Physical soil constants. — Contribution to a possible programme of the First International Commission

(Physikalische Bodenkonstanten. — Constantes physiques du sol)

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The activities of the First Commission of the International Society of Soil Science have — after the death of the first president, Dr. Albert Atterberg, in 1916, under the leadership of Prof. Dr. Václav Novák (President of the First Commission from 1924 to 1930) — principally centred on the mechanical analysis of the soil. At the meeting of the First Commission at Rothamsted, from October 15th to 19th, 1926, the international methods A and B were laid down. The conclusions of this meeting were originally published in a pamphlet by Novák (Brno, Czecho-Slovakia, 1927). After being discussed and definitely laid down at the First International Congress (Washington, 1927), they were published in the Proceedings of the Society, Volume IV (1929), No. 3, p. 216—218. The further resolutions passed at the meetings of the First Commission at Prague (1929) and Leningrad (1930), were published by Novák in Volumes IV and V of the Proceedings.

At the meeting of the First Commission at Prague (1929), Dr. Crowther, speaking also in the name of Dr. B. A. Keen, gave a summary of the results obtained at various institutes with the determination of the sticky-point in a couple of samples sent round by Dr. Keen. This investigation was found to have yielded widely divergent results at the institutes participating, whilst most of the institutes, on making checking tests, had obtained values which again differed fairly widely.

It will be generally agreed that it is highly desirable that the First Commission should continue its useful labours. For this purpose the first requirement is the laying-down of a programme of work. There is no lack of points for investigation in this field. Dr. Keen's work, "The Physical Properties of Soil", published in 1930, alone offers an abundance of material.

I. The purpose of this short communication is in the first place to allude to a few of the chief physical soil constants which call for the consideration of the First Commission. Foremost amongst these are the following: the permeability of soil to water; the moisture equivalent; the specific gravity and volume weight, which together give the pore space volume; the specific surface; the capillarity pressure and the velocity of capillary rise. Added to these, for the heavier soils, are the „Fließgrenze", the „Ausrollgrenze", and the „Plastizität", according to Atterberg (1). In contrast with the results of the determination of the sticky-point according to Keen, the checking tests of the Atterberg constants yield figures which agree very closely.

In addition to the moisture equivalent of the soil, it would further seem advisable to determine the value called by Porchet (2) the "coefficient de permabilité" and indicated by him by the letter μ. This value is determined by partly drying a soil, initially saturated with water, by a stream of air; the difference between the pore space volume and the water retained by the soil after partial drying, is the value μ according to Porchet.

In the table given below, sub III, a few instances of these values in the case of three typical sandy Dutch soils are shown.

In all these methods a good definition of the constant in question, together with international standardisation of procedure, is urgently required.

II. In the second place this short communication is intended to point out that the work of the First Commission in regard to the mechanical analysis of the soil is not yet finished. This may be demonstrated by the following brief summary of a few tests made on a sandy soil No. Wm 460 by the Institute of Soil Science at Groningen. The pretreatment was in accordance with the international method A (H_2O_2, HCl, NH_4OH). Fractions I and II were poured away in an Atterberg cylinder (decantation method), of fraction I a column of 10 cm after 8 hours, and of fraction II a column of 10 cm after $7\frac{1}{2}$ minutes. With the aid of Stokes' formula: $V = 34720\ r^2$, V being the settling velocity and r the radius of soil particles, it can be calculated that the particles of fraction I are smaller than 0.002 mm diameter, whilst those of fraction II are between 0.002 and 0.016 mm diameter.

The further grading of the particles larger than 0.016 mm was carried out with the aid of:

a) the Atterberg cylinder (decantation method);
b) the Kopecký cylinder (elutriation method);
c) sieving through various meshes.

The particles larger than 0.016 mm were thus graded into the following three fractions: 16—76 (with sieves 16—74); 76—152 (with sieves 74—147), and larger than 152 (with sieves 147), diameter expressed in thousandths of a millimetre. With the method (a) the settling velocity of the particles, and with the method (b) the velocity of the running tewar, was calculated from the diameter (= 2 r) with the aid of the above-mentioned Stokes' formula. For the sieve method (c) a Ro-Tap testing sieve shaker with the sieves belonging to this, made by the W. S. Tyler Company, Cleveland, Ohio, was employed. In method (a) it may further be remarked that in the case of sandy soils with a high proportion of fraction IV (particles larger than 0.152 mm diameter) the decantation of this fraction in the Atterberg cylinders takes a very long time, whilst it is impossible accurately to determine when the final point has been reached.

Soil Sample Wm 460, with 97.4 % sandy particles (larger than 0.016 mm diameter) yielded the following results according to method:

Table I

	fraction 16—76	fraction 76—152	fraction 152—2000	Total 16—2000
a) (decantation)	1.1	38.6	54.7	97.4
b) (elutriation)	2.5	45.5	49.4	97.4
c) (sieves)	1.8	19.4	76.2	97.4

With the aid of microscopic measurements of the size of the particles of the three different fractions it was determined that the 38.6 % of fraction 76—152, by method (a), was mainly of a diameter greater than 0.152 mm, and thus belonged to the following fraction (152—2000). The same was found to be the case with the 45.5 %, by method (b). The 19.4 % by method (c) was almost entirely between the limits 0.076 and 0.152 mm, but even of this 19.4 % a small part belonged, according to the microscopic tests, to the fraction 152—2000.

On the strength of these results I would suggest that the First Commission should place on its programme of work the question: according to which of the three methods mentioned above, namely (a) decantation, (b) elutriation, and (c) sieving, should the grading of the particles larger than 0.016 mm diameter (settling velocity = 10/450 = 0.0222 cm/sec.) be carried out. In the testing of a large number of Dutch sandy soils the sieve method mentioned in (c) was followed.

III. In the third place the results of the determinations on three typical Dutch sandy soils are given here. These were performed in the manner described above, viz., pre-treatment according to the international method A (H_2O_2, HCl, NH_4OH); decantation of the clay fraction (fractions I and II) in Atterberg cylinders (settling velocity less than 0.0222 cm/sec.; according to Stokes' formula $V = 34720\ r^2$, particles smaller than 0.016 mm diameter); further grading of the particles larger than 0.016 mm diameter according to the sieve method mentioned sub c. In percentages of clay + sand = 100 the following results were found.

Table II

Diameter of particles in 0.001 mm	No. B 5172	No. B 5173	No. B 5168
smaller than 16	5.5	1.2	0.7
16—43	14.7	0.4	0
43—74	46.3	2.5	0.4
74—104	19.1	3.6	1.0
104—147	9.1	17.4	3.4
147—208	4.2	37.6	5.9
208—295	0.9	22.3	18.3
295—417	0.2	11.9	44.9
417—589	0	2.3	18.8
589—833	0	0.6	4.8
833—1168	0	0.1	1.2
1168—1651	0	0.1	0.6
1651—2000	0	0	0
Total	100	100	100

The results of the mechanical analysis of each soil sample were set out in the form of summation curves showing the relationship between summation percentages and logarithms of settling velocity (3).

The steepest portion of the curves represents the fraction present in greatest frequency. This has been termed by Robinson the modal fraction; I will in future speak of the characteristic fraction. In the case of soil sample No. 5172, this characteristic fraction is seen to be between 0.043 and 0.104 mm diameter, of which No. 5172 contains no less than 46.3 + 19.1 = 65.4 %. In the case of B 5173 the fraction 0.104 — 0.295 mm, of which this sample contains 17.4 + 37.6 + 22.3 = 77.3 %, is the characteristic fraction. In that of B 5168 this is the fraction of 0.208—0.589 mm, of which this soil sample contains 18.3 + 44.9 + 18.8 = 82.0 %.

In the following table, in addition to the results of the mechanical analysis, a few other physical soil constants are included (for the significance of these constants see sub I).

Table III

	No. B 5172	No. B 5173	No. B 5168
Diameter of characteristic fraction (in 0.001 mm)	43—104	104—295	208—589
Percentages of characteristic fraction in dry soil (105° C.)	65.4	77.3	82.0
Capillarity pressure ($t = 17°$ C.)	150	55	28
Pore space volume in %	41.7	34.4	33.1
Volume percentages water after partial drying	16.0	7.7	5.5
μ according to Porchet	25.7	26.7	27.6
Volume weight	1.55	1.75	1.78
Filtration coefficient according to Dupuis-Darcy (cm per second × 10.000, 10° C and pore space 35 vol. %)	2	83	303

These values have been found to characterize the three typica sandy soils very well as soils, and from the point of view of their practica qualities also.

IV. Finally the mean of the results of an investigation of ten samples of boulder clay (Geschiebelehm) is included. These samples were taken from borings in the Zuyder Zee and used in covering the great enclosing dam from the coast of Noord-Holland to Friesland. There was very little difference between the composition of the 10 samples of boulder clay, so that there was no objection to taking mean figures. For purposes of comparison the results of determinations with a sample of heavy boulder clay and a sample of sea-clay from the young Anna Paulowna Polder (Noord-Holland) have been included.

Table IV

Average = The average of ten samples boulder clay (Geschiebelehm)
B 2613 = Heavy boulder clay, with a great deal of $CaCO_3$
B 2517 = Young sea-clay (Anna Paulowna-polder).

	Average	B 2613	B 2517
Contents in percentages in dry matter of:			
NaCl	0.3	0.5	0
$CaCO_3$	0.8	24.3	4.1
Organic matter	0	0	5.2
Clay (particles smaller than 0.016 mm)	26.3	49.4	50.0
Sand (particles from 0.016—2.0 mm) .	72.6	25.8	40.7
"Fließgrenze" according to Atterberg	17.5	26.3	41.6
"Ausrollgrenze" according to Atterberg	13.8	17.2	28.9
"Plastizität" according to Atterberg	3.7	9.1	12.7
Sticky point (Dr. Keen)	14.9	22.8	n. d.*)

As is seen by the above table, it is quite possible to characterise the three types-boulder clay, heavy boulder clay, and sea-clay-with the aid of the physical constants given.

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References

1. International Reports on Pedology (Intern. Mitteilungen für Bodenkunde), I (1911), II (1912), and III (1913).
2. Analyse hydrodynamique des terres. Exemple d'application au drainage, par Dr. Porchet, ingénieur en chef du génie rural, Extrait des Annales de la Direction Générale des Eaux et Forêts, Fascicule No. 58, Paris, 1930. See also: Prof. Dr. Diserens, Zürich: Einführung in die Untersuchungsmethoden für kulturtechnische Arbeiten; Sammlung der Vorträge des ersten Fortbildungskurses der Konferenz schweizerischer Kulturingenieure vom 8. und 9. April 1926 an der Eidgenössischen Technischen Hochschule in Zürich, 1927, 155.
3. Robinson, Bangor, was the first to make allusion to the use of these summation curves for expressing the mechanical composition of soils; see The Journal of Agricultural Science, XII (1922), p. 306—321, and XV (1924), p. 626—633.

*) n. d. = not determined