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SOIL MECHANICS IN AGRICULTURE

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Soil mechanics constitutes a branch of soil physics. From among the physical characteristics it deals with the investigation of mechanical properties.

In broader sense soil mechanics also examines the rocks of other celestial bodies, the conditions of sea-bottom, lower earth layers and topsoils. We must, however, consider separately the agricultural soil mechanics in a narrow sense, dealing distinctly with the thin topsoil, most important from the viewpoint of agricultural cultivation.

The task of agricultural soil mechanics is to give, on the one hand, the characteristics necessary to the mechanical foundations of agricultural work, and on the other hand to develop methods of computation, suitable for a quantitative (or at least qualitative) description of mechanical states or processes.

The soil structure is considerably more complicated than that of metals, compound materials, building materials, used in engineering practice. The reason for this is that its solid liquid and aerial constituents may coexist in several formations including both quantitative and qualitative characteristics. Within a region under investigation there is always an essential inhomogeneity and anisotropy. There proceeds a constant in the soil due to chemical, biological, thermal, atmospherical effects and the fluctuation of water-content. These changes are further increased with artificial interventions, such as mechanised cultivation, fertilization, irrigation, etc. Therefore the role of time is very essential that when the soil-mass in question is investigated, in what state and under what circumstances.

A further difficulty in agricultural soil-mechanical investigations is that the processes include generally also limiting states.

Though man has since ancient times close links with the topsoils, exhausts them in their natural state or by intervention; moreover, according to history through the last millenia marvellous constructions are connected with the soil, brought into existence as a result of purposeful activity, neverthless scientific achievments are registered only in the last hundred fifty years. The soil mechanics may be regarded as a scientific discipline only since the 20's of our century. Our country has inmediately joint up to this branch of science, and at present several institutions are dealing with it in accordance with the requirements of building engineering.

The theory of soil mechanics, like other branches of natural science, makes simplifying assumptions to obtain a model, which can be investigated by mathematical means. Then one has to solve the mathematical problem by taking account of the so-called boundary and initial conditions. The model is, however, only an approximation, and therefore the final results must always be compared with experimental data.

One of the simplest assumptions is that the relation between the load and deformation is linear. Then one can apply the well known results and methods of linear elasticity. This approximation can be well applied even at present to several dimensioning problems. It is however inadequate to describe the actual processes and limiting states. Therefore in the last decades there were attempts to use more complicated (so-called rheological) models, which take account of the role of time as well. The results, obtained by the application of different theories, are largely diverse, and may be used only for qualitative judgements. Since the 60's one can observe a certain endeavour to develop a unified theory, but the results are not satisfactory so far.

According to what has been said above there is an absolute need for measurements to determine, on the one hand, the mechanical characteristics of the soil and use them to establish the form of the constitutive law and the values of the constants in it; and on the other hand to check the range of validity of calculations, that is to compare the calculated and actual (measured) strains, deformations, etc.

A considerable part of measurements may be carried out in laboratories only. There are many methods offered in this field. Presumably, sooner or later there will be accepted a unified method of measurement in the whole world, which is a fundamental condition for future progress.

The other part of measurements is carried out on the spot, that is, the soil is investigated in its natural, undisturbed state.

From our introductory remarks it follows that the scientific application of soil mechanics is possible only when the necessary mechanical characteristics of the soil have already been determined. Therefore, as a first step, it is necessary to specify the quantities to be measured and choose a measurement method.

MECHANICAL CHARACTERISTICS

From among the limiting states of the soil those of the slip and rupture are very essential. We assume that the soil is a homogeneous and isotropic continuum. Though for the structure of the soil in a small volume this is not the case, but in a greater volume these assumptions are already valid, at least statistically. Then for the description of strain distribution it suffices to know the mean stresses σ_1, σ_2, and σ_3 in three mutually perpendicular directions.

The limiting state may be found only experimentally. Let τ_{max} denote the tangential stress that corresponds to rupture. If we plot the values of σ, corresponding to all values of τ_{max}, then we obtain the limit-curve, characteristic for rupture according to Mohr's theory (Fig. 1).

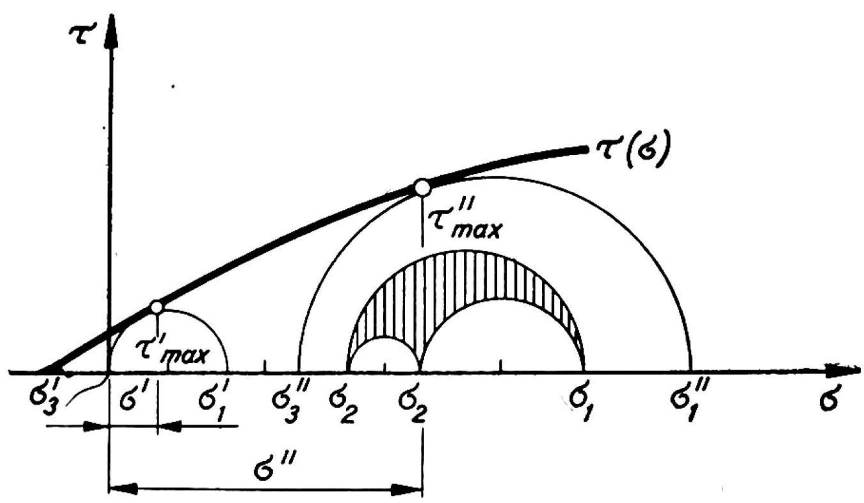

Fig. 1. Mohr's circles

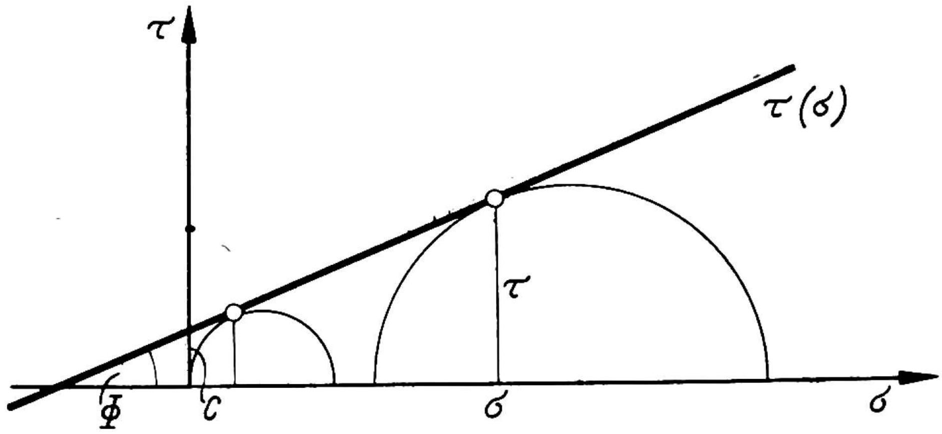

Fig. 2. Coulomb's aproximation

Experience shows that the limit-curve may well be approximated by a straight line (Fig. 2). This was recognized already by Coulomb. In view of this assumption the limit-curve is characterized with two data. From Figure 2 it is seen that

$$\tau = c + \sigma \operatorname{tg} \varphi,$$

is the equation of the straight line in question. Here the constant c denotes the cohesion, while φ stands for the angle of viscosity.

The limiting state of maximum stress that is the strength of the soil, is characterized by two fundamental quantities: the cohesion φ and the angle of viscosity.

For the sake of completeness it must be mentioned that a long lasting load on the soil leads to time dependent strength characteristics. In view of this φ and c also depend on the load period and thus the limit-curve of rupture is placed lower. If the load changes with time, then one has to make additional measurements to determine the corresponding limit-curve.

The behaviour of soil is characterized by the deformation, arising in consequence of the applied load. This is most easily seen in case of a uniaxial strain state.

If the material of the soil were elastic like that of metals, then a simple linear relation

$$\sigma = E \varepsilon,$$

would suffice to determine the deformation corresponding to a given load (Fig. 3). Note, that the time has no role in this relation.

Experience shows, however that the soil does not obey the above law. Let us increase the load from zero value and measure the corresponding deformation. Measurements give the curve of Fig. 4. From this diagram it is also seen that the role of time, expressed in the rate of increase of load is essential. Hence it follows that the soil can not be regarded as an ideally elastic body. The diagram also shows that the strength of the soil is influenced by the way of increase of load. In other words, it is justified to raise the question, that in which way do the mechanical characteristics, considered so far, change with time, and what additional characteristics must be introduced. This question is answered by rheology.

Since due to its structural composition the soil may be considered to exist in a state, intermediate between a solid and fluid (maybe with

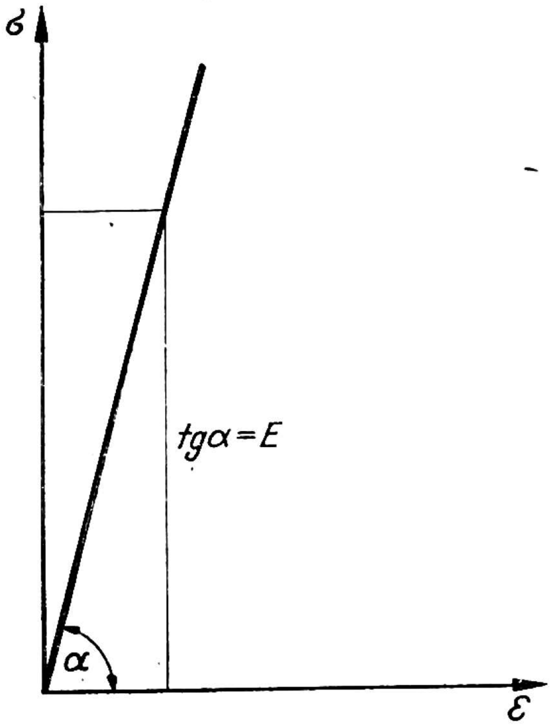

Fig. 3. Hooke's model

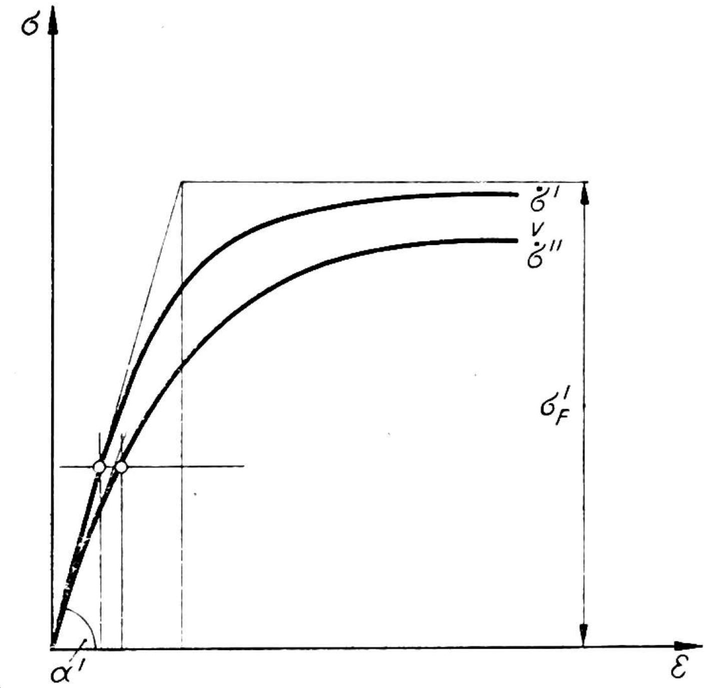

Fig. 4. Deformation curves for soil

large viscosity) we have to account for that in constructing an appropriate constitutive law.

Let us assume that the soil is a homogeneous, isotropic continuum, that is, let us disregard its structural composition, and microstructure. The constitutive law will be given by a function, expressing the relation between σ and ε.

$$\psi\,(\sigma, \dot{\sigma}, \varepsilon, \dot{\varepsilon}) = 0.$$

The simplest assumption is that this function is linear and has the form

$$\sigma = E\,\varepsilon + V\dot{\varepsilon} - R\,\dot{\sigma},$$

which corresponds to the so-called Poynting-Thomson rheological body. Here E, V, R are constants.

At first sight our constitutive law may look as arbitrarily chosen, but it can be seen immediately that it represents a better approximation, then the account of the first term only, which would correspond to an ideally elastic body. Our constitutive law accounts also for the influence of the rate of stress and strain. At the same time on the basis of experimental results we can say that the soil exhibits also creeping of viscosic character and relaxation properties as well. It is obviously decided by experiments that this relation may be regarded as a constitutive law at

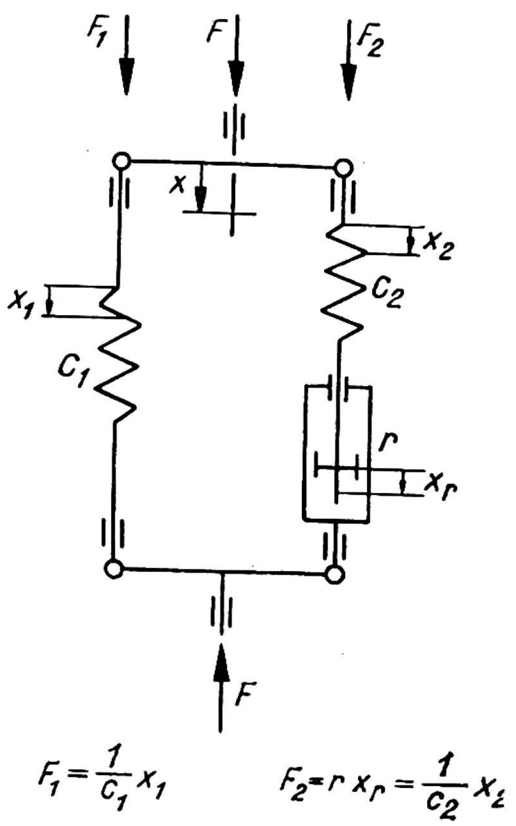

Fig. 5. Poynting-Thomson model

all, and in which approximation. According to our experience, it represents a good approximation as a constitutive law for certain kinds of soil. In this case the constants *E*, *V*, *R* mean material constants.

Thus we can state that the determination of rheological constants, defined by the constitutive equations, is a fundamental task of soil mechanics.

The physical model, corresponding to our constitutive law may be constructed by connecting elastic and damping elements, as shown in Fig. 5. Let us give rise in the test body to a specific strain ε_o by applying load to it in a suitable manner, so that the value of stress σ_o is achieved. From this moment we seek for the deformation, leaving the stress unchanged. The solution of the differential equation is

$$\varepsilon = \frac{\sigma_o}{E} + \left(\varepsilon_o - \frac{\sigma_o}{E}\right) e^{-\frac{E}{V}t}.$$

Fig 6. shows the solution. The phenomenon of increasing deformation due to constant stress is called creep.

Let us maintain now the strain constant, equal to its initial value. Then the solution of the differential equations is

$$\sigma = E\varepsilon_o + (\sigma_o - E\varepsilon_o) e^{-\frac{t}{R}}.$$

The results are represented in Fig 7. The decrease in stress due to constant deformation is called relaxation.

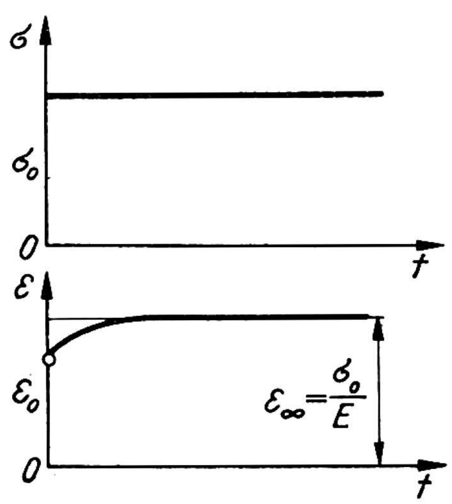

Fig. 6. Creeping curve

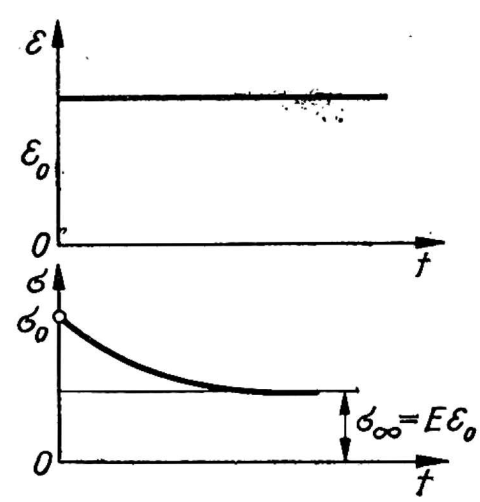

Fig. 7. Relaxation curve

MEASUREMENT METHODS

Strength data can be obtained from literature and practice in the usual way.

The method of measurement of rheological constants is even less developed. We shall describe in detail only the simplest method of uniaxial test.

The form of the test-body is chosen to be a circular cylinder.

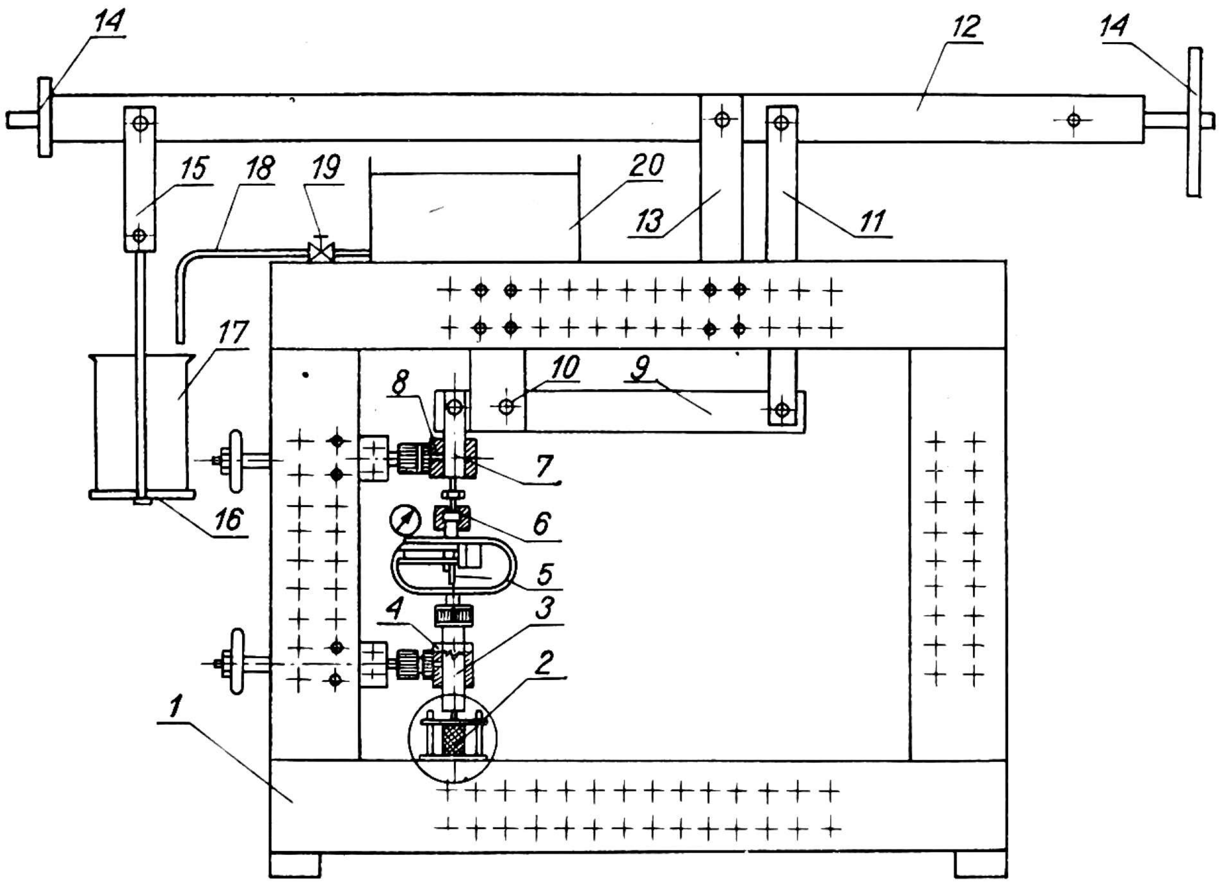

Fig. 8. The loading apparatus

The load aquipment is shown on Fig. 8. The test body 2, placed between the plates, is adjoint to the rigid frame 1. Force is exerted by a lever of second kind 9, embedded pivotly in the support 10. The water, stored in the tank 20, arrives through the tubing 18 by opening the regulable water-tap 19.

In the creep-test the required initial values ε_0 and σ_0 are realized by means of a constant rate of load.

The test essentially consists of the measurement of the change in length, which is carried out by a periodic read-off of the indicator.

Fig. 9 shows a measurement-curve for a clayey soil.

In relaxation tests the adjustment of ε_0 and σ_0 is the same as above. An essential difference is the inclusion of a separate electrical regulating equipment to maintain a constant value of strain.

Fig. 10 shows a measurement-curve for a clayey soil.

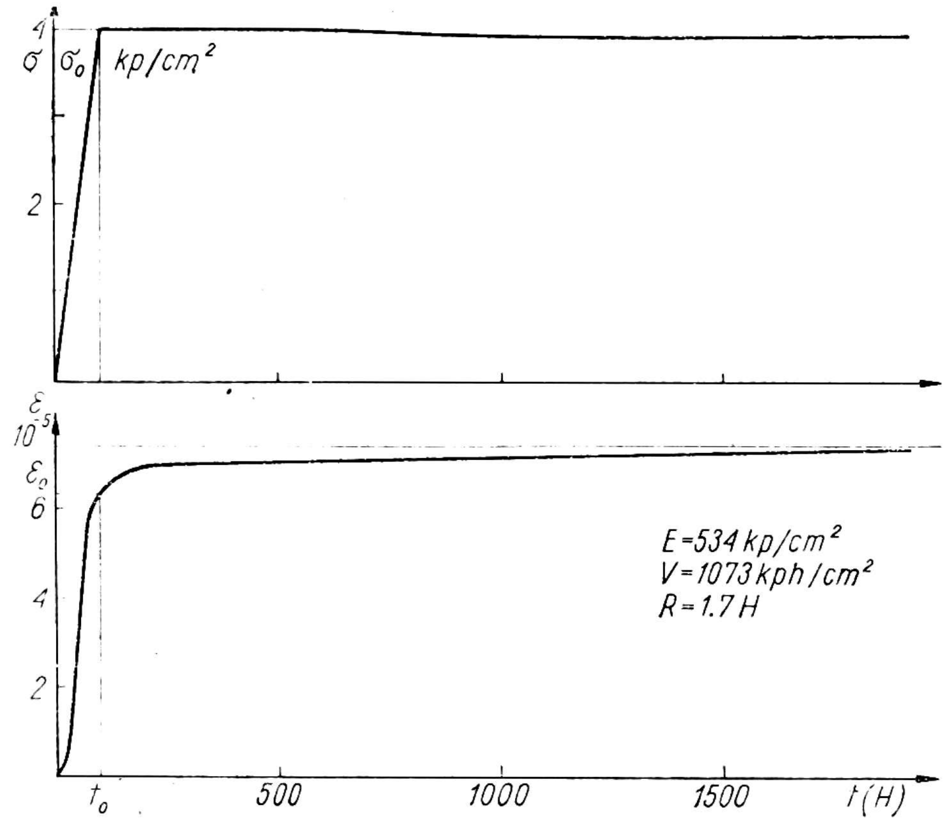

Fig. 9. Obtained creep curve

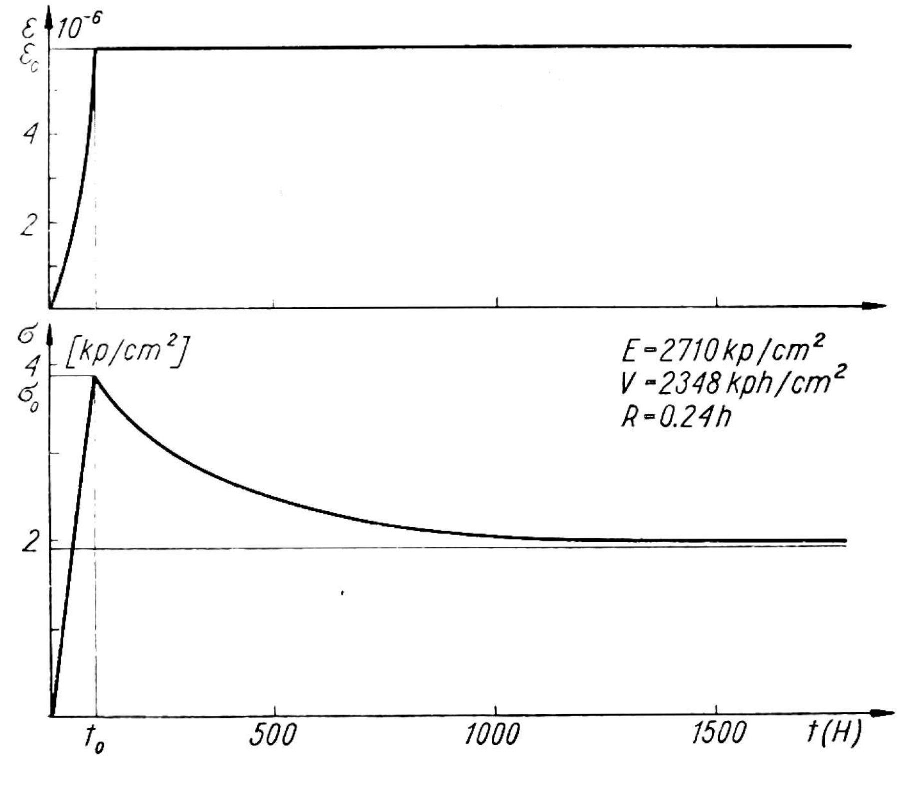

Fig. 10. Obtained relaxation curve

The material constants can be determined either from the creep-test or from the relaxation test.

The experience of further measurements indicates that our measurement method is quite satisfactory.

At the same time it is proved that the assumed constitutive law provides a good approximation to the behaviour of the investigated materials.

Using the above outlined measurement method one can examine several kinds of soil-samples in undisturbed state under different circumstances. With their help one is able to clarify the influence of certain essential factors on the mechanical properties of the soil.

It is worth to extend the rheological test, by introducing multiaxial investigations. A three-axial test seems to be most suitable, in which the test body of cylindrical form (maybe, a pipe) would be loaded on its covering by fluid pressure, while in axial direction by a pressing force.

Measurements on large samples indicate a further possibility for development. They would give mean characteristics with respect to a larger soil-mass, which permit to obtain results, closer to reality. Measurements, carried out on the spot on large samples with due care and caution, have a similar advantage.

J. Huszár

MECHANIKA GLEBY W ROLNICTWIE

Streszczenie

Praca podsumowuje wyniki badań mechanicznych charakterystyk gleb na Wydziale Mechanicznym Uniwersytetu Rolniczego w Gödöllö. Głównym celem prowadzonych prac jest poszukiwanie właściwego modelu zjawisk reologicznych w glebach poddanych działaniu sił. Przyjmuje się liniową zależność między naprężeniem, odkształceniem i ich pochodnymi po czasie. Najpopularniejszym modelem spełniającym powyższe założenia jest model Poyntinga-Thomsona (standardowy). Doświadczalnie bada się stałe reologiczne w jednoosiowym stanie naprężenia realizując w próbce pełzanie i relaksację. Wyniki wskazują, że założone prawo modelowe opisuje zjawiska mechaniczne w badanych materiałach z dobrym przybliżeniem.

Я. Хусар

МЕХАНИКА ПОЧВЫ В СЕЛЬСКОМ ХОЗЯЙСТВЕ

Резюме

В настоящем труде сравниваются результаты механических характеристик почв выполненных в Механическом факультете Сельскохозяйственной академии в Гёдёллё. Основной целью проводимых исследований являются поиски за со-

ответствующей моделью реологических явлений в почвах подвергнутых действию сил. Принимается линейная зависимость между напряжением, деформацией и их производными во времени. Наиболее популярной моделью отвечающей вышеуказанным требованиям является модель Пойнтинга-Томсона (стандартная). Экспериментально определяются реологические константы в одноосевом состоянии напряженности, с учетом ползучести и релаксации в образце. Полученные результаты приводят к заключению, что предположенная модельная закономерность позволяет описывать с хорошим приближением механические явления в исследуемых материалах.