the working fatique rate (rate of wear) given by the soils laboratory.

The soils studied were : marls in swampy ground (Serson district of Algeria) and cohesionless marly silt near Algiers.

These comparisons have brought out such a measure of agreement that the percussion driven pile unit can be recommended to engineers as an extremely useful instrument.

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