OVERDRUK UIT MEDEDELINGEN VAN DE LANDBOUWHOGESCHOOL EN DE OPZOEKINGSSTATIONS VAN DE STAAT TE GENT. 1959. DEEL XXIV. N° 1
„INTERNATIONAL SYMPOSIUM ON SOIL STRUCTURE, GHENT, MAY 28-31, 1958."

# SOME REMARKS ON PORE SPACE AND PRESSURE ON MARINE CLAY SOILS

H. Kuipers

Instituut voor Bodemvruchtbaarheid, Groningen
Nederland

## 1. Introduction

Many practical farmers in the Netherlands, especially on clay soils are convinced that soil structure on their fields is growing poorer in recent times as the result of increased mechanization. This rather general anxiety stimulated the study of soil compaction. As the problem of soil compaction is a very complicated one the results mentioned here are only meant as a first general impression.

## 2. Pore space in practice

In the northern marine clay district of the Dutch province Groningen several series of determinations of pore space were available. They showed a certain relation between pore space

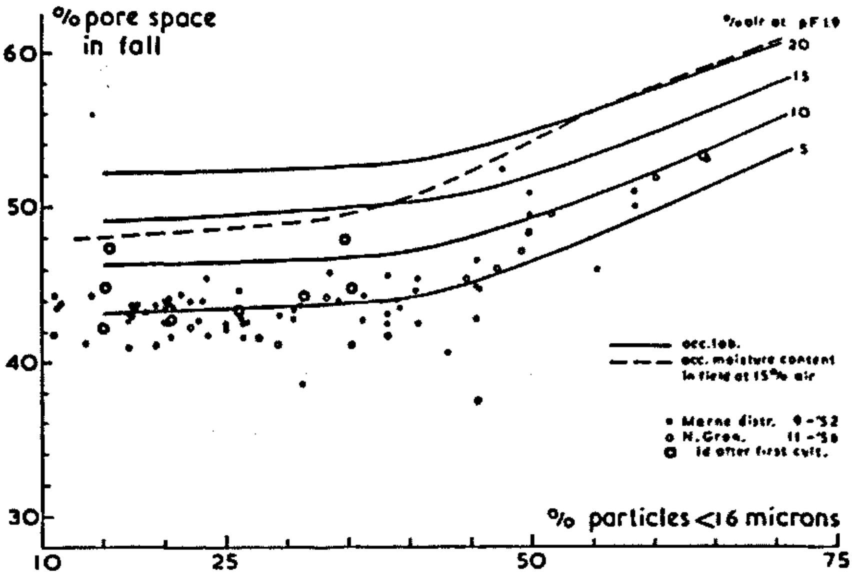


Fig. 1
Relation between pore space and clay content in autumn under practical conditions

and clay content of the soil (fig. 1) and differences between spring sampling when the crops start to grow and autumn sampling are generally speaking small.

Whether these pore spaces were high or low should be judged by their air content, when the soil was at field capacity. From one series of soils, the water content at pF 1.9 was determined on aggregate samples of the fraction 3.4 — 4.6 mm. and on another series water- and air content of the soil on a certain day in November 1956, a rather wet month. Both water contents give about the same relation with clay content of the soil and so the curves obtained may be regarded as rather good approximations of the field capacity. Starting from these two relations and a specific gravity of the soils of 2.65 gram/cm$^3$, calculations were made as to what should be the relation between clay content and pore space if air content at field capacity should be 5, 10, 15 or 20 %. The results are shown in fig. 1 by different lines. It appears that the pore spaces found in practice group rather well around the line indicating an air content of 5 % at field capacity. The series of soils sampled in November 1956 indeed showed this mean air content.

So the impression is obtained that under practical conditions pore spaces are to be expected that correspond with an air content of 5 % when the soil is at field capacity. As in our country the last few years showed very wet periods in the growing season insufficient aeration of the soils was to be expected and so the farmers complaints of poorer structures may be the result of temporary impeded aeration of the soil in the growing season.

Now there raises the question is mechanization likely to be the cause of these low porosities. Measurements of changes in pore space during the passage of agricultural machines only showed compression in the top few centimeters of loose soil, and then the soils appeared to be compacted to the same pore space as found in the lower layers of the top soil.

At this pore space the soil seems to be strong enough to withstand the pressure exerted on it.

On the other hand, if containers are filled loosely with soil and exposed to the climatical conditions it is remarkable that pore space remains unusually high, even in rather unstable soils and that much energy is required to establish a normal pore space by mechanical forces.

## 3. Laboratory compression test

In the laboratory, soil compression tests were carried out. To standardize the conditions aggregate samples of the fraction 3.4 — 4.6 mm were examined. Rings of about 50 cm$^3$ and a height of 5 cm were filled with air dry aggregates. After evacuation to about 1/20 atm. the samples were saturated with water and finally the water content corresponding with pF 1.9 was established by means of a suction force. The samples were compressed slowly at a rate of about 0.1 cm/minute and the pressure on the soil was read from a balance. Typical results are given in fig. 2.

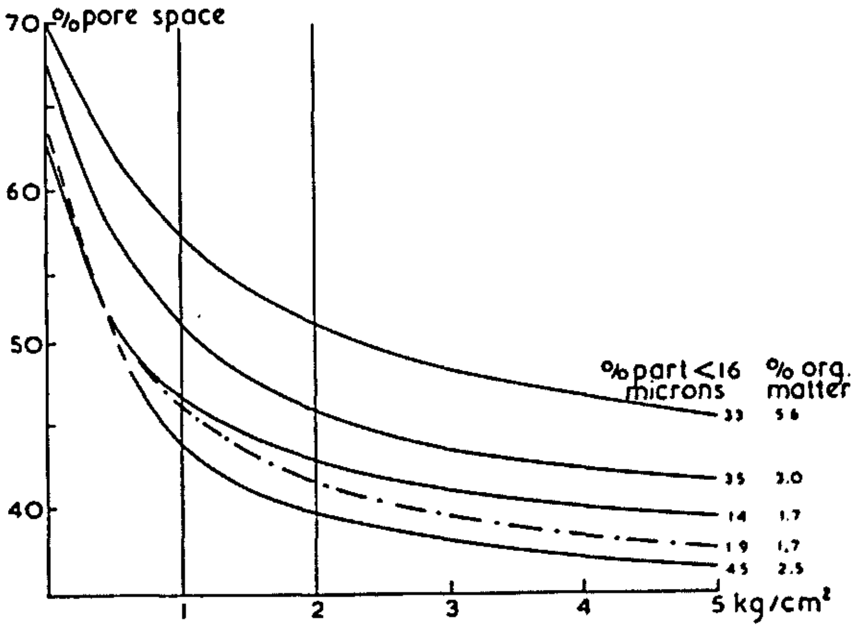


Fig. 2

Examples of compression curves

On the horizontal scale the pressure is shown in kg/cm² and on the vertical one the pore space in % of total volume. All curves are of the same type. If the compaction is small, the pressure only rises slowly as would be expected, as pore space is very high when the compaction tests start. As compaction proceeds the pressure rises more quickly until at last only very small increases in compaction are obtained with great increase in pressure. The cause is, that soil air has disappeared and so further compaction is only possible if water is pressed out of the soil, and this can be done only at a relatively slow rate. From the graphs it can be seen that the pressures at which air content is approching zero are of the order of 1 to 2 kg/cm².

In the field the soil has the opportunity to deform in all directions, and it is not possible to simulate exactly in the laboratory conditions in the field. Nevertheless it may be expected that pressures of the order of magnitude of 1 $kg/cm^2$ will cause a rather low pore space if they are exerted when the soil is at field capacity.

From a series of soils of the northern clay district, pore space was calculated at the moment that the pressure was 1 $kg/cm^2$ during the compaction tests. The results are shown in fig. 3.

In this figure is also drawn the curve relating pore space to clay content according to fig. 1, which was based on samples from practical fields.

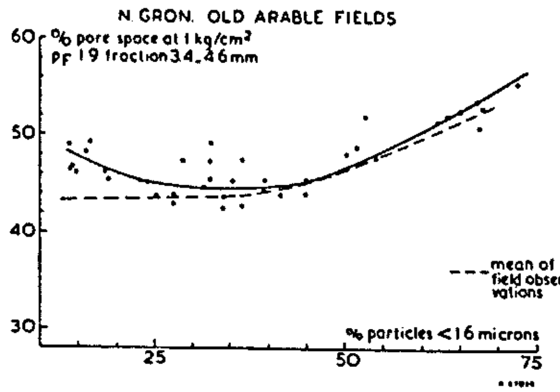


Fig. 3

Relation between clay content and pore space at a pressure of 1 $kg/cm^2$ during compaction tests at a moisture content corresponding with pF 1.9

It appears that there is a fairly good agreement between both values. The light soils show relatively too high a pore space after compaction. But in practice these soils are known to have a low water stability which could be the cause of their low porosities in practice.

## 4. Conclusion

Generally speaking the impression obtained from the figures is that pore space in the northern clay district is so low, that under wet conditions aeration may be expected to become insufficient. When the soil is rather wet these low porosities can be established by pressures of the same order as may be expected under practical conditions (1). Although the laboratory tests are not strictly comparable with practical conditions, the conclusion can be drawn, that soil pressure caused by agricultural machinery is likely to be an important factor in soil structure deterioration.

## LITERATURE

1. SÖHNE, W. — Druckverteilung im Boden und Bodenverformung unter Schlepperreifen. *Grundlagen der Landtechnik.* Heft 5, 49-63, 1953.

## SAMENVATTING


### Enkele bemerkingen betreffende de porositeit in functie van de druk uitgevoerd op marine kleigronden

Het vochtgehalte bij pF 1,9 werd bepaald op aggregaten van 3,4 à 4,6 mm, nadat deze voorafgaandelijk onder vacuum bevochtigd waren. De onderzochte aggregaten waren afkomstig van oude cultuurgronden uit het zeepoldergebied. Het vochtgehalte bij pF 1,9 komt tamelijk goed overeen met dit gevonden op het veld bij een vochtige herfst en is eveneens functie van het kleigehalte van deze gronden.

Op het veld bestaat er eveneens een verband tussen kleigehalte en porositeit. Practisch mag men aannemen dat het luchtgehalte bij pF 1,9 ongeveer 5 % bedraagt.

Monsters bestaande uit aggregaten van 3,4 tot 4,6 mm bij een vochtgehalte overeenstemmend met een pF 1,9 werden door het uitoefenen op de monsters van gecontroleerde druk aan druktesten onderworpen. Bij een druk tussen 1 à 2 kg/cm² heeft men in het grondmonster een luchtgehalte dat tot nul nadert.

Wordt het poriënvolume bepaald, wanneer de druk 1 kg/cm² is, dan worden waarden gevonden gelijkend op deze gevonden in het veld, uitzondering gemaakt voor zeer lichte gronden waar een groter poriënvolume gevonden wordt.

Uit deze metingen kan men afleiden dat in het veld de grond zodanig samengedrukt is, dat het luchtgehalte kritisch wordt wanneer de grond nat is.


## RESUME


### Quelques remarques concernant la porosité en fonction des pressions exercées sur des sols argileux marins

Le taux d'humidité à pF 1,9 a été déterminé sur des agrégats d'un diamètre compris entre 3,4 et 4,6 mm après saturation préalable dans le vide; ces agrégats provenaient d'anciens sols de culture de la région des argiles marines. Cette teneur en humidité correspond relativement bien aux taux d'humidité enregistrés au champ lors d'un automne humide et est aussi fonction de la teneur en argile de ces sols.

Au champ il existe également une relation entre la teneur en argile et la porosité. Ces deux relations suggèrent qu'en pratique la teneur en air au pF 1,9 sera d'environ 5 %.

Des grumeaux à pF 1,9 et d'un diamètre compris entre 3,4 et 4,6 mm furent soumis à des „essais cellulaires" (essais de compression dans un espace limité latéralement) avec compression progressive lente. A des pressions comprises entre 1 et 2 kg/cm² la teneur en air du sol tend vers zéro. Si la porosité est déterminée à un moment où la pression du sol atteint 1 kg/cm², on obtient des valeurs comparables à celles trouvées au champ, sauf pour les sols très légers, où l'on trouve une plus grande porosité. Ces mesures suggèrent qu'au champ les sols sont comprimés si fortement, que la teneur en air devient une propriété critique lorsque les sols sont humides.

## ZUSAMMENFASSUNG


### Bemerkungen zum Porenvolumen und Druck auf Marinen Tonböden

Von einer Serie von Bodenproben wurden Aggregate von 3,4 — 4,6 mm im Vakuum vorbefeuchtet. Anschliessend wurde die Feuchtigkeit bei einem pF Wert von 1,9 bestimmt.

Die Bodenproben stammen von alten Ackerkrumen aus der Marsch. Die Wassergehalte stimmen mit der Feuchtigkeit unter praktischen Bedingungen in einem feuchten Herbst gut überein, und es ist eine Korrelation mit dem Tongehalt des Bodens festzustellen, sowie eine Korrelation zwischen Tongehalt und Porenvolumen. Aus diesen zwei Beziehungen wäre abzuleiten, dass praktisch der Luftgehalt bei pF 1,9 ungefähr 5 % sein wird.

Bodenaggregatproben der Fraktion 3,4 — 4,6 mm und bei einer Feuchtigkeit von pF 1,9 wurden einem langsamen Zusammendrückungsversuch bei verhinderter Seitenausdehnung unterworfen.

Bei Drücken zwischen 1 und 2 kg/cm² ist der Luftgehalt im Boden ungefähr null. Wenn das Porenvolumen in dem Moment, in dem der Druck im Boden 1 kg/cm² erreicht, bestimmt wird, findet man Werte, die solchen unter praktischen Bedingungen annäherend gleich sind, ausgenommen wenn es sich um leichten Böden handelt, welche ein höheres Porenvolumen zeigen.

Diese Messungen legen den Gedanken nahe dass unter praktischen Umständen der Boden so stark zusammengedrückt ist, dass der Luftgehalt einen ausschlaggebenden (kritischen) Einfluss haben wird, wenn der Boden feucht ist.