ZESZYTY PROBLEMOWE POSTĘPÓW NAUK ROLNICZYCH 1976, z. 168

THE INFLUENCE OF DEFORMATION ON PORE SIZE DISTRIBUTION IN THE SOIL OF VARIOUS MOISTURE

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The use of heavy tractors in agriculture always raises among farmers the question if and in what conditions such big loads can cause a harmful compaction of soil. Under the term "harmful compaction" above all a high decrease in pore volume is understood, both in the arable layer and subsoil, which is of great importance for proper plant growth. This problem is particularly important in the area of a track left by a tractor. The influence of a heavy load can be observed at the whole depth of the soil profile by the number decrease of large pores of 30×10^{-6} m diameter. This was shown among others by the papers [3, 5]. In recent years, studies on the relationship between the use of heavy tractors and soil structure and crop yield were carried out [2, 11]. Field studies were conducted simultaneously with a number of measurements made in laboratory. Söhne showed in his papers [6, 7, 8] what important and useful conclusions for the farmer can be obtained from simple experiments on soil compaction. Altemüller [1] studied the distribution of granules and aggregates in deformed soils by using microscopic methods. Sommer dealt in his papers [9, 10] with the problem of the behaviour of models of various soils using the edometer. Among all physico-mechanical factors, which influence the properties of deformed soils, water content plays the decisive role.

The objective of this paper is the problem how soil with various moisture content behaves under the influence of loading with a particular consideration of changes in the distribution of pores.

The measurements were carried out for soil formed from loess taken at the depth 0—0.02 m with 2.15% of humus content and of the granulometric composition given in Table 1.

Air-dry soil was sifted and aggregates < 0.001 m were taken for

Table 1

Granulometric composition of the investigated soil

Grain size $x10^{-3}m$	1-0.1	0.1-0.05	0.05—0.02	0.02—0.005	0.005—0.002	<0.002
Fraction %	6.3	11.5	43.7	25	5.7	7.5

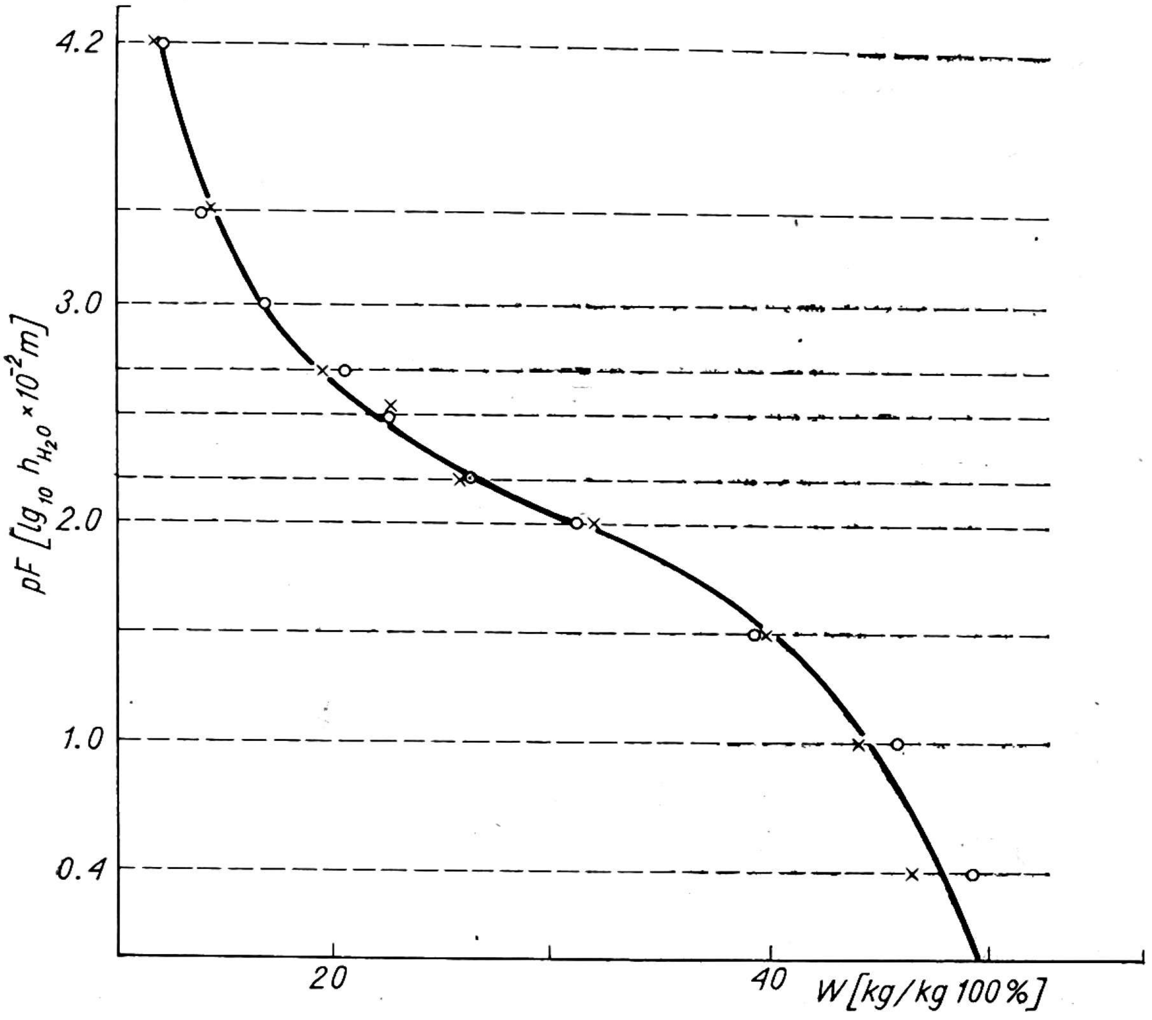

Fig. 1. Water characteristics of the soil studied

studies. The samples were loosely deposited in cylinders, and water characteristics were determined, i.e. the relationship between moisture and soil water potential (*W*, pF) pF — lg_{10} of the level of free water balancing the force of water retention in soil). To maintain the relationship at lower pF values gypsum blocks made in the Institute of Agrophysics, Polish Academy of Sciences, were used. A sample soaked with water was placed on a gypsum plate which provided a capillary contact of soil water with free water which was at the given level. As soon as a balance between soil and free water was reached suction was increased and thus the next point of characteristic was obtained. By means of the above mentioned gypsum blocks measurements were performed for pF

Table 2

F and moisture values

pF	10^{-2}m (H_2O)	10^4N/m^2	Moisture kg/kg · 100%
0.0	—	—	49.1
0.4	2.5	0.02	47.5
1.0	10	0.1	44.8
1.5	31.6	0.3	39.2
2.0	100	1.0	31.2
2.2	160	1.6	26.7
2.5	345	3.45	22.3
2.7	500	5.0	19.9
3.0	1000	10.0	16.3
3.4	2500	25.0	14.1
4.2	15000	150.0	12.0

values from 1.0 to 2.5. Other points of the diagram were obtained from measurements carried out in high-pressure chambers which were described by Richards [4]. To obtain a complete water characteristics of the soil studied the pF values and their corresponding moisture values were used.

After reaching the balance at the given pF value, the soil sample was subdued to deformation in the edometer with a water outlet of a diameter ratio to the high of the cylinder: 64.8 : 20 (m/m). For each of five different moisture levels (pF: 1.0; 1.5; 2.0; 2.2; 2.5) three loads (1, 2, 3×10^5 N/m^2) were used. At each loading soil settling in time up to $t = 6 \times 10^3$ s was examined. It appears from the results obtained for all possible combinations of different moisture content and loading values that in the semi-logarythm scale the relation (settling, time) is linear (Figure 2). In each diagram of the presented set the parameters are the pressures used 1, 2, and 3 respectively. For all moisture values a decrease of the inclination angle of the lines with pressure increase from 1 to 3 at the same pF value can be observed.

In Fig. 3 consolidation curves for maximal loading at different moisture values are summarized. From the presented relation follows that at higher pF values, i.e., at lower moisture levels the lines comprise a higher range of settling. Consolidation curves at all loads for the lowest and highest moisture level (pF 1.0 and 2.5) were also compared (Fig. 4). Significant differences in parameters of the presented lines occur at the highest load, both for a low and high moisture level. For loads 2 and 1 the differences are small, and the lines are almost identical. Soil samples, after being deformed in the edometer, were dried at 378°K and subdued to porosymetric analysis. For this purpose a mercury porosymeter "Carlo Erba" make s. 1500 was used.

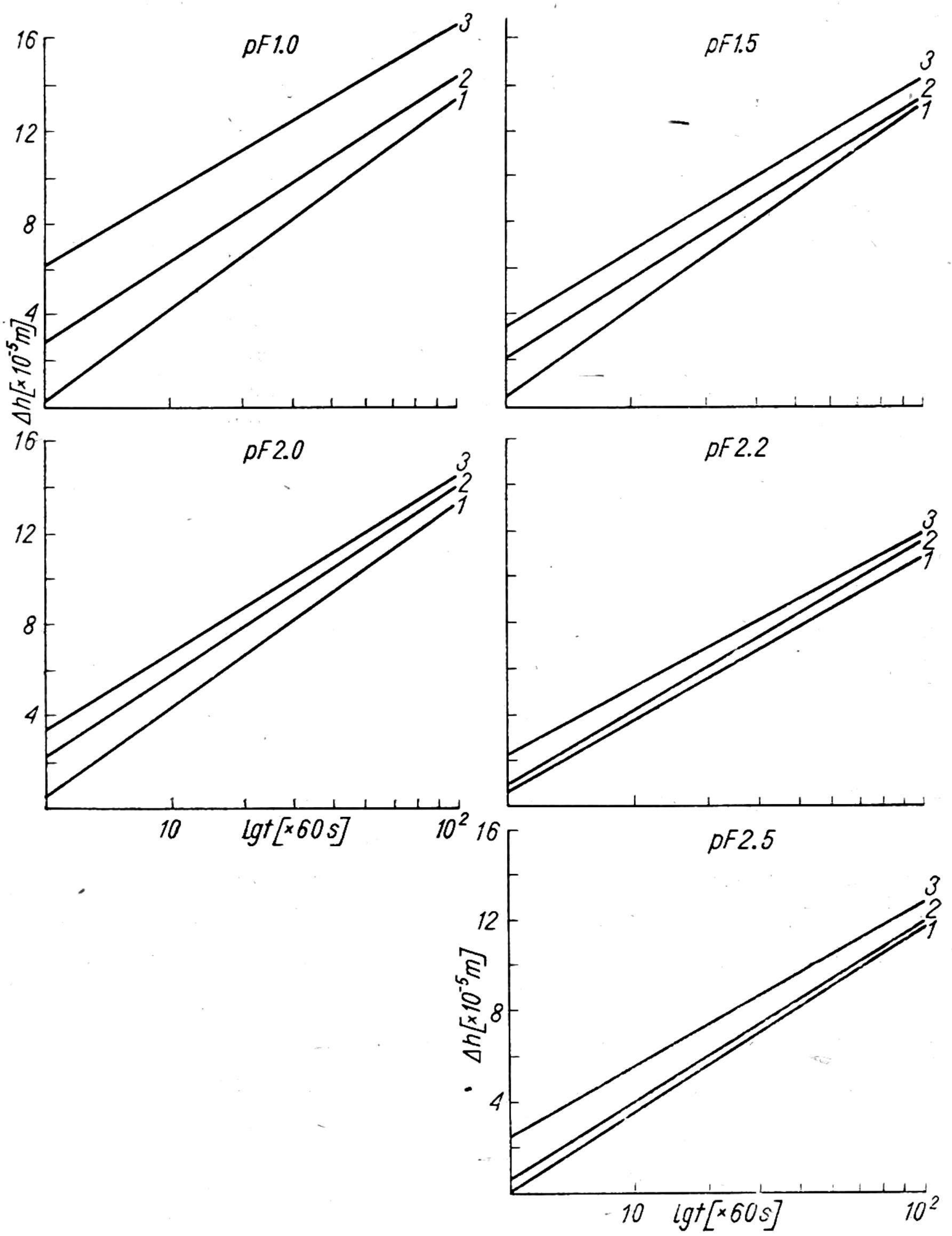

Fig. 2. Consolidation lines 3, 2, 1 — Parameters, pressure aplied in the edometer, (3, 2, 1 × 10^5 N/m^2 respectively)

The soil in the form of an aggregate of the weight about 2×10^{-3} kg was placed in a dilatometer, deaerated and than filled with mercury and increasing pressure was applied. In this way, in the self-recorded diagram the relationship between the volume of pores filled with mercury and the applied pressure was obtained, which, on taking into consideration a simple relation between the radius of the filled-up pores and the applied pressure, gives a direct relationship between the volume and radius.

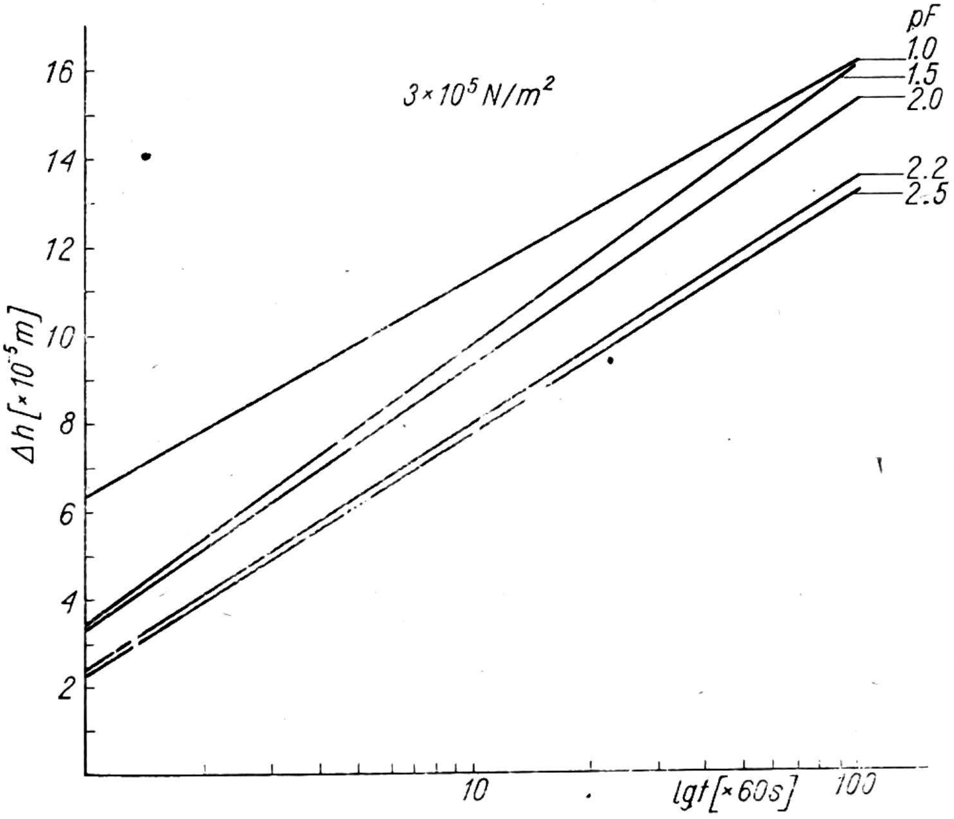

Fig. 3. Consolidation lines for all moisture level with pressure 3 ×10^5 N/m^2

Table 3

The tangent values of the inclination angle for different loads and moisture values

Moisture kg/kg · 100%	Load x 10^{5}N/m^2	tgα
44.8	1	0.7536
	2	0.7002
	3	0.5774
39.2	1	0.8391
	2	0.7813
	3	0.7536
31.2	1	0.7813
	2	0.7265
	3	0.7002
26.7	1	0.7265
	2	0.7002
	3	0.6249
22.3	1	0.7536
	2	0.7265
	3	0.6745

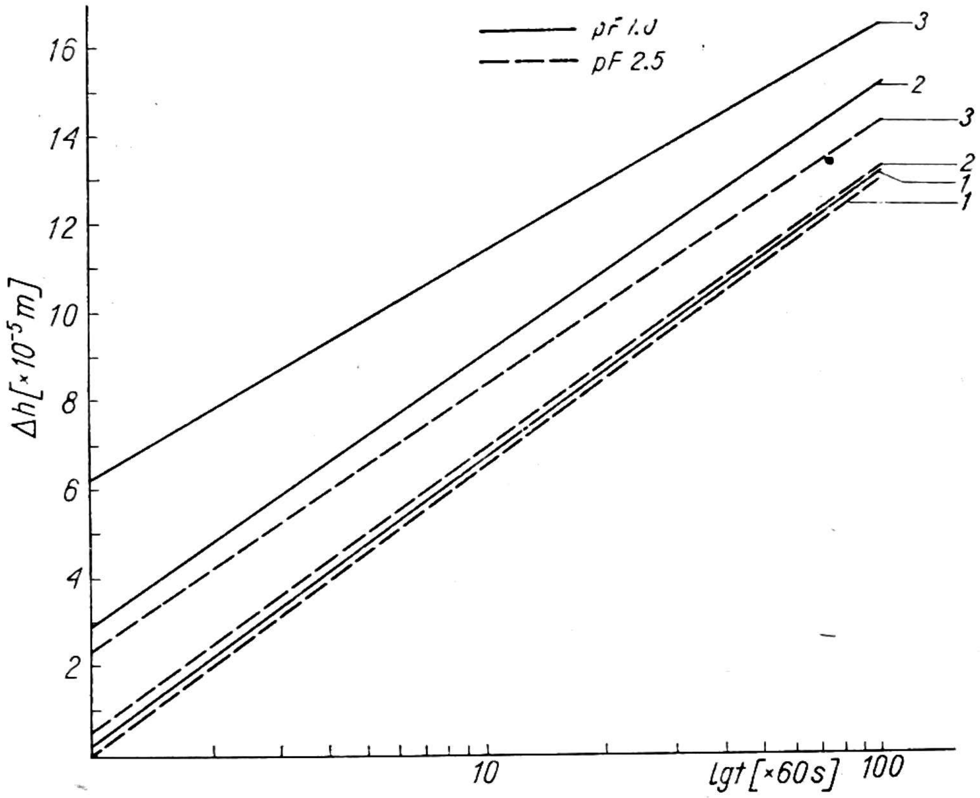

Fig. 4. Consolidation lines with different loads for moisture corresponding to pF 1.0 and pF 2.5

It follows from the results obtained that with pressure increase at each of the five moisture levels the total pore volume decreased. This was most conspicuous on comparing the loads 1 and 2 × 10^5 N/m^2, whereas for the loads 2 and 3 × 10^5 N/m^2, the differences in the change of total volume were slight. In Fig. 5 and 6 integral curves of pore distribution for all moisture levels with loading 1 (Fig. 5) and with loading 3 (Fig. 6)

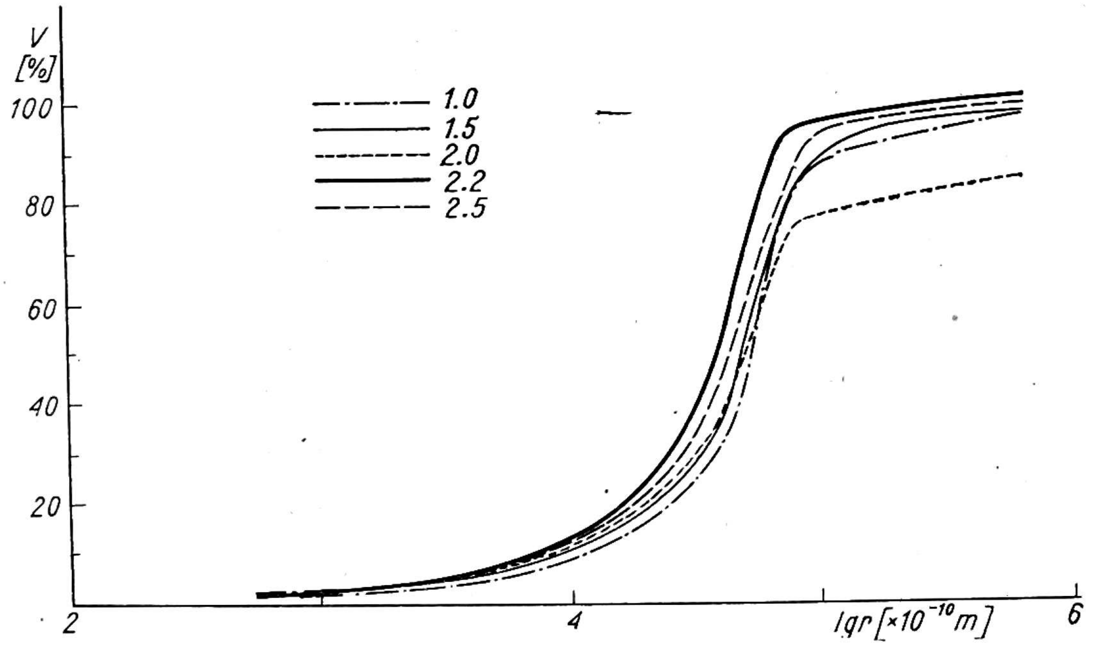

Fig. 5. Integral curves of pore distribution with load 1, for all moisture levels

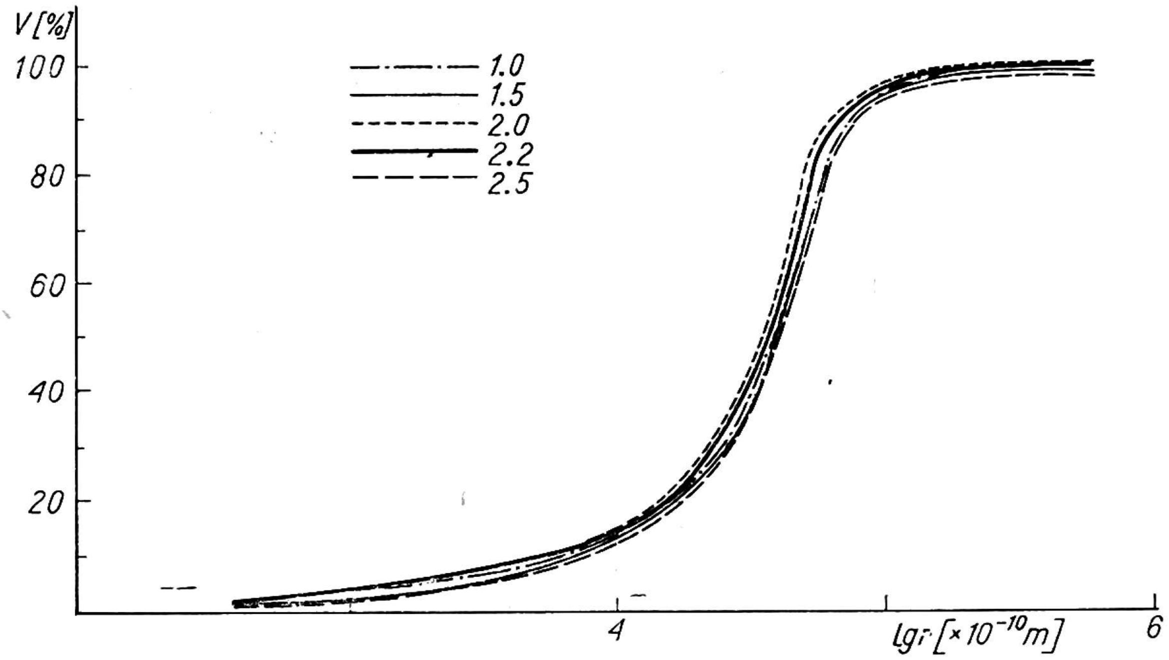

Fig. 6. Integral curves of pore distribution with load 3, for all moisture levels

are presented. The course of curves does not practically change with a higher pressure (it is similarly for pressure 2×10^5 N/m^2) whereas with a lower pressure significant changes occur. A distinctly different course has the curve concerning moisture at pF 2.0 (upper limit of water available for plants).

For all results obtained also differential curves of pore distribution are presented (Fig. 7). In these diagrams, changes in percentage participation of pores of the same radius at different pressures and moisture levels can be distinctly observed. The area of the size of pores containing water available for plants, i.e., from the radius $r = 98 \times 10^{-9}$ m to $r = 148 \times 10^{-7}$ m (pF 4.2 and 2.0 respectively), was specially marked in all diagrams. Among these pores also the size of those containing water easily available for plants (148×10^{-7} m to 148×10^{-8} m) was also distinguished.

The percentage participation of pores of radii in the above mentioned range changes distinctly at moisture levels corresponding to pF 1.0 and 1.5, i.e., at higher moisture levels. For lower moisture levels, irrespective of the pressure, the number of pores containing water easily available for plants does not practically change.

For pF 1.0 with the load 1, the studied soil contained about 46% of pores of the radius 6×10^{-8} m, whereas with the loads 2 and 3 the volume of pores of the same radius decreased and was about 26%. At moisture pF 1.5 changes in the volume of pores of similar size are also distinct. Thus for the load 3 we have the highest volume about 44%, for

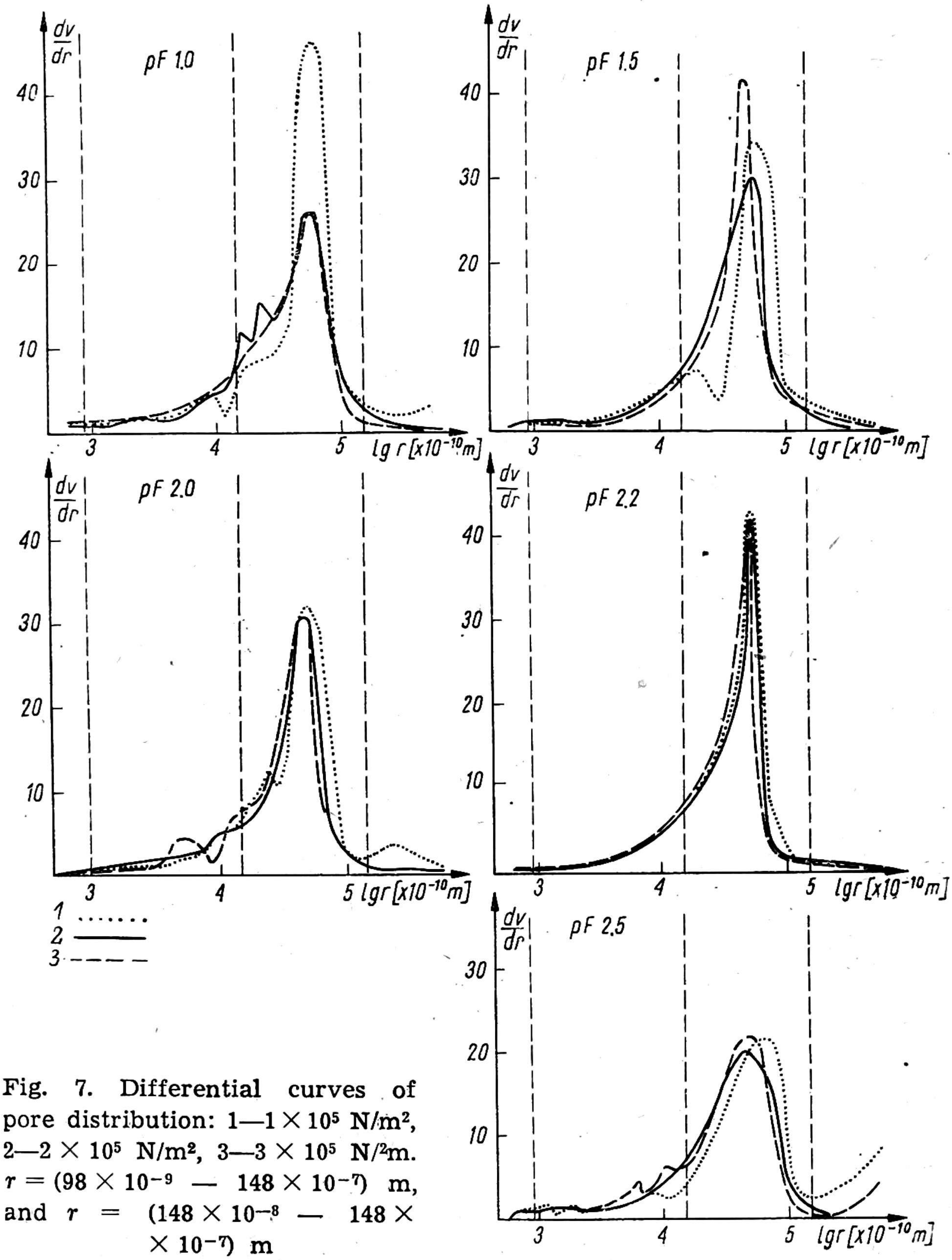

Fig. 7. Differential curves of pore distribution: 1—1×10^5 N/m², 2—2×10^5 N/m², 3—3×10^5 N/²m. $r = (98 \times 10^{-9}$ — $148 \times 10^{-7})$ m, and $r = (148 \times 10^{-8}$ — $148 \times 10^{-7})$ m

the load 2 — the lowest one about $30\,^0/_0$ and with the lowest pressure — medium volume about $35\,^0/_0$.

The presented results constitute a small part of more extensive studies, and the conclusions drawn cannot be treated as general laws. In our further studies various soil material will be involved and differentiation of loads with respect to the time of their application is planned. The result obtained will be theoretically analysed.

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BADANIE WPŁYWU ODKSZTAŁCEŃ GLEBY NA ROZKŁAD PORÓW PRZY RÓŻNEJ WILGOTNOŚCI

Streszczenie

Praca przedstawia wpływ obciążenia na funkcję rozkładu porów według rozmiarów w glebie lessowej. Pomiary wykonano na próbkach o różnej wilgotności. Wilgotność ustalono przez doprowadzenie próbki do równowagi przy zadanej warotści pF i potem poddawan oobciążeniu w edometrze. Programy badań obejmowały pięć różnych wilgotności i trzy wartości obciążenia. Po wysuszeniu wyznaczono rozkład porów przy pomocy parozymetru rtęciowego. Wilgotność próbek ustalono na mikroporowatych płytach gipsowych wykonanych w Instytucie Agrofizyki. Stosunek średnicy do wysokości próbki w edometrze był 64,8 : 20.

Badania porowatości wykonano na porozymetrze rtęciowym firmy „Carlo Erba” wzór 1500.

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ИССЛЕДОВАНИЕ ВЛИЯНИЯ ДЕФОРМАЦИЙ ПОЧВЫ НА РАСПРЕДЕЛЕНИЕ ПОР В УСЛОВИЯХ РАЗЛИЧНОГО УВЛАЖНЕНИЯ

Резюме

В труде рассматривается влияние нагрузки на распределение разной величины пор в лёссовой почве. Измерения проводились на образцах с различным увлажнением. Влажность определяли путем приведения образца к равновесию для данной величины pF, а затем подвергали его нагрузке в эдометре. Программы испытаний охватывали пять различных влажностей и три величины нагрузки. После сушки устанавливали распределение пор с помощью ртутного порозометра. Влажность образцов определяли на микропористых гипсовых плитах выполненных в Институте агрофизики. Соотношение между диаметром образца и его высотой в эдометре составляло 64,8 : 20,0.

Исследования порозности проводили на ртутном порозометре марки „Карло Эрба”, модель 1500.