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Report on Dynamic Soil Tests.

Bericht über die dynamischen Bodenuntersuchungen.

Rapport sur l'auscultation dynamique des terrains.

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Foreword.

Static load tests on soil under directly imposed loads or under pressure by hydraulic presses are admittedly unsatisfactory in various respects. The results depend to a very great extent upon the area of the surface loaded. Even the early tests made by *Engesser*[1] (1) showed that for the same degree of loading per unit of surface the amount of subsidence increased with the area subjected to loading. *Engesser*'s theorem was subsequently proved by the test results obtained by *Kögler* (2, 3, 4) and others. For a given surface area the amount of subsidence has a minimum value that increases rapidly when the area is decreased but more slowly when the area becomes larger. So far, however, the tests carried out have not employed surface ares of more than about 1 m^2. It is extremely difficult to draw conclusions from such tests by extending them to loaded surfaces of sizes encountered during practical building operations. A further drawback of the static load test lies in the fact that the effect of loading does not penetrate very deep. In this connection *Kögler* and others have shown that its effect extends to a depth equivalent to about five or six times the diameter of the surface loaded. Thus, in these loading tests it is as often as not impossible to make any allowance for deeper layers of soil which under certain circumstances can exert a very considerabler influence on the amount of subsidence, so that it is easy to arrive at false conclusions from test loading.

With a view to obviating these drawbacks, the 'Degebo' — Deutsche Forschungsgesellschaft für Bodenmechanik (German Research Institute for Soil Mechanics) — has for the past seven years been elaborating processes for dynamic soil tests.

§ 1. Description of apparatus.

On the soil to be tested is placed a machine capable of exerting on the soil beneath it forces running sinoidally and in any desired direction. These machines are of extremely simply construction; they function on the principle of eccentric masses rotating in opposite directions on two shafts (Fig. 1). Sinoidal forces

[1] The numbers design the conforming number of the index.

acting vertically to the surface of the ground, as well as forces and turning moments acting in any desired direction can be produced with them. These oscillators are manufactured by Messrs. Losenhausenwerk, Düsseldorfer Maschinenbau-Aktien-Gesellschaft, Düsseldorf-Grafenberg. The weight of the machine, the magnitude of the centrifugal forces and the number of revolutions of the shafts can be altered.

The waves set up under strip or point loading in the homogeneous, elastic half-space extending to infinity have been investigated by *Rayleigh* and *Lamb* (7, 8). Progressive thrust waves, compression waves and surface waves are caused, whose speed of propagation is as 1.7: 1: 0.9 respectively. These waves are observed almost exclusively in macroseismics. The waves produced by the machine just described, which has a given mass and a finite ground area, have recently been the object of strict mathematical research by *H.* and *E. Reissner* (36). We shall refer to this work in due course. Simplified assumptions are here made for the practical application of the oscillations produced in the soil for the purpose of determining the properties of the latter.

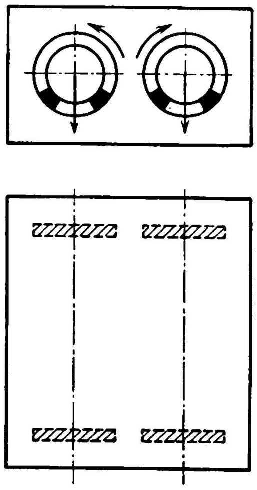

Fig. 1.

The arrangement of masses for vertical agitation.

In a number of the tests the machine and a certain portion of the ground is considered as an oscillating mass element standing on a more or less elastic base, namely, the soil to be examined. In the second group of tests the waves emanating from the machine are investigated.

§ 2. The machine on an elastic base.

When the oscillator placed on the ground is agitated by vertical, periodic forces, the machine can as a first approximation be considered as a mass element vertically unrestrained. The ground exerts a linear rebound action and a shock-absorbing power which, as a first approximation, can be valued as proportional to the velocity. Now the whole action of movement is governed by the linear differential equation with fixed coefficients:

$$M \frac{d^2 x}{dt^2} + b \frac{dx}{dt} + cx = P \sin \omega t,$$

or when divided by M:

$$\frac{d^2 x}{dt^2} + 2 \lambda \frac{dx}{dt} + \alpha^2 x = \beta \sin \omega t.$$

In this equation M is the oscillating mass,

$b \frac{dx}{dt}$ the shock-absorbing force, and

cx the elastic rebound action,

$P \sin \omega t$ the periodic agitation force whose rotary frequency is ω.

In the test the rotary frequency is now allowed to assume all possible values. The amplitudes x of the machine are recorded by a vibrograph affixed to the machine. Further, the phase displacement between the position of the eccentric mass and the oscillating machine is recorded, the indications of the vibrograph continuously giving the position of the eccentric masses as well. Thirdly, the energy imparted to the machine is measured.

A test of this kind shows that the amplitudes x of the oscillating mass element rise from O to maximum value as the number of rotations increases, and fall again asymptotically towards a definite value if the rotations are increased still further. The record of the amplitudes therefore contains a point of resonance when the frequency of the agitating agent coincides with the natural frequency α of the undamped oscillation of the mass element. This resonance point is also apparent in the record of imparted energy and that of phase displacement (Fig. 2—5).

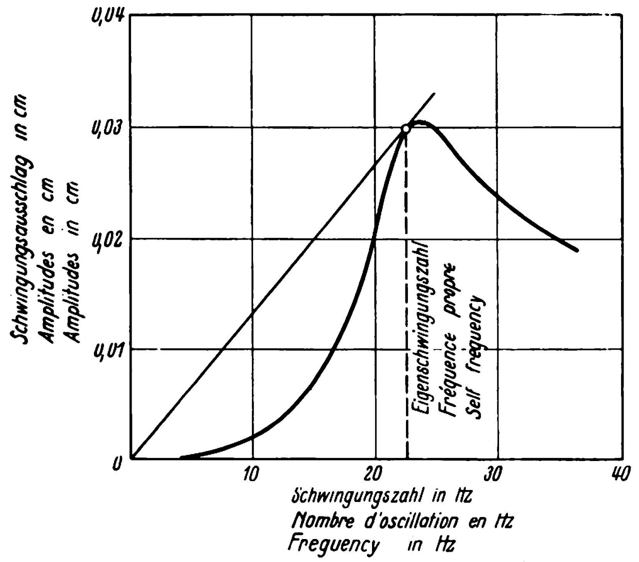

Fig. 2.
Amplitudes of the moving mass on the ground in dependence of the frequency.

The curves recorded in the test for amplitude, energy and phase can be used in calculating the constants α and λ in the differential equation of the oscillating concentrated mass. The evaluation process, which cannot be given in detail here, is described in the 'Veröffentlichung der Deutschen Forschungsgesellschaft für Bodenmechanik', Heft 1 (Publication of the German Research Institute for Soil Mechanics, No. 1) (14). As amplitudes, imparted energy and phase are recorded on different instruments, the accuracy of the values α and λ can also be determined. The mean deviation of the α figures varies between 3 and 5%; that of the damping figure λ, is considerably greater. The reason for this lack of accuracy cannot be gone into here.

The natural frequency figure $\alpha = \sqrt{\frac{c}{M}}$ depends upon the elastic properties of the soil. The results of a long series of tests on soils of the most widely differing natures are arranged in Table I in the order of increasing α. In the third column of the Table will be found the loads per unit of surface. A comparison between the two columns reveals that there is a relation between the value α and the admissible loading. The values of α rise in accordance with admissible loading, so that α can be used as an immediate standard of measurement for the loading to which the ground is subjected. The use of α to determine the carrying property of the soil is more advantageous than the determination of admissible loading by static load tests, in that when establishing the value of α experimentally many much larger portions of soil are involved than in static testing, so that the influence of deeper layers also becomes evident. Furthermore, with this method the size of the surface under load does not play such a decisive part as in the static testing method. Of course in the dynamic test, too, only such values of α can be immediately compared as have been obtained with a

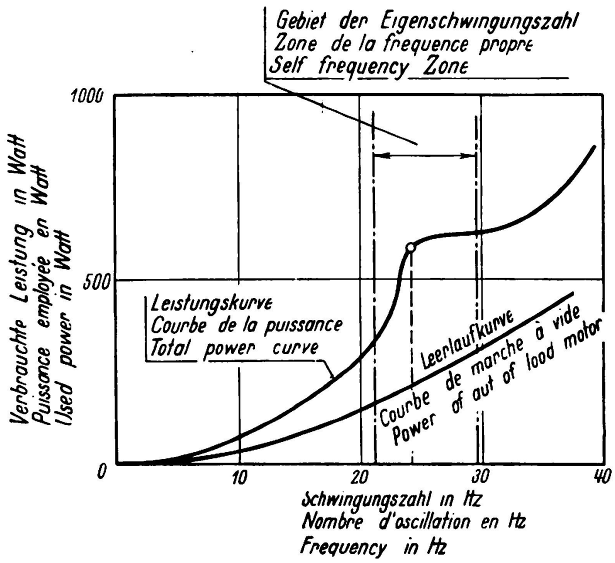

Fig. 3.
Power in dependence of frequency.

standard apparatus, i. e. with a machine of definite weight, ground area and centrifugal force. There is, however, a possibility of making a mutual comparison between results given by machines of other constants.

The damping value λ is dependent on the one hand upon the internal friction of the soil, and on the other upon the deformation energy exerted to produce non-elastic, permanent subsidence. If the internal friction and the deformation energy are great, the damping is also great. But since these two circumstances, friction and permanent subsidence, have an influence upon the damping, it cannot of course be concluded that soils of great shock-absorbing power must reveal great permanent subsidences, for a soil with great internal friction can also possess great shock-absorbing power without being subject to great permanent subsidences.

Fig. 5 shows the action of subsidence as it occurred in a test, independently of the frequency of agitation. If this compressive action is brought into relation with the amplitude curve, it will be found that for very many soils the subsidences at first increase, slowly, grow rapidly when the resonance zone is reached, and beyond this zone again increase but slowly. The permanent subsidences occuring in non-cohesive soils are mainly caused by the collapse of unstable arrangements of granules with regard to each other. When the ground is agitated, the friction between the oscillating particles of soil decreases so much in the resonance zone that the arrangements of particles, blocked by static loading, collapse, until finally they attain maximum compactness during the process of oscillation.

It is therefore possible to predict with a good degree of reliability the behaviour of the ground under dynamic loading and vibration, by considering the value obtained for the shock-absorbing properties of the soil, and the amount of subsidence.

In the case of strongly cohesive soils by dynamic loading of the ground cannot of course give adequate information as to the influence of time on the compressions. For this further investigations will naturally be required — laboratory

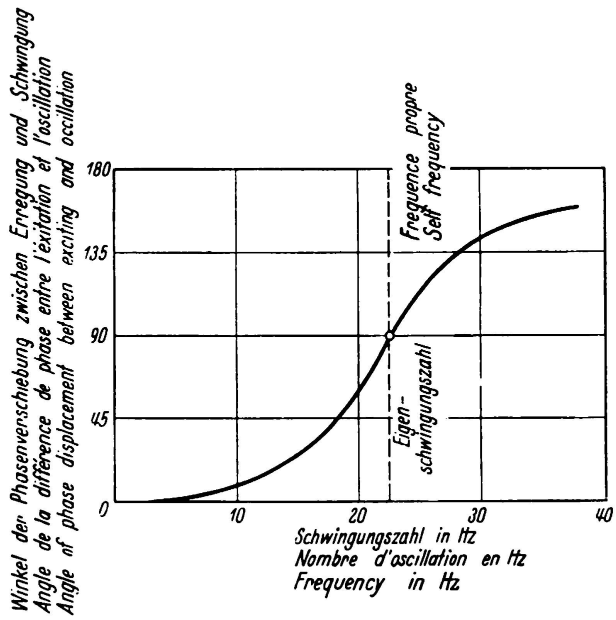

Fig. 4.
Phase displacement between agitation and oscillation in dependence of the frequency.

tests on cohesive soils, carried out on undisturbed specimens by the well known processes. But even for non-cohesive soils it is advisable to supplement the dynamic tests by investigating undisturbed specimens and ascertaining the size-distribution of the granules, the degree of porosity and the compactability of the soil.

§ 3. Speed of continuous surface waves.

The nature of the waves produced by the machine has not yet been fully explained. It is, however, possible to carry out the following measurements: A seismograph is used to record, at sufficiently close intervals along a straight line emanating from the oscillator, the amplitudes of a small surface area of the ground approximating a surface point, and at the same time the position of the eccentric weight in the oscillator. If, now, simultaneously with the position of the eccentric mass we now follow, say, that of a wave crest, which can easily be found in the various records at a sufficiently short distance from the points of measurement, it will be seen that this wave crest is propagated at a certain rate. For it a graphic time-table (Fig. 6) can be drawn up similar to a railway time-table. In homogeneous ground this table yields a straight line (Fig. 6b) at an angle to the time axis. The tangent of its angle of incline reveals the speed of propagation. If the wave enters soil of a different density during its progreß, this rate curve gives a different speed; where there is a transition from one type of ground to another the rate curve is suddenly bent (see Fig. 6a).

These tests have been carried out on the most widely-differing kinds of ground and the results noted in Col. 1 of Table I appended. It will be noticed that in this Table the speeds are also arranged in order of magnitude, rising from 80 m/sec to 1100 m/sec. The propagation speed of these waves is thus — just like the constant of elasticity of the soil established above — a standard of measurement for the quality, i. e. the carrying capacity, of the ground. This standard is an even more sensitive one than the elastic constant α found above.

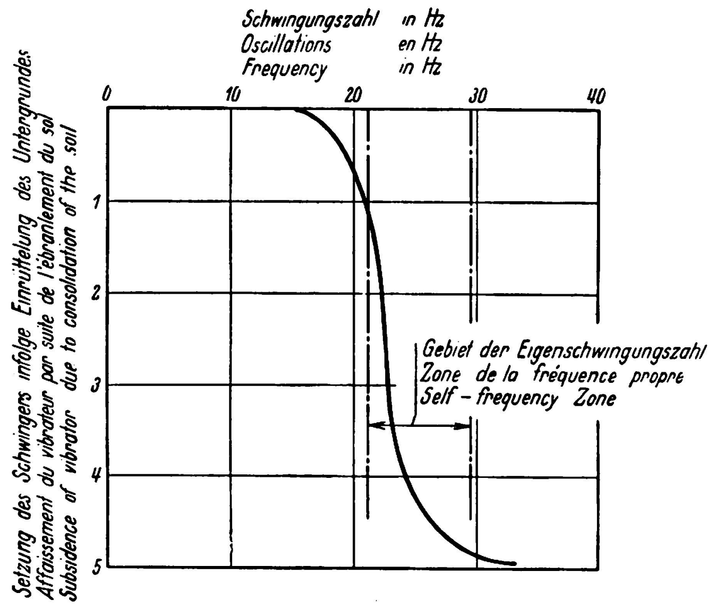

Fig. 5.
Subsidence of swinging mass due to shaking of the soil in dependence of the frequency.

If, now, the machines are placed at different points on the piece of landwhere soil properties are to be measured at the surface, and the propagation speeds measured in various directions, a map can be drawn up giving the surface properties of the ground (Fig. 7).

By measuring simultaneously the waves produced in the same soil by impact as caused by drop-weights or explosions, a conclusion may be arrived at concerning the nature of the waves set up by oscillation. Impact waves show much greater speeds and are generally referred to as compressive waves. The waves of far lower propagation speed produced by the oscillator and measured at the surface are therefore transversal or Rayleigh waves in homogenous half-space. It is a task for contemporary research workers to determine the exact character of these waves.

On recording the amplitude curve of a surface point, it will be seen that sinoidal agitation force gives a purely sinoidal amplitude diagram as well. It is only in the immediate proximity of the machine that this sinoidal form is sometimes disturbed, other and secondary periodic forces of a different frequency from that of the rotating eccentric mass exerting an influence upon it. As Fig. 8 shows, the amplitude decreases rapidly as the distance from the oscillator grows larger, the relation forming more or less an exponential curve. This kind of decrease has been observed by quite a number of investigators (37, 38, 39).

Various types of soil possess various degress of absorption. Available measurements would seem to indicate that absorption is dependent upon wave-lenght, and is greater for short than for long waves.

Propagation speed, too, is frequently found to depend on wave-length (dispersion), although further investigation is necessary if the questions of absorption and dispersion are to be fully understood.

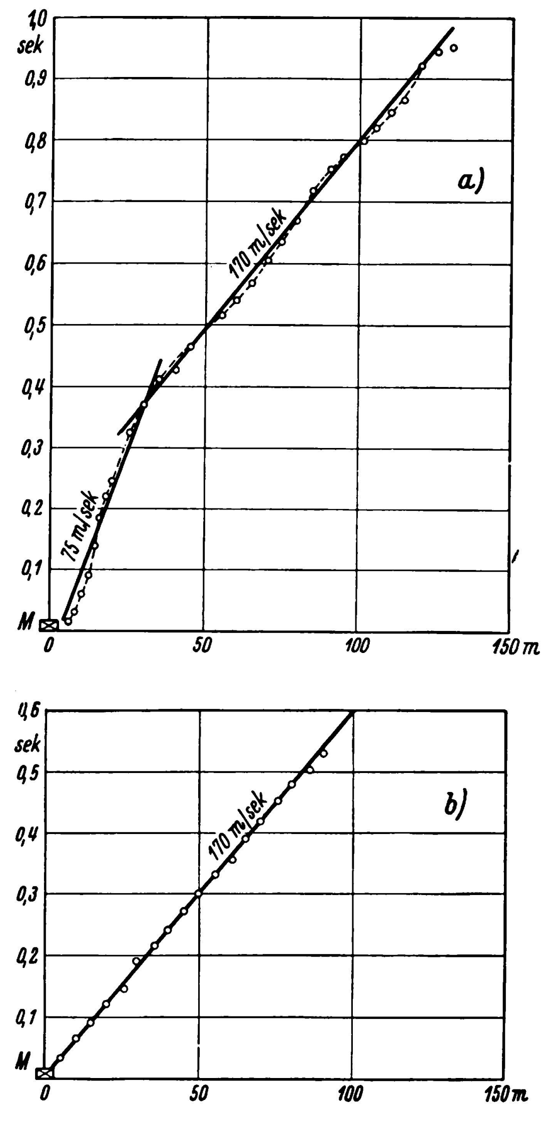

Fig. 6.
Time curve of the elastic waves caused in the soil by the swinging mass
a) in stratified ground,
b) in homogeneous ground.

§ 4. The waves in stratified soil.

If, at a certain depth below the surface, the upper layer terminates in a plane parallel to the surface and gives way to a soil of different texture, and if in this case the absorption of the waves in the top layer is greater than in the layer below, then the rate curve (Fig. 6) also reveals a sudden kink, the speed for the top layer appearing first in the neighbourhood of the machine. The speed for the deeper-lying layer is revealed at a greater distance. Here the surface wave has already been absorbed and the oscillation of the deeper layer appears at the surface. This interpretation of the rate curve is confirmed by other investigations carried out on top and deeper layers.

The separate branches of the rate curve are not straight lines but reveal slightly curved sinoidal lines placed on top of the straight lines. Their significance has been investigated in the 'Degebo' Publications, No. 4 (15). Even in the rate curve the speed gives an indication of the character of the deeper layer.

If the amplitudes of the points lying on a straight line emanating from the oscillator are further observed, it will be found that, as already mentioned, they

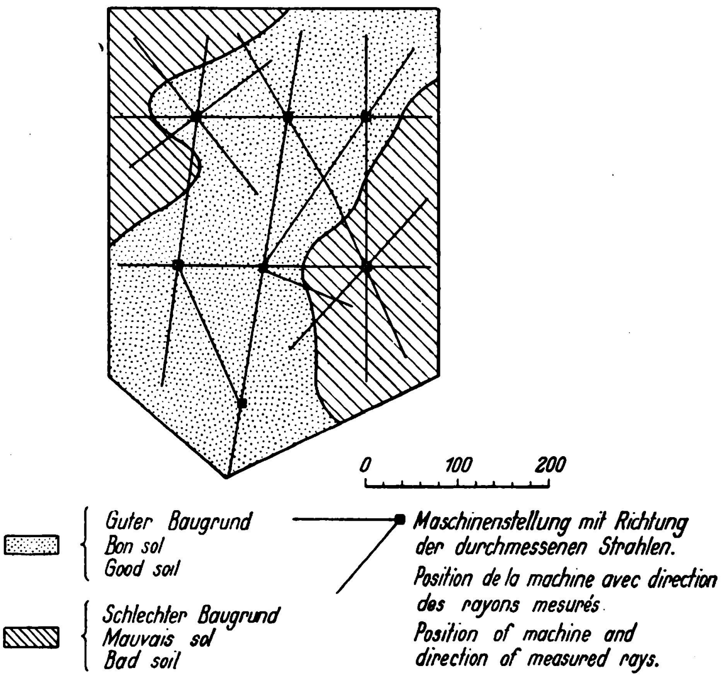

Fig. 7.

Result of a dynamic soil test. Determination of limits between good and bad soil.

decrease at an approximately exponential rate in homogeneous soil as the distance from the oscillator increases. In ground composed of layers, on the other hand, a steady decrease does not occur, but at certain places the amplitudes again appear as definite maxima. There can be various reasons for such maxima. When the individual layers are perfectly homogeneous, these maxima are only to be explained by interference between the waves of the upper and lower layer, or by the overlapping of waves thrown back at the dividing surface. If the maxima are determined along all possible straight lines emanating from the oscillator, they will lie in concentric circles about the latter if the soil is homogeneous and the plane separating the layers parallel to the surface. Making certain assumptions as to the flow of these waves, as is done in seismics when examining subterraneous deposits, it is now possible to ascertain the depth of the plane separating the two layers by observing how far distant the interference rings lie. If the dividing plane is not parallel to the surface, ellipse-like, con-focal curves are formed instead of concentric circles. Distorted curves may also appear if the ground round about the machine is not homogeneous. It can be determined which of the two cases, non-homogeneity or a sloping plane of separation, has to be dealt with by taking measurements along a straight line in a direction away from the machine, and vice versa, measuring towards the machine.

When investigating the internal structure of the ground with the aid of the dynamic process, the wave-length employed naturally plays a very important part. Fig. 8a—b shows the course of the amplitudes for two measurements taken at the same place, one with a wave-length of 15 m and the other with a

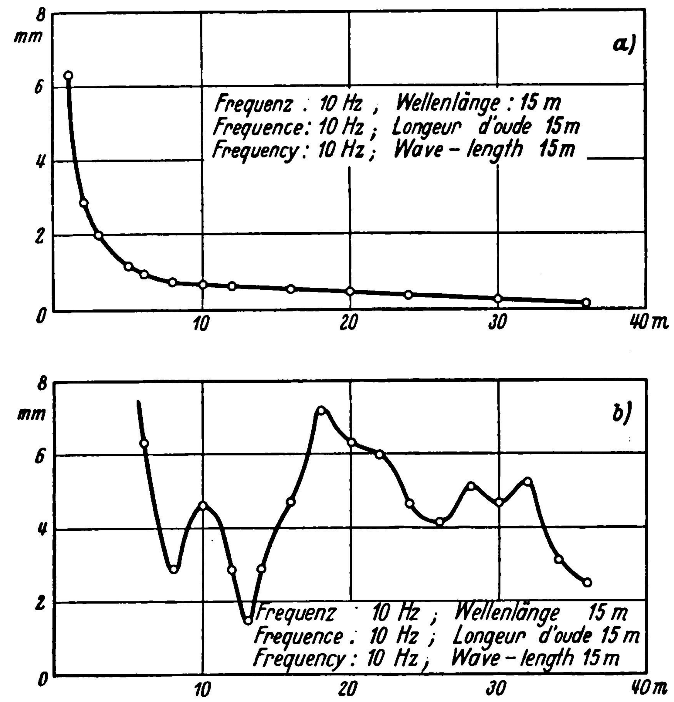

Fig. 8.
Amplitudes of soil oscillation in dependence on the distance from the agitator
a) for long waves,
b) for short waves.

wave-length of 7.5 m. The first curve runs fairly smoothly, the second reveals a large number of maxima and minima. Here symptoms of deflection become apparent; if the wave-lengths are not in the right proportion to the various differently composed portions of the ground, the waves are deflected around these irregularities. This fact is also of importance when waves are to be screened in the ground.

§ 5. Application.

The application of the process has already been referred to in the preceding paragraphs. A few examples taken from actual practice will now be briefly considered.

1) Determining the α values and compressions.

On ground where borings and superficial examination had led to the assumption of a good degree of regularity of the sub-soil, it was necessary, in view of the dynamic demands to be made upon it, to predict the subsidences that might be expected at the various foundation sites, as uneven subsidence of the separate foundation elements might have extremely bad effects. The foundation plan of the projected building and the points where the machine was placed are shown in Fig. 9. At these points the applied energy curves, the amplitude curves and the subsidence were measured. The figures for α fluctuated between 21.7 and 24 Hz, the subsidences between 7 and 3 mm. The examinations were carried out with a standard apparatus of 1 m² base area, 2700 kg weight and equal eccentricity. The subsidences cover all dynamic loading applied during a certain period. Tests for compactness carried out in the laboratory with undisturbed soil specimens confirmed the irregularities revealed by the α figures and the subsidences. On the basis of the data so obtained, and taking into consideration the size of the ground area of the foundations, admissible loading was calculated

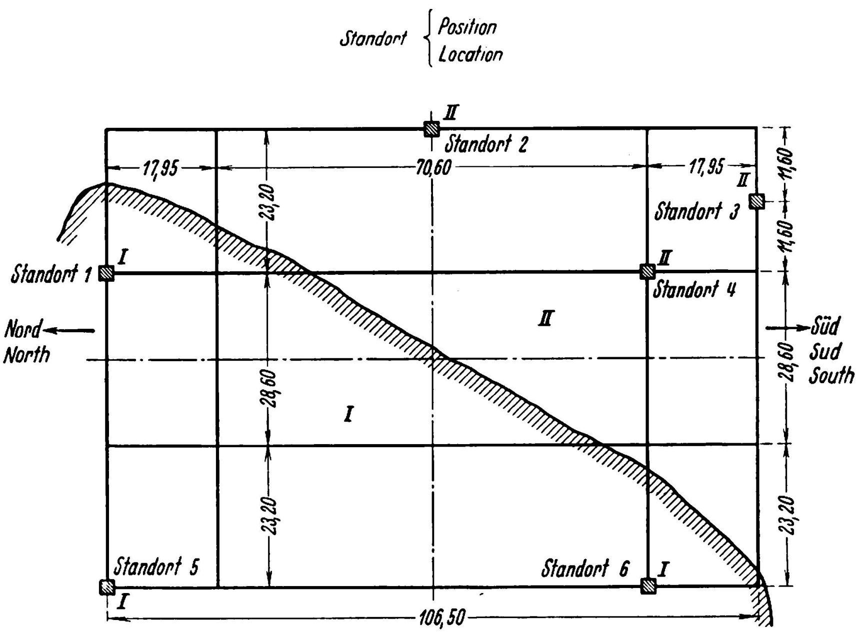

Fig. 9.

Layout for a dynamic soil test. Positions of agitator on the site plan of proposed building. The shaded line indicates the boundary between good and bad ground.

for each pier to give the same amount of subsidence for all. The admissible pressures for the one groups of foundations was 2 kg/cm², for the other 2.5 kg/cm². For sites of smaller foundation area it is sufficient to determine the α figures and the subsidences, making allowance for damping; these factors will give adequate information as to the regularity of the sub-soil. Investigation of undisturbed soil specimens in the laboratory is necessary for the pre-calculation of subsidence in the case of cohesive soil, and even with non-cohesive soit it is desirable.

When constructing the foundations of turbines at the present time it is the custom to calculate the natural frequency of the machines on their elastic foundations of two-dimensional frame constructions, it being understood that the whole of the body, through its foundation slab, rests on solid ground. In this case it is assumed that the elastic yield of the ground can be disregarded in relation to the deformations of the frame foundation. This assumption, however, is not always fulfilled. Thus, if under certain circumstances the elastic yield of the ground has to be considered when calculating frequency even for turbines, in the case of block foundations it is quite impossible to proceed without a

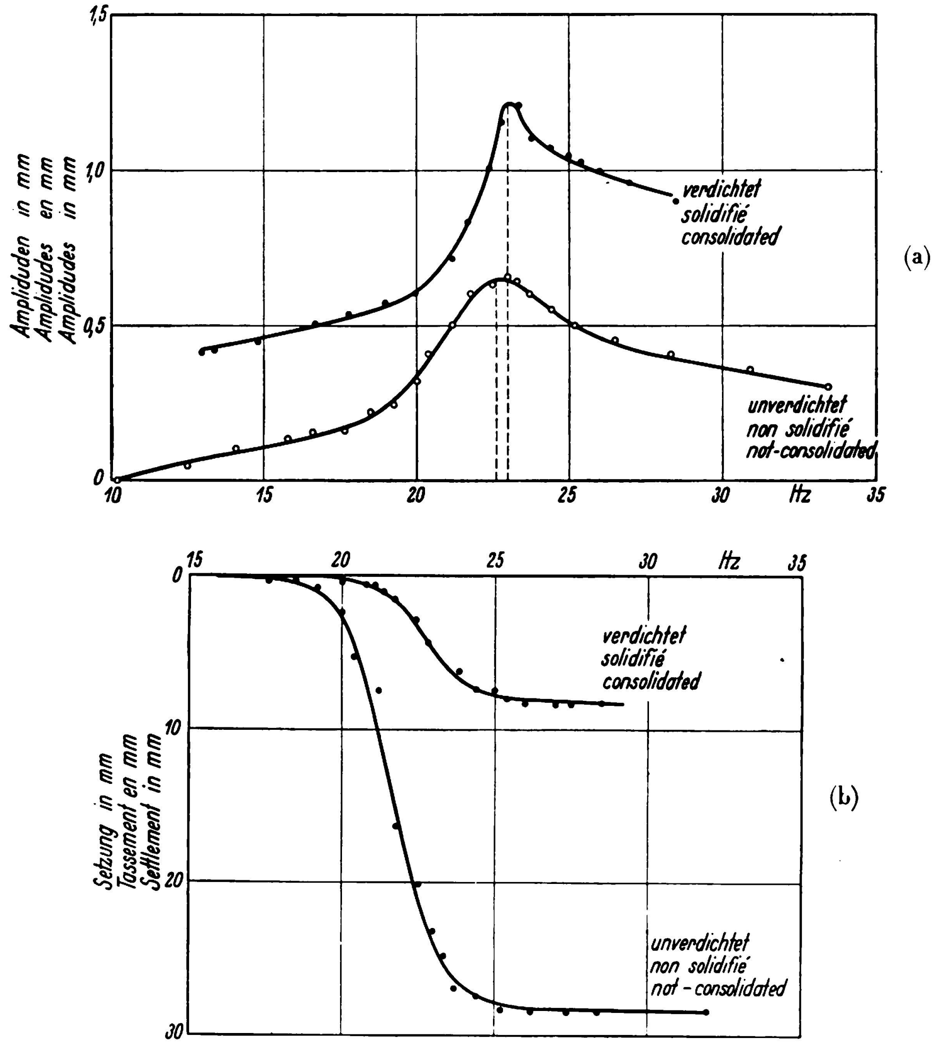

Fig. 10.

a) Amplitudes and
b) Subsidence of agitator in dependence on the frequency before and after consolidation.

knowledge of this yield. Here the machine and the foundation block together form a rigid body supported by an elastic base on the ground. The natural frequencies of the six degrees of freedom of the rigid body depend upon the distribution of its mass and the elastic constants of the ground. The α values, oscillating mass of ground and also elastic constants have been determined several times for such foundations by means of the above process. In view of the symmetry mostly possessed by the body, the problem can be treated as a two-dimensional one, so that only an elastically supported plate with two or three degrees of freedom — according to its other symmetrical properties — need be calculated (35).

Practical cases treated till now have given extremely good coincidence between precalculation and the natural frequencies subsequently measured. The latter are also obtained with the aid of an oscillator and by recording the resonance curves in the manner explained. If the instruments available are delicate enough, it is possible to record the resonance curves of the amplitudes even for machines and foundations of several thousand tons' weight with an oscillator of 2000 kg centrifugal force.

The effect of artifical compacting can be tested by subsequently measuring only the α values and the subsidences. Fig. 10a—b illustrates amplitude curves and subsidence curves, as recorded for an artificially compacted dam before and after compacting. Compacting increased the α figure from 22.6 to 23.0 (Fig. 10a), i. e. but very slightly, whereas subsidence dropped from 28 mm to 8 mm (Fig. 10b). The subsidence curves show the course already mentioned. Subsidence takes place mainly within the resonance zone. The amplitude curve of the uncompacted soil greatly differs from that of the compacted soil. The resonance peak in compacted soil becomes much more pointed, a sign that internal damping has decreased. In the loosely arranged soil a greater portion of energy is consumed during oscillation than in the soil that has become more dense and elastic.

2) Determining the speeds.

If it is a question of examining the building site on a large tract of land, the various properties can be successfully determined by speed measurements, the propagation speeds being obtained at various places in various directions along straight lines (Fig. 7). If the ground is perfectly uniform and uncompacted, the same speed will be ascertained from every point and in every direction. If, however, the ground is irregular, there will be kinks in the rate curves (Fig. 6 b). In Fig. 7 is shown a site plan drawn up for the various kinds of ground on the basis of these measurements. It has already been mentioned that the kink in a rate curve also occurs for ground composed of different soil layers. It can be decided which of the two cases is the one in question by comparing the measurements taken at the various points shown in Fig. 7.

The method of determining propagation speeds can also be successfully applied in practice for the solution of various other problems. The compacting of earth dams for roads and barrages, for instance, is an important question at the present time. One case is that of two railway dams built about twelve years ago of sand from the Mark district of Germany; one of these was subjected only to atmospheric influences during this period of twelve years, since no traffic passed over it, the other being under regular railway traffic the whole time. Propagation speed measurements at the borrowing pit and on each of the dams gave very informative differences. The dam not used for traffic gave a figure of 180 m/sec, well below that of the propagation speed of the natural ground, viz. 230 m/sec at the borrowing pit. Consolidation raised the propagation speed of the dam under traffic to 340 m/sec. Unfortunately, the speed for the new-built dam is not known. On the basis of other measurements, however, it can be estimated at its most unfavourable figure as one-half the speed of the natural ground. The preceding results show that when an earth dam is allowed to lie idle, its consolidation is but very slowly influenced by atmospheric action, and that the latter can never cause the same degree of density as is produced by vibration.

Speed measurements have also proved reliable for testing the effects of the various artificial methods of attaining consolidation in dams, e. g. washing, rolling, tamping, vibrating, etc. The periodical "Die Straße" (Nr. 18, 1935) published a report on tests of this nature.

The examination of built-up earthen road dams and of roads as such also comes within the range of the speed measuring process. In general it will be found that the effect of a concrete road slab, for instance, on a dam consists in an increase of average propagation speed from the slab and the sub-grading. Only in one single case was it found that, slab and sub-grading oscillated as a uniform body. The construction in question was a gravel dam with an extremely

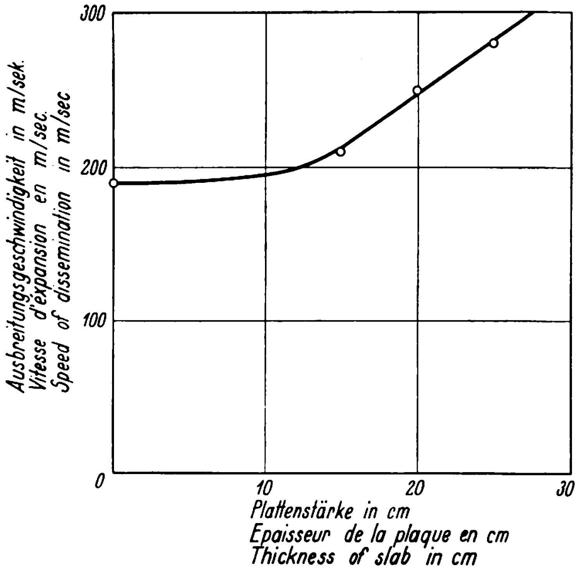

Fig. 11.
Rate of propagation of elastic waves in a road dam carrying concrete road slabs, in dependence on the thickness of the slabs.

favourable grain distribution, arranged in layers of about 30 cm and compacted by rolling and tamping. At the gravel pit from which the material was taken the elastic waves in the gravel had a propagation speed of 420 m/sec; in the dam itself, treated as described, a propagation speed of 560 m/sec was recorded. After a concrete surfacing of 25 cm thickness had been applied, an examination of the whole dam with a wave-length of 22 m revealed no alteration of propagation speed. At other places the speed of the waves in built-up ground was 125 m/sec; in the dam with a surface of 25 cm the propagation speed was 270 m/sec. From these observations it must be concluded that in the first case the dam and its concrete surfacing oscillated as a uniform whole, while in the second instance the concrete, resting on a more or less elastic base, undergoes vibrations due to bending. Finally, measurements were also taken to test the influence of the thickness of the surfacing for the same base. Fig. 11 illustrates the increase in propagation speed for increasing thickness of the surfacing, the base remaining the same. If sufficient experience and measurement results were available, it would most likely be possible to ascertain the minimum thickness required for a given speed in the dam alone. Of course the substructure of the dam also affects the total result; for the sake of simplicity this influence was not taken into consideration in the above.

3) The examination of stratified soil.

If it is desired to employ in a reliable manner the interferences occuring in soils composed of layers for the calculation of the thickness of these layers, it has hitherto been necessary to make various and rather arbitrary assumptions concerning the setting up of these interferences. In a few cases one or the other theory leads to correct results. In other cases, especially when there are more than two layers, the results of calculation are still very uncertain. In this connection further progress can only be made when more light has been thrown on the question of the various kinds of waves produced. The necessary investigation work has now been taken in hand, and its results and their practical applications will be reported on in due course.

Conclusion.

After six years of research work, including numerous theoretical and practical tests, we have come to the conclusion that the dynamic examination of soil is a valuable process. Of course this process alone cannot reveal all the properties of the ground. As has been stated in the preceding, cohesive soils in particular require the application of other well-known methods, such as those elaborated by *Terzaghi* (20, 40) and his disciples, for determining the influence of time on cohesive soils.[2]

The measurements hitherto made of amplitude and output curves, etc., and the greatly simplified theory of the oscillating concentrated mass with one degree of freedom, have enabled satisfactory coincidence to be attained and the significance of many phenomena to be interpreted. The work by *Erich Reissner* (36) on the stationary, axial-symmetrical oscillation, caused by a vibrating mass, of a homogeneously elastic half-space, particularly in relation to dynamic soil tests', which will shortly appear in Issue 5 of the Veröffentlichungen der Deutschen Forschungsgesellschaft für Bodenmechanik (Publications of the German Research Institute for Soil Mechanics), has further proved the justification of the simplified theory.

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[2] At the present time dynamic soil tests are being carried out by the Seismos Society for Soil Testing, Hanover. This concern possesses both instruments and experience in having carried out many soil tests for mineral deposits on the Mintrop process, and the material may also be used for dynamic soil tests.

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Tables.

No.	Kind of Soil	Diffusion speed	Natural frequency α	Adm. compression of soil kg/cm²
1	3 m moor on sand	80 m/sec	4.0 Hz.	—
2	Powder sand	110 „	19.3 „	1.0
3	Tertiary period clay, moist	130 „	21.8 „	—
4	Loamy sand, fine-grained	140 „	20.7 „	—
5	Moist medium-coarse sand	140 „	21.8 „	2.0
6	Jurassic clay, moist	150 „	—	—
7	Old deposit of sand and cinders	160 „	—	—
8	Medium-coarse sand and sub-soil water	160 „	—	2.0
9	Medium-coarse sand, dry	160 „	22.0 „	2.0
10	Loamy sand on marl shingle	170 „	22.6 „	2.5
11	Gravel with larger stones	180 „	23.5 „	2.5
12	Loam, moist	190 „	23.5 „	—
13	Marl shingle	190 „	23.8 „	3.0
14	Fine sand with 30% medium-coarse sand	190 „	24.2 „	3.0
15	Loam, dry, with limestone pieces	200 „	25.3 „	—
16	Medium-coarse sand, undisturbed	220 „	—	4.0
17	Marl	220 „	25.7 „	4.0
18	Diluvian loess, dry	260 „	—	—
19	Gravel below 4 m sand	330 „	—	4.5
20	Coarse shingle, compact	420 „	30.0 „	4.5
21	Variegated sandstone (deteriorated)	500 „	32.0 „	²/₃ adm. compressive stress
22	Medium-hard keuper sandstone	650 „	—	
23	Variegated sandstone (non-deteriorated)	1100 „	—	

Summary.

The dynamic testing of subsoils has been developed in two directions. In the first instance a certain spring constant is determined; whose value increases in different soils in about the same way as the permissible soil pressure found by experience. A second procedure is based on the rate of propagation of forced elastic waves, which can be used as a scale for the bearing capacity of the soil. The measurements allow at the same time to determine the subsidence as function of the agitator frequency which allows the prediction of subsidence in case of static and dynamic loading. The dynamic procedures in use have still the disadvantage of pure static trial loading.