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THE APPLICATION OF SOME MEASUREMENT TECHNIQUES TO STUDY DEFORMATIONS IN SOILS

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In recent years a considerable increase in the concern of the mechanics of granular media has been observed. It has appeared, however, that there is still a number of not fully learnt properties of these media to be taken into consideration. One of the basic principles of the behaviour of granular media is compactness varying in the process of deformation.

The knowledge of a soil medium's capacity to change the unit weight is significant in mechanization of agriculture on analysing the work of tillage machines and in the mechanics of the vehicle-land system, on analysing the affect of the driving wheel parts of agricultural tractors on the soil. The knowledge of soil density variations during mechanical cultivations is of great importance, above all from the point of view of agrotechnique.

Variations of soil density are connected with volume variations and their studies are usually carried out in a traxial apparatus. The problem of uniaxial deformations, however, is a very fruitful idealization of a number of engineering problems, and in the case of granular media it is particularly applicable. There are only a few papers dealing with this problem.

In the Institute of Agricultural Mechanization, Academy of Agriculture Lublin studies on acoustic properties of loess subdued to single loading out by using the ultrasonic technique, as well as its unit weight variations in relation to the layer thickness — during and after loading.

The solution of the problems of mechanics of soil media, however, requires complex studies. Therefore attempts to apply photoelasticity to studies of stresses and deformations in soil are made in the Institute. The problem of model studies by photoelastic method of deformations in soil has not been fully solved. The basic difficulty is modelling of physico-mechanical properties of soil.

ULTRASONIC METHOD

A number of theoretical and experimental papers on the application of ultrasonic waves to studies of soil appeared in recent years. They confirm the usefulness of this method in studies of such soil properties as:

— granulation,
— moisture,
— compactness,
— stress distribution,
— kinetics of structure formation,
— freezing rate,
— tixotropy.

The above mentioned papers analyse the influence of physico-mechanical properties of the soil on propagation of waves and they shown the posibility of practical use of these relations in variaus branches of technique (mining, geotechnique, building, road engineering). A concidence of the results of theoretical and experimetal papers can be observed.

The carried studies are only the first attempts to apply the ultrasonic technique to examination of soil and their authors do not generally give any conclusions. It is also difficult to compare the obtained results, becuse the studies were carried out in various kinds soil and utrasonic heads of a different wave range were used.

The influence of pressure on the velocity of wave propagation in the soil was studies using very high unitary stresses (e.g. Cariewa's — up to 65 kG/cm^2, Machowski's — up to 110 kG/cm^2). More extensive papers are those of Cariewa and Pałka; the former concerns the studies of sand and the latter — compact soils, heavy and sandy loams, clams, clays and silts. The results obtained by these authors, however, cannot be utilized in agriculture.

Despite the different purpose of studies and apparatuses and methods used, it was shown in the present studies that the velocity of wave propagation in the soil depends on: mechanical composition of the soil, compactness, elastic properties of the skeleton, porosity, moisture, structure and external pressure.

In our Institute, staudies on the possibility of the use of the impulse ultrasonic method in studies of soil density in individual layers were carried aut on an universal strenght machine specially equipped. Ultrasonic flow detector made in Poland was used in the studies, which was supplied with a set of ultrasonic heads.

The subject of the studies was loess as a soil:

a) being of great practical importance for agriculture,
b) characterized by small-granular structure,
c) sufficiently homogeneous.

The studies were carried out on samples of disturbed adn undisturbed structure. Samples of natural structure were taken in steel cylinders of 250 and 500 cm³. The samples of disturbed structure (of various shape, density and moisture) were prepared from natural samples by crumbling and sifting.

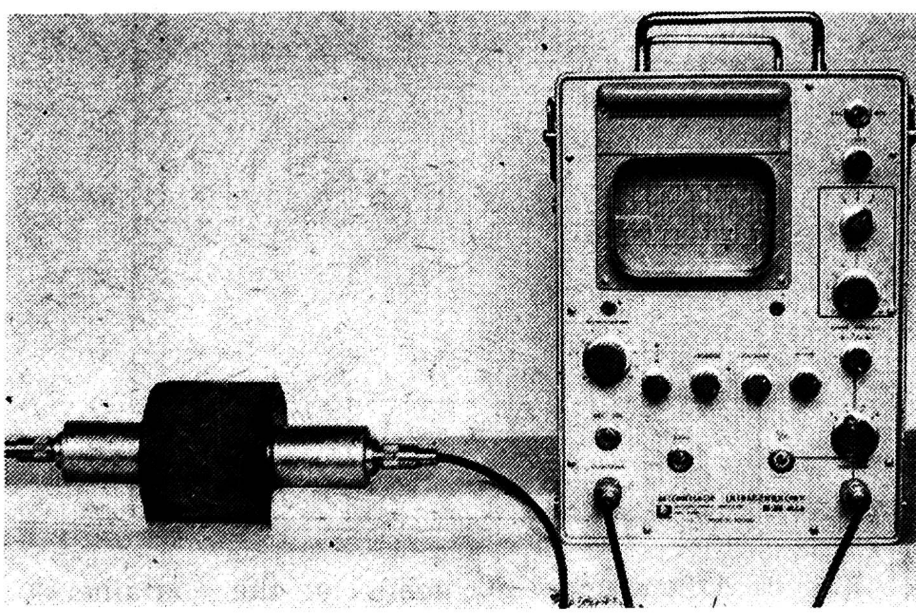


Fig. 1. Utrasonic flow detector method of soil studies

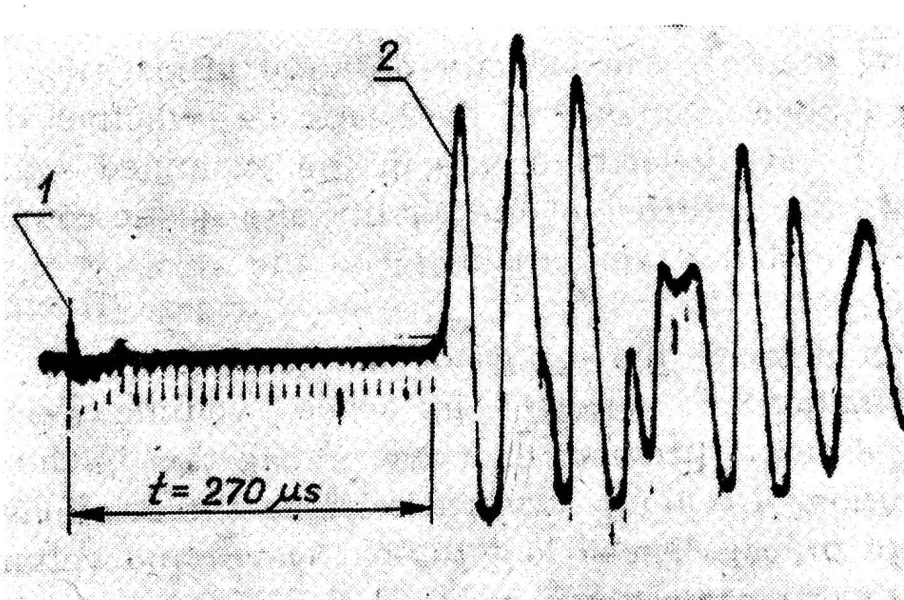


Fig. 2. Oscillograph record of a investigated soil sample: *1* — impulse start, *2* — output impulse from the sample

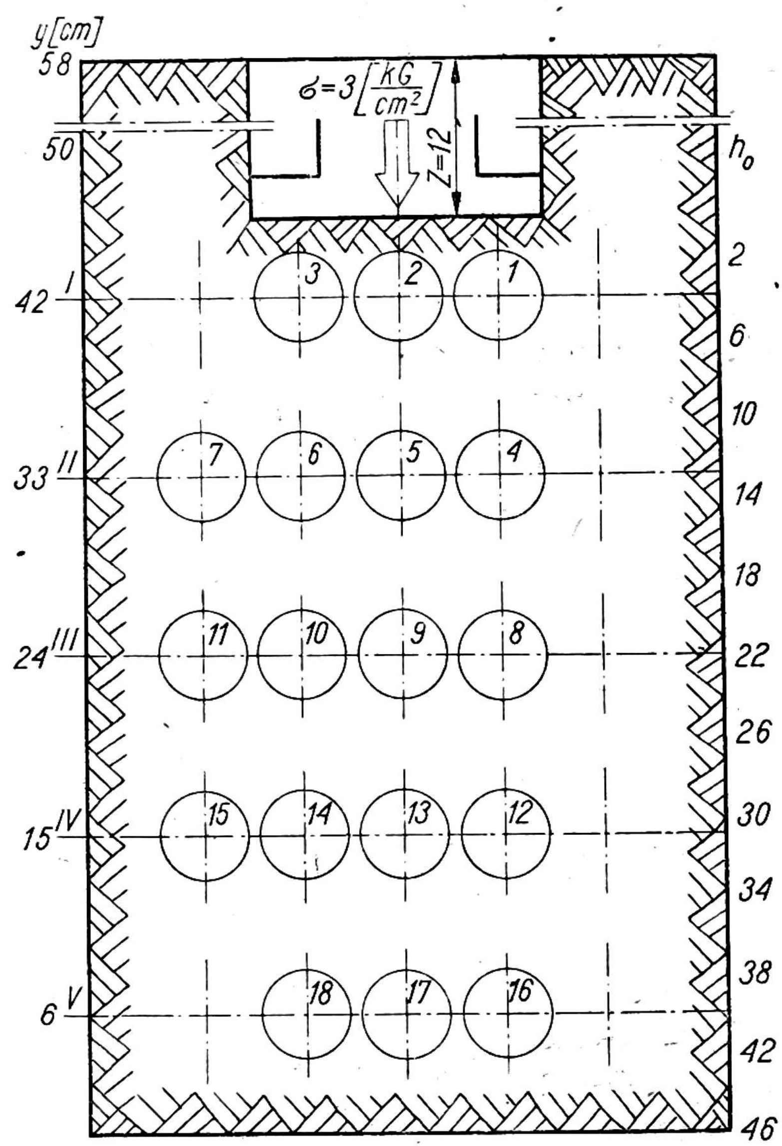


Fig. 3. Arrangement of heads on the container

The study plan composed:

a) checking whether the velocity of wave propagation in loess depends on the applied frequency of the heads, i.e., whether the dispersion phenomenon of wave velocity occurs in the examined soil;

b) checking the influence of the quality of acoustic coupling between ultrasonic head and the sample studied on the velocity of wave propagation;

c) selection of proper dimensions of samples;

d) determination of moisture influence, volume weight and soil structure and external pressure on wave propagation in the soil;

e) preparation of scaling curves describing the relationship between the velocity of propagation of longitudinal waves and volume weight of the soil for its various moisture;

f) determination — for loaded and unloeded soil — of density distribution in the particular layers (with the use of scaling curves);

g) examination of the effect of loess moisture on the rate of its density in the particular layers;

h) examination of the effect of individual pressure on soil compactness of various moisture;

i) examination of changes of acoustic properties in the particular layers — after unloading the soil;

j) examination of the possibility of the application of ultrasounds to determine constant elasticity of the soil.

The results of the studies showed that with the ultrasonic method density distribution of the soil can be examined when loaded and after unloading it, previously accomplishing scaling curves. The ultrasonic heads G-70 specially made for the studies carried out (producing transverse and longitudinal waves in the soil), make the determination of constant elasticity for dry and compact soil possible.

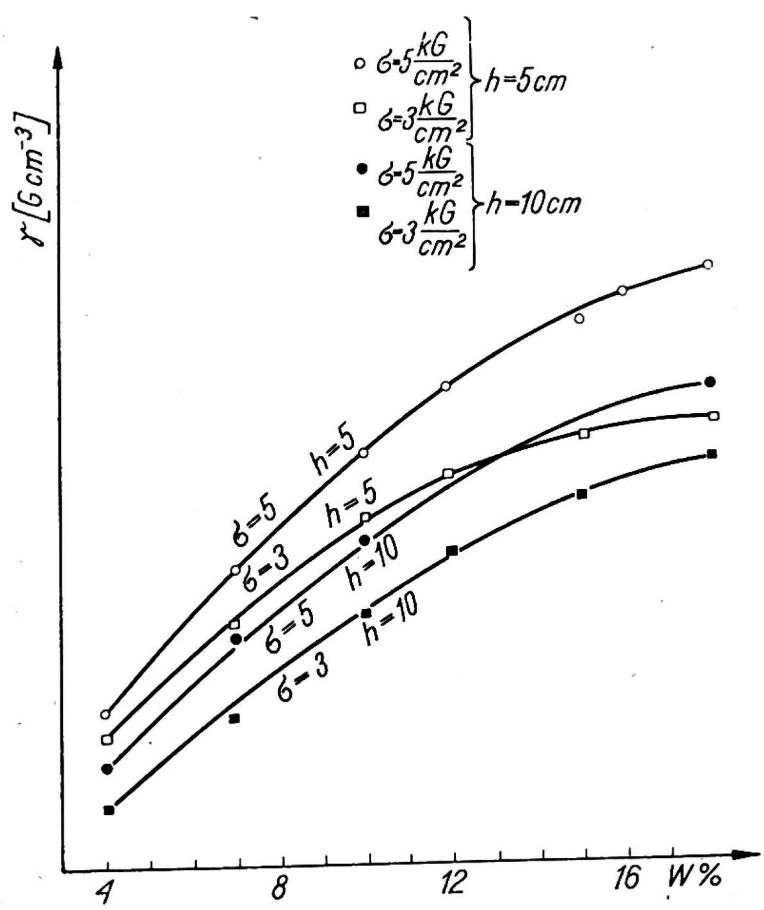


Fig. 4. Unit weight changes (γ), humidity (w) relationship for two different stresses: h — distance from loading level

It was found that in the frequency range 20-500 kHz the dispersion phenomenon of wave velocity does not occur in loess soil. This makes the comparison of the results of studies obtained by various authors possible, which were carried out at different frequencies.

The ultrasonic method can be used for evaluation of homogenity of a group of soil samples of undisturbed and disturbed structure. This method allows to find by comparison whether structural bindings have not been disturbed and in case of their being destroyed — it make the determination of the time needed to obtain the required structure possible.

The studies showed that restraining properties of the soil change in a very wide interval. A detailed study of this phenomenon would render new possibilities of utilizing the ultrasonic technique in studying physico-mechanical properties of soil.

It was found that relaxation of soil after being unloaded is observed only in the top layers. This phenomenon should be particularly studied. At constant moisture of the soil, with the increase of its volume weight the velocity of wave propagation increases. This relationship is very distinct and makes the application of ultrasonic technique to studies of soil density possible.

PHOTOELASTIC METHOD

Photoelastic methods used in studies on distribution of stresses in constructions elements have not been widely used in mechanics of soil. They are used to a small degree in studies connect with civil engineering. In this case photoelasticity serves above all to check experimentally the same theoretical problems connected with foundation settlement. These are qualitative studies.

The possibility to apply photoelasticity to studies on mechanics of the machine-soil system and the resulting advantages as well as the results of initial studies conducted in our Institute are presented in the references. Studies of this kind have been so far undertaken, according to the available information, only in Canada by Kim and Staley. Using the photoelastic method, they obtained a stress distribution which appear round the grousers. Gelatin-glycerine gel was used as model material finding it useful for imitating loamy soils on the basic of rheological considerations.

Attempts were also undertaken to model granular media by means of aptically active materials. The precursors of this method were Dantu (France) and Wakabayashi (Japan). As model material were used:

a) a collection of glass rolls, discs or beads,

b) broken glass (glass sand).

Continuing the above mentioned studies De Josselin de Jong used resin CR-39. All the methods used for modelling a soil medium were limited to studying that medium on loading it with a rigid stamp. Stress trajectories were obtained, whereas the stress values themselves were unknown.

In the case of photoelastic studies the main difficulty is constituted by the selection of an aptically active soil medium suitable for modelling. The most simple and cheapest photoelastic material seems to be gelatin--glycerine gel. Its properties were discussed in details by Milbauer and Perla and Osokina. On the basis of the studies on optically active materials of a small Young module, to which the above mentioned gel belongs, Osokina found that elastic deformation of these materials consists of instant deformation (ε_0) and the so-called high-elastic one (ε_1), and the modulus of elasticity is expressed by the formula

$$\frac{1}{E} = \frac{\varepsilon}{\sigma} = \frac{\varepsilon_0 + \varepsilon_1}{\sigma}\frac{1}{E_0} + \frac{1}{E_1},$$

where

E_0 — modulus of elasticity for $t = 0$,

E_1 — modulus of elasticity for $r = t_1$.

Osokina thinks that if the mechanical properties of this material are accurately determined, it can be used for photoelastic analysis of stress connected with soil mechanics.

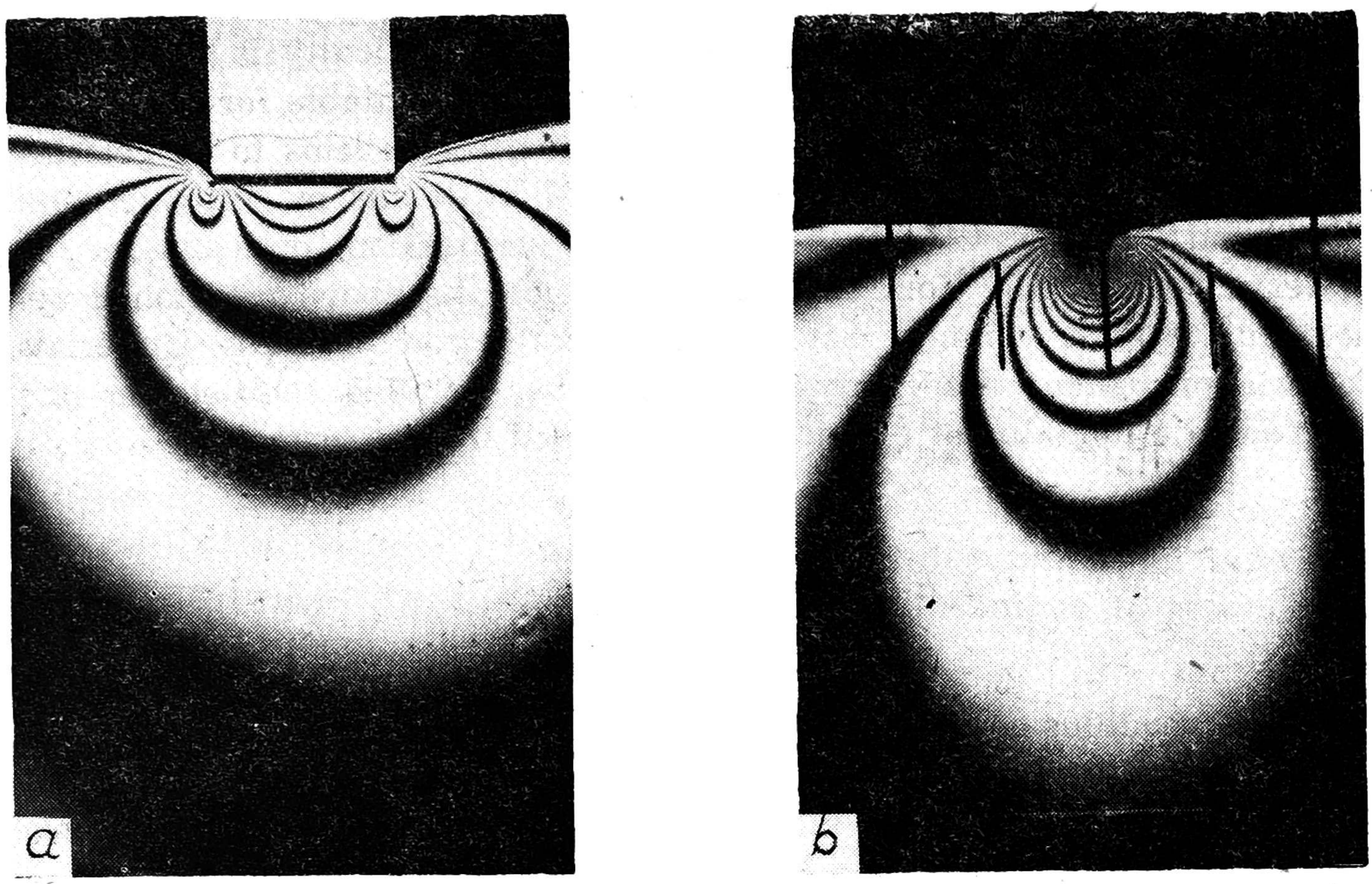
Because of fast aging of the gelatin-glycerine gel resulting in change of its mechanical and optical properties, new model materials are searched for. The required features are found, e.g., in polyurethane materials called "urethane rubber" by Durelli, or soft epoxy materials.

In our initial studies carried out the model material of a soil medium was gelatin-glycerine gel. The range of the loads was chosen in this way, so as the model studies possessed features of linear elasticity. Modelling of the soil medium was based on assumption of the elasticity theory. The results obtained were compared with those obtained from Boussinesq formulae for a plane state of stress. A general method for photoelastic was given by Frocht and Pindera; however, the method for determining stresses and deformations in soil has not been worked out yet.

The assumed principles of linear elasticity may appear not quite valid because of rheological properties of soils. They were adapted correct interpretation of the obtained results of studies and to check the validity of the application of photoelasticity to studies of soil mechanics.

Three types of loading were used in the studies: concentrated strenght, a rigid stamp and a rigid wheel. The isochromatic and isoclinie distribution was examined. The obtained photoelastical pictures for the particular kinds of loading show differences; however, a similarity can be observed on loading the model with concentrated strenght and the rigid wheel.

The next stage of the studies consisted in drawing the stress trajec-



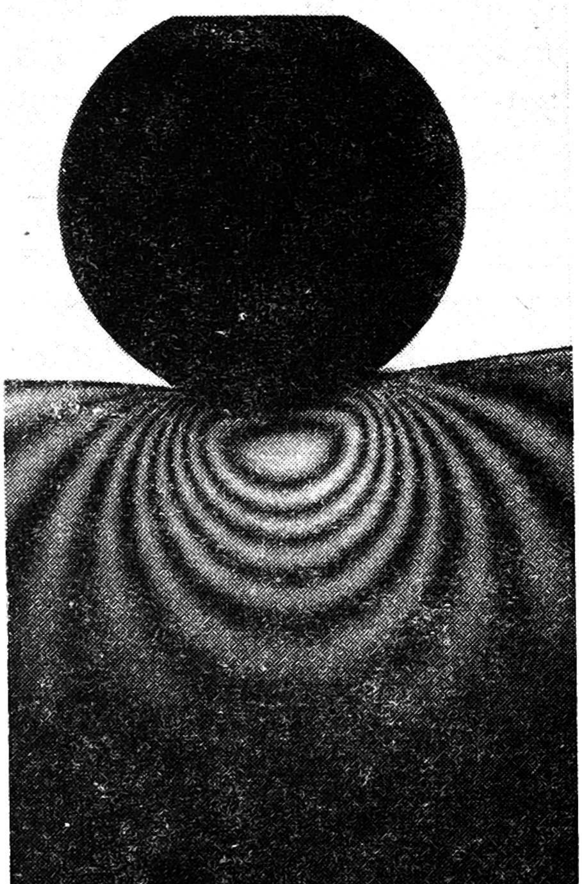


Fig. 5. Isochromatic distribution: *a* — under the rigid stamp, *b* — under the concentrated strength, *c* — under the rigid wheel

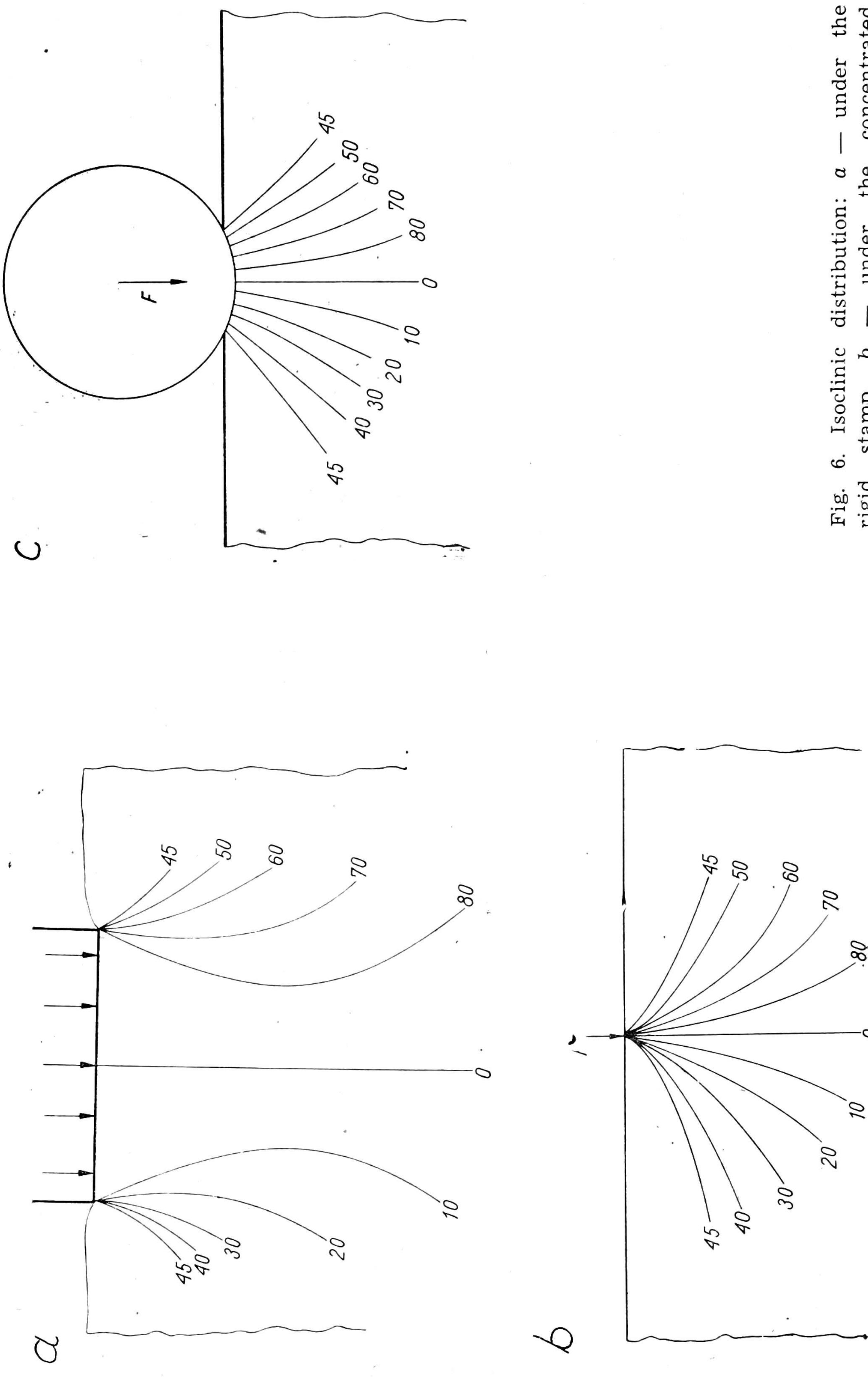


Fig. 6. Isoclinic distribution: *a* — under the rigid stamp, *b* — under the concentrated strength, *c* — under the rigid wheel

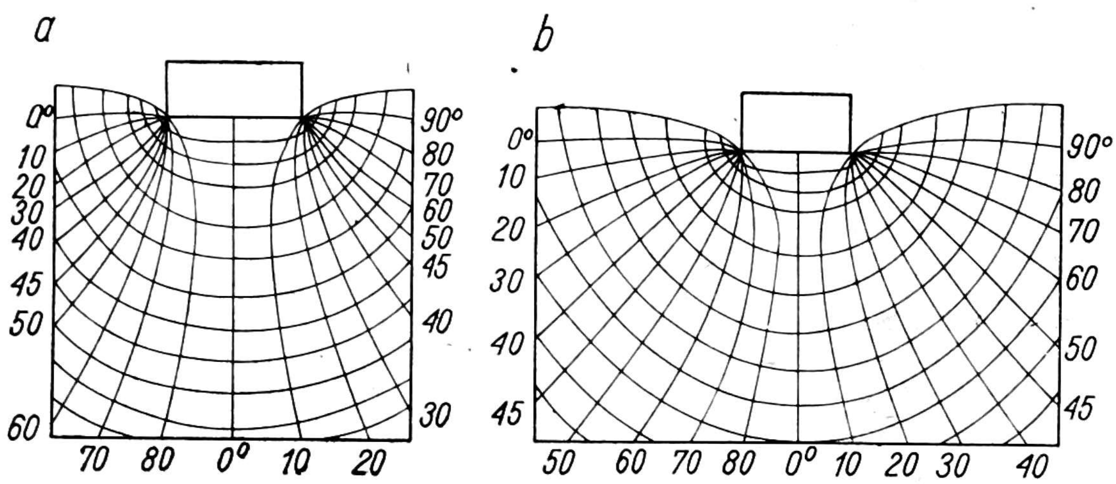


Fig. 7. Stress trajectories distribution: *a* — under the wide stamp, *b* — under the narrow stamp

tories on loading the model with two stamps of different width, and they confirmed the validity of the assumption as regards the usefulness of the photoelastic method for studying the mechanics of the machine--soil system.

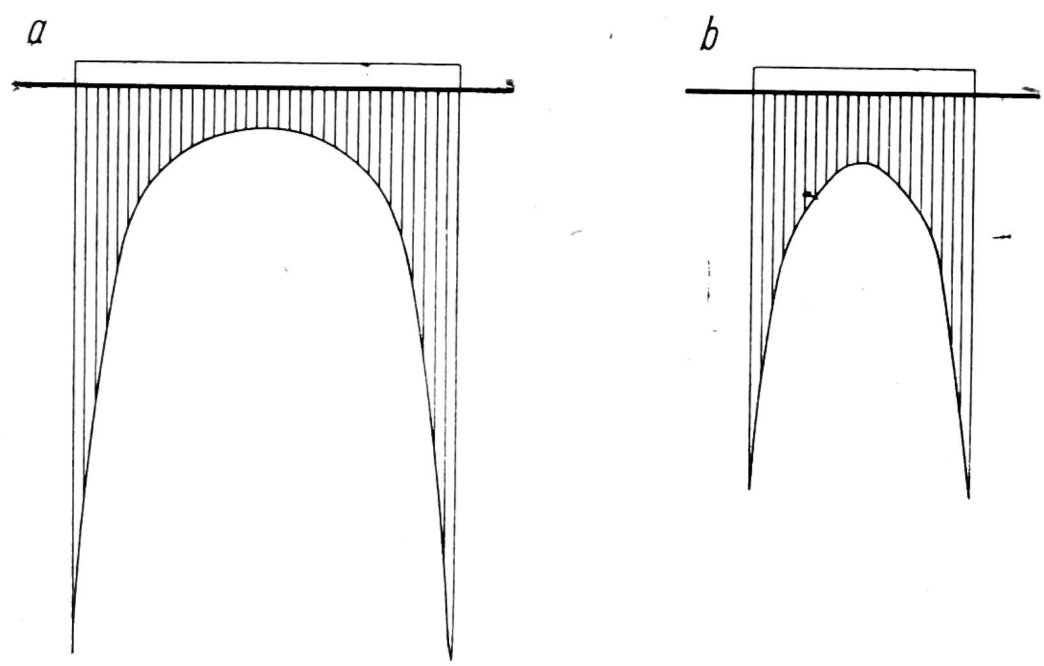


Fig. 8. Contact pressure distribution: *a* — under the wide stamp, *b* — under the narrow stamp

The studies were carried out in a polariscope with the vision field of 100 mm in diameter. To satisfy the assumption of an infinite semiplane, the dimensions of the soil model were 90×12×180 cm. It was between two plates of organic glass (plexi) to maintain a plane state of stress. The friction between them and the model was eliminated by proper greasing with silicon oil. For registration of fringe pattern monochromatic sodium light was used whose wave length λ was 0.5889 μm. The isoclines were recorded in white light obtained from wolfram lamps.

Because of high stress-optical coefficient of the gelatin-glycerine gel the forces applied were below 1 kG.

In further studies rheological features of the model material and soil medium will be taken into consideration and a polariscope with the vision field of 300 mm in diameter will be used. Studies on stresses and deformations are planned to be carried out in soils in a double aspect:

a) mechanics of the machine-soil system,

b) mechanics of the vehicle-land system.

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ZASTOSOWANIE NIEKTÓRYCH TECHNIK POMIAROWYCH DO BADANIA DEFORMACJI GLEB

Streszczenie

Autorzy przedyskutowali możliwości zastosowania metody ultradźwiękowej i elastooptycznej do opisu deformacji gruntu. Na podstawie badań własnych i danych literaturowych autorzy wnioskują, że metoda ultradźwiękowa może służyć przy badaniu następujących właściwości gleb: granulacji, wilgotności, zwięzłości (compactness) rozkładu naprężeń, szybkości zamarzania i tiksotropii.

Druga zaproponowana metoda badań gruntów polegała na zastosowaniu materiałów optycznie czułych. Uzyskano rozkłady izochrom, izoklin, naprężeń kontaktowych i trajektorii naprężeń głównych dla elementów obciążających w kształcie koła, oraz wąskiego i szerokiego stempla.

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ПРИМЕНЕНИЕ НЕКОТОРЫХ ИЗМЕРИТЕЛЬНЫХ ТЕХНИК В ИССЛЕДОВАНИИ ДЕФОРМАЦИИ ПОЧВ

Резюме

Авторы обсуждают возможности применения ультразвукового и поляризационно оптического метода для описания деформации почвогрунта. На основании собственных исследований и данных литературы авторы приходят к заключению, что ультразвуковой метод может использовываться при исследовании следующих свойств почвы: грануляции, увлажнения, связности, распределения напряжений, скорости замерзания и тиксотропии.

Второй предложенный метод исследования почвогрунтов заключается в применении оптически чувствительных материалов. Получены распределения изохром, изоклин, контактных напряжени и траектории основных напряжений для элементов нагрузки круглой формы, а также узкого и широкого штампа.