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# THE NEW APPARATUSES FOR MEASUREMENTS OF PHYSICO-MECHANICAL SOIL PROPERTIES

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The study of such physico-mechanical properties of soils as compactness, stickiness, cohesion, internal and external friction, penetrability, unit resistance to cutting and their dynamics will make possible the determination of optimal conditions of mechanical cultivation and application of agricultural treatments having the positive effect on physico-mechanical properties of soils, as well as giving significant information for the designers and constructors of agricultural machines.

That is why a new version of soil adhesiometer nad two prototypes of penetrometers — with hydraulic and manual drive, as well a modified version of triaxial apparatus was designed in the Institute of Agrophysics.

Adhesiometer constructed by Dobrzański, Grochowicz, Orłowski and Walczak [3] is an elestromagnetic apparatus for determination of stickiness of soils, which is a phenomenon of forces occuring between soil and a solid object to which it adheres (e.g. metal, wood, rubber). The significance of stickiness in a soil has been pointed out in a large number of papers dealing with this problem, as well as by constant search for new and more efficient apparatuses for determination of adhesive forces.

The authors propose to calculate the coefficient of stickiness in the following way: on the plane of the soil a disk is placed (metal, wooden etc.) of a known area and it is ballasted by a standard force for a difinite time. After removing the ballast the force needed to break the disk off the soil is calculated. The coefficient of stickiness is obtained by dividing the force of stickiness by the area of the disk. This coefficient depends on: soil property and its moisture content, temperature, the kind of adhering material and the degree of smoothness of its surface, as well as the value and time of initial ballasting.

The force breaking off the disk from the soil in apparatus is supplied by an electromagnet. Here advantage was taken of the dependences of the lifting force of the electromagnet on the intensity of the current carried in its winding and the distance between its core and the ferromagnetic body attracted

$$F = k\frac{I}{d}, \tag{1}$$

where:

F — lifting force of the electromagnet,
I — intensity of the electric current,
d — distance between the electromagnet core and the body attracted,
k — coefficient of proportion.

For a constant distance the lifting force is proportional to the electric current intensity and this value is measured. The value of the breaking off force or coefficient of stickiness is estimated from the dependence nomograph of attraction force on electric current intensity at a given distance. In the apparatus a system of automatic current growth and an automatic circuit breaker (at the moment of breaking off the disk) has been applied. The value of the current is recorded by blocking the ampere meter pointer at the moment of breaking of the disk.

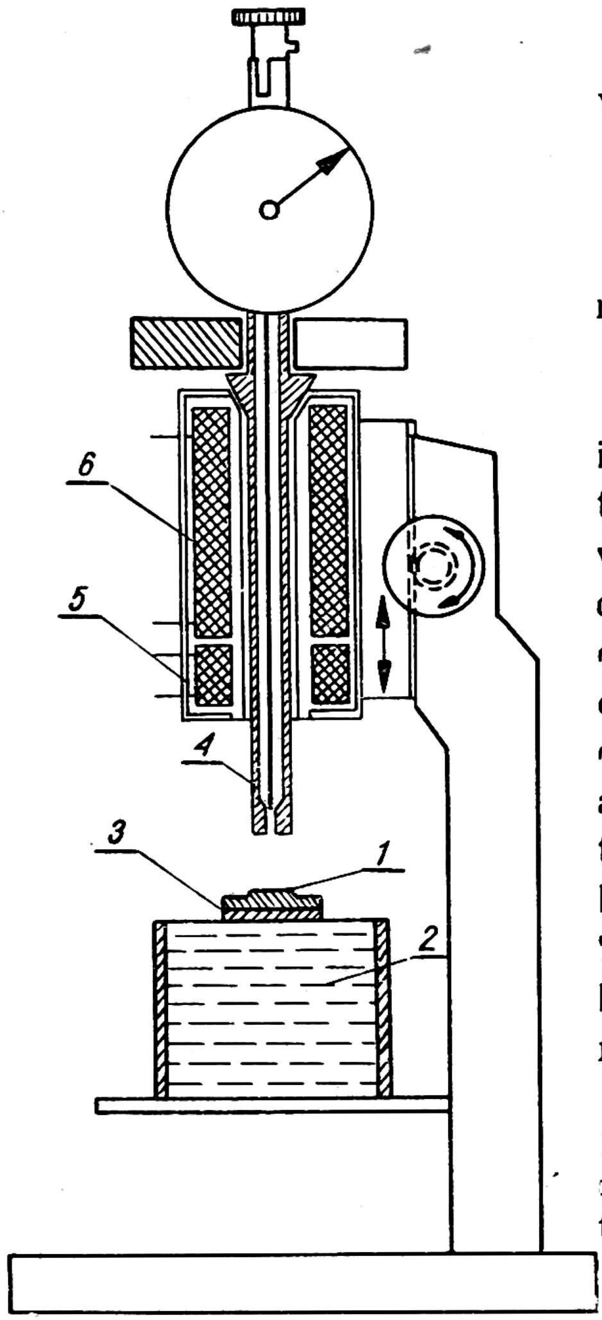


Fig. 1. The measuring part of adhesiometer. *1* — metal disc, *2* — soil sample, *3* — adhered material, *4* — electromagnet-disc distance control, *5* — breaker coil, *6* — electromagnet

The apparatus, in comparison to the existing types, allows to reduce the time of a single measurement and to guarantee a vertical break off. Furthermore, the whole system is not shaken when ballast is taken off.

The next two apparatuses constructed in the Institute of Agrophysics are soil penetrometers. The measure of penetrability is the resistance of the soil to cleavage, expressed as the ratio of the force needed to insert a conic penetrator (at a given vertex angle) into the soil, to the area of its surface. The penetrability of a soil depends on its texture, humidity and many other properties connected with its „structure". As an example of utility of penetrability determinations, Sołtyński [6] presents the results of the American military scientists, who making use of this soil property determined the possibility of vehicle traffic on the soil. The interest taken in this soil property is evidenced by a large number of various penetrometers, also called soundings: hand-soundings, spring soundings (a self-recording sounding of Goriaczkin) lever and pneumatic soundings (pneumatic sounding of Rząsa), falling-weight penetrometers driven into the ground by means of a standard weight falling from a definite height.

In the first version of sound constructed by Dechnik, Grochowicz, Stawiński and Walczak [1] hydraulic transmission of power to the penetrator was utilized, resulted in a relatively simple solution of the problem of recording the soil profile penetrability.

The second prototype made by Gliński, Orłowski, Pukos and Walczak is a spring sound with a hand drive. To obtain precise measurement the

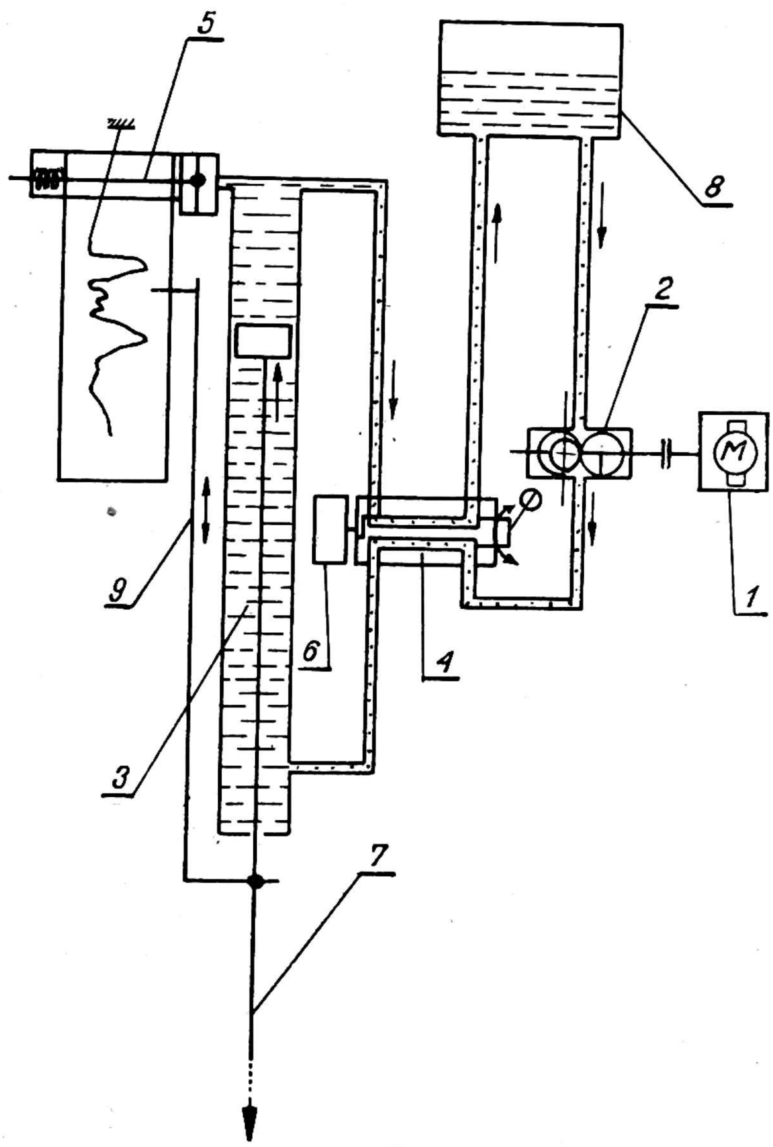


Fig. 2. Schema of the soil penetrometer: 1 — electric motor, 2 — oil gear pomp, 3 — cylinder, 4 — hydraulic change-over switch, 5 — hydraulic indicator, 6 — steering of the hydraulic change-over switch, 7 — penetrator, 8 — expansion tank, 9 — drive of the recorder

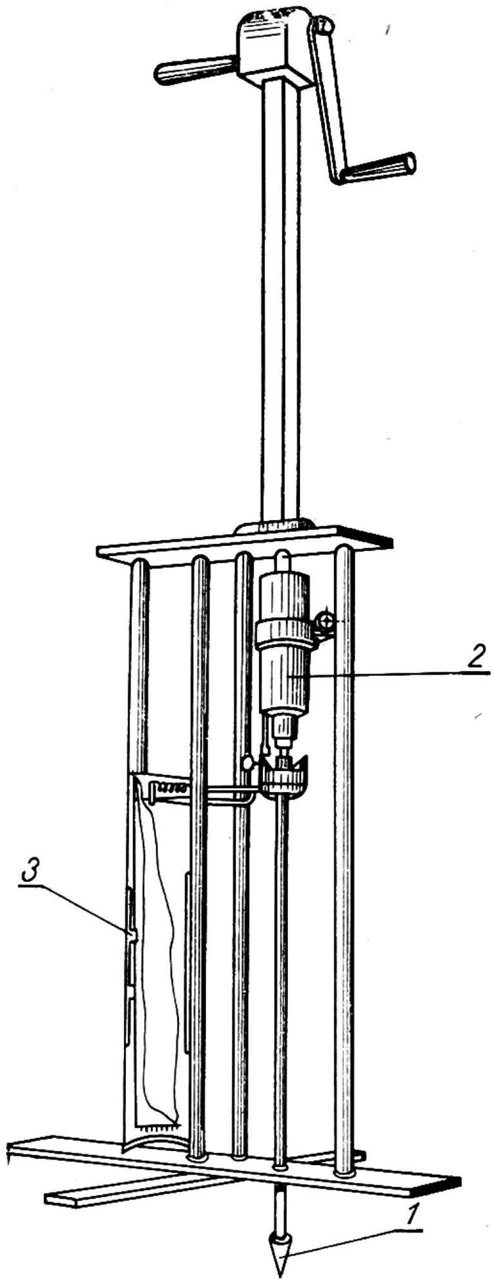


Fig. 3. The manual recording penetrometer: *1* — cone penetrator, *2* — sensor, *3* — recorder

authors [7] used a small compression spring and a sensitive recorder. The advantages of this apparatus are: small weight (120 N), easy operation in the field condition and precise registration of the penetrability changes in the soil profile. The new design of the registrator which permits the exact reproduction of the penetrability changes even for very variable soil profiles, as well as the measuring system of the adhesiometer, have been patented.

The advantages of the penetrometers constructed in the Institute of Agrophysics compared to all existing and known apparatuses the penetrator, the most exact reproduction are: a constant velocity in the movement of of the penetrability changes (application of an incompressible medium transfering the force of drive-penetrator and recorder) easy of operation and economy of the time recquired for carrying out the measurements.

To stress the interest of the explorers taken in the penetrability measurements we should like to perform new results abtained by English scientists Dexter and Tanner [2] from the National Institute of Agricultural Engineering in Bedford. From their studies on spheres penetrating soil it follows that the force of penetration of the spheres depends on the speed of movement, as well as on the sphere radius. Furthermore, a finite force is recquired to push spheres of zero size into soil, because soil particle of finite size still have to be pushed aside.

The theme of studies developed in the Laboratory of Soil Physics of the Institute of Agrophysics is „Theoretical Basis And Experimental Methods of Soil Physics". According to this theme Pukos and Walczak [5] made a review of rheological models from a point of view of their utility to description of mechanical properties of agricultural materials. The authors stressed the fact that the rheological models are not only the ilustration of the system of differential equations reflecting mechanic features of a medium. They give also the possibility of the description of the behaviour of various soils by one model, which means, that common mechanics for various kinds of soils can be used. The model M/V, quite precise for practical purposes can be such a model. If immediate subsidence is slight (compact sand, loam) the sum $G_1+G_2$ is big, it is small for loose sand, peat etc. Similarly viscosity is big for clay and small for sand, taking into consideration the rate of increase of strain. The plasticity limit $\Theta$ determines the moment of the biginning of plastic flow for this kind of model.

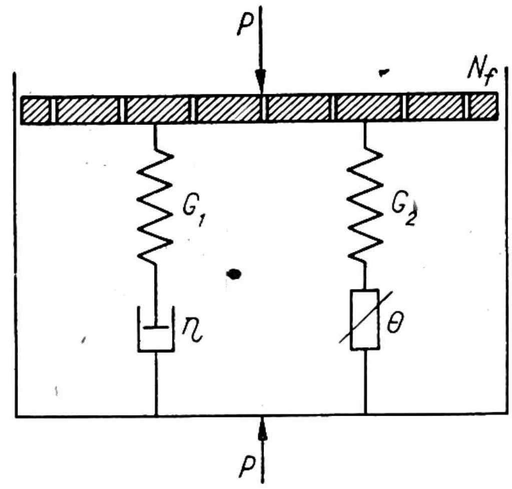

Fig. 4. Kisiel's model M/V

Considering the possibility of experimental verification of the rheological models the authors assume that the rheological equation

$$R(\sigma_{ij}, \dot{\sigma}_{ij}, \varepsilon_{ij}, \dot{\varepsilon}_{ij}) = 0, \tag{2}$$

(where $\sigma_{ij}$, $\varepsilon_{ij}$ are respectively the tensors of the stress and the strain) is true only for infinitelly small volume of considered medium around the point in question. As the experimental measuring of the stress and the strain in infinitesimal sample is impossible, and the measurements inside the samples of finite dimensions are difficult, there is a necessity of assuming homogenity of stresses and deformations in the sample as a whole. The distribution of external loads should also be geometrically similar in the process of deformation, which means the geometrical similarity of sample shape.

It seems that the triaxial apparatus as compared to various kinds plastometers, viscometers, cutting apparatuses etc. enables to achieve the most uniform and controlled condition of stresses and strains. The loading of the sample is achieved either by the pressure pads filled with a liquid or a gas, or by controlled movement of rigid plates contacting the sample. The former design ensures homogenity of stress, the latter ensures the homogenity of strain.

Apart from the homogenity of stress and strain in sample, the triaxial apparatus enables various experimental-courses in the phase spaces of stresses and strains. This is a crucial point, especially when constant isotropic part or constant deviator of stress tensor is used; it allows to separate the experiments concerned with volume changes from those concerned with clear cutting.

At the Institute of Agrophysics pilot studies concerned with constant isotropic stress

$$\sigma_1 + \sigma_2 + \sigma_3 = \text{const.} \tag{3}$$

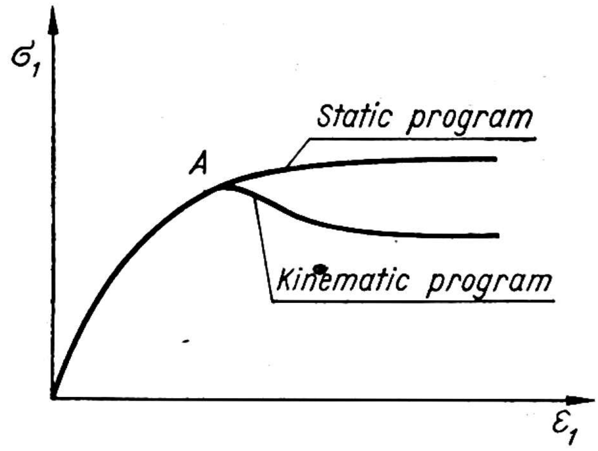


Fig. 5. Programmes of the triaxial test

(where $\sigma_1$, $\sigma_2$, $\sigma_3$ are the normal companents of stress tensor) have been carried out. This condition was achieved through respective diminuation of hydrostatic pressure in the apparatus cell, accompanying the increase of the axial force applied to the sample. It turned out that, as it was supposed, in this kind of experiment there are no volume changes.

Another advantage of this triaxial apparatus is the possibility of realization of two programmes of studies: static (controlled stress in time) and kinematic (controlled strain in time). When classic experiments concerning triaxial compression are performed $\sigma_2 = \sigma_3 =$ const.) with changing stress $\sigma_1$ (the changes being achieved by direct axial loading of the sample by definite force), the function of the axial stress against the axial strain is increasing monotoniously. For the kinematic programme, when a given velocity of shortening the sample is controlled and the stress resulting from this shortening is recorded, this function will be different. However, the kinematic programme supllies us with more complete information concerning the properties of the material as it follows for observation of the experiment, when the range of deformation is relatively great; in the static programme the process of deformation (after the point $A$ has been reached) is characterized by violent destruction and its stopping becomes impossible. Moreover there is the possibility of observation when the derivative of axial deformation $\dot{\varepsilon}$ is constant, which is important when constructing rheologic models with viscosity coefficient, reflecting the mechanical properties of the material as an evident function of time.

Following these considerations the triaxial apparatus of Norwegian type for kinematic programmes of experiments has been modified at the Institute of Agrophysics. This Norwegian apparatus as compared to other kinds known in Poland is very precise and is additionally characterized by the following advantages:

1. It is possible to control the pressure in the pores of soil as well as outflow of the liquid from sample.

2. There is the possibility of obtain various constant rates of axial deformation of the sample (0.3-12 mm per hour).

3. It enables simultaneous consolidation of several samples and succesive loading with a help of the driving system.

4. Making use of hydraulic chamber it is possible to control constant

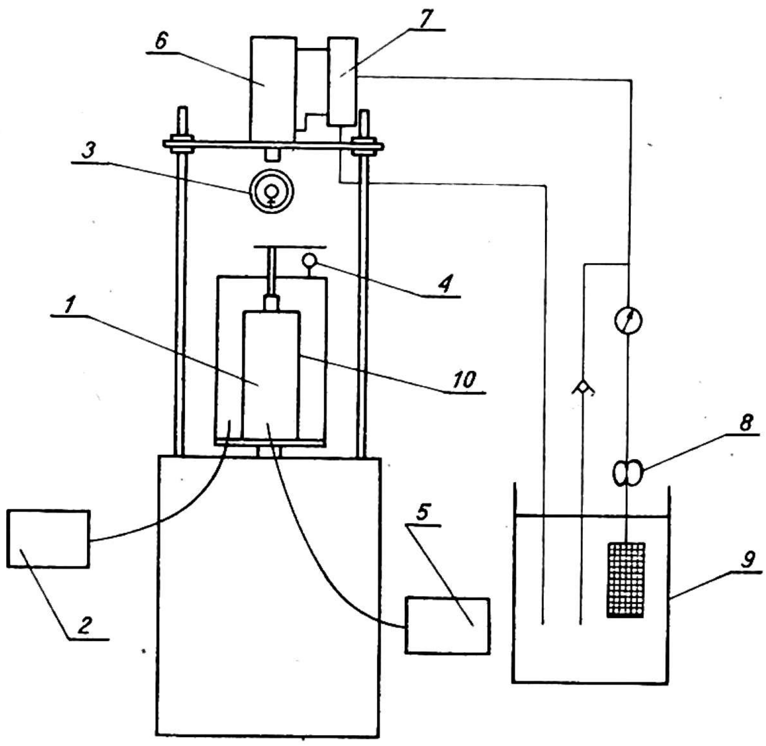


Fig. 6. Modified triaxial apparatus: *1* — soil sample, *2* — system producing and measuring the water pressure in cell, *3* — tensometrical dynamometer, *4* — measurement of the axial deformation of sample, *5* — measurement of the water pressure in sample, *6* — cylinder, *7* — electromagnetic control, *8* — constant-productivity pump, *9* — expansion tank, *10* — thin latex gum

pressure through a long period of time, compensating slight outflows that can occur in this system.

To increase the strain velocity range hydraulic driving system has been designed, composed of a pump (with the constant efficiency and controlled throughout a wide range) and a cylinder electromagnetically controlled, which allows to obtain the velocity of the piston movement up to 3.9 meters per second. To record the stresses and strains tensometric sensors were used, plus an oscillograph with the velocity of the strip movement up 10 m/s. Slow-rate-measurements are carried out with a help of clock-type sensors and a ring dynamometer.

A device forming cylindric samples out of incohesive soil has been constructed, as well as cutting „undisturbed" samples off cohesive soils. An automatic control unit is about to be completed; it will allow to stop or to diminish the load at a given value of strain or stress. This will enable to separate the plastic and elastic properties of soils. Moreover, thus obtained curves of histeresis of the stress-strain plot can be examined statistically. It seems that lacking constitutive equations of granular medium the statistic methods are the only way to avoid the continuous medium mechanics.

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## NOWE APARATY DO POMIARÓW MECHANICZNYCH WŁAŚCIWOŚCI GLEB

### Streszczenie

W pracy przedstawiono trzy aprary skonstruowane w Instytucie Agrofizyki oraz zmodyfikowany aparat trójosiowego ściskania. Autorzy podali opis konstrukcji i danych technicznych elekromagnetycznego przylepnościomierza oraz rejestrujących zwięzłościomierzy. Jeden ze zwięzłościomierzy ma napęd hydrauliczny, a drugi ręczny. Pokazano zalety prototypów w porównaniu z używanymi dotychczas. Zmodyfikowany aparat trójosiowy pozwala uzyskać stałą prędkość deformacji próbki glebowej. Zakres prędkości jest od $2{,}2 \cdot 10^{-7}$ m/s do 3,5 m/s. Opisano też układy sterowania i rejestracji.

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## НОВЫЕ АППАРАТЫ ДЛЯ ИЗМЕРЕНИЙ МЕХАНИЧЕСКИХ СВОЙСТВ ПОЧВЫ

### Резюме

В статье описываются три аппарата построенные в Институте агрофизики ПАН, а также модифицированный аппарат трехосевого сжатия. Авторы описывают конструкцию и приводят технические данные электромагнетического аппарата для измерений прилипаемости и аппаратов определяющих связносты почвы. Один из аппаратов по определению связности почвы имеет гидравлический, а другой — ручной привод. Рассматриваются преимущества прототипов аппаратов в сравнении с используемыми до сих пор. Модифицированный трехосевой аппарат ебеспечивает постоянную скорост деформации почвенного образца. Пределы скорости составляют $2{,}2.10^{-7}$ м/сек — 3,5 м/сек. Описываются также органы управления и регистрации.