SOIL CONSISTENCY AS A FACTOR DETERMINING THE SOIL STRUCTURE OF CLAY SOILS

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SUMMARY

The deterioration of the aggregation of several Dutch clay soils during the period after ploughing seems to be caused by a plastic transformation of the soil aggregates under influence of mechanical forces, resulting from walking and riding on the soil surface and gravity. It depends on the consistency and moisture characteristics of the soil, on the drainage of the top soil and on other factors influencing the moisture percentage of the soil.

The location of the point pF 1.9 ("field capacity") on the moisture percentage scale with regard to the upper plastic limit, the sticky point and the lower plastic limit appears to be a better index for the structure of clay soils than figures obtained from a wet sieving analysis.

Some results of experiments on the effects of lime, gypsum and soil conditioners in respect of soil structure are illustrating this.

INTRODUCTION

Soil structure, usually defined as the arrangement of the soil particles, is the result of a joint action of several forces. Some of them are influencing soil structure generally in a favourable way (e.g. the forces due to the tillage of clay soils), others (e.g. the mechanical forces caused by walking and riding on the soil surface) have an opposite effect. Most of these forces are not working constantly, but only off and on and generally not all at the same time. Hence the soil structure at a certain moment (the actual soil structure) is varying highly in course of time.

Therefore soil structure cannot be characterized by an actual structure (e.g. by a total pore size, a pore size distribution etc.) only, but additional figures on the structure stability are necessary.

Development of a method, however, to obtain these figures requires knowledge on the nature of the destructive forces. A wellknown conception ascribes these forces to the dispersing action of water on the soil and this resulted in the wet sieving methods for aggregate analysis.

The results obtained by one of these methods (PEERLKAMP, 1948) were rather good with sandy soils, but unsatisfactory with clay soils. Apparently the dispersing action of water is not the most important cause of the decrease of soil structure in clay soils and the question arises what will be the most destructive factor.

The results of an attempt to loose this problem and to develop a method characterizing the structure stability of clay soils will be described in the next sections.

DETERIORATION OF STRUCTURE OF CLAY SOILS

An experiment with soil conditioners on small plots with different clay soils, brought from elsewhere, was showing only slight differences in soil structure. The structure of the untreated soil appeared to be too good. Compression of the moist soil brought the untreated soil in a more natural condition and increased the differences in soil structure.

A special type of clay soil (Zuurdijk clay) with a poor structure shows a deterioration during autumn, which starts not only at the soil surface, but throughout the ploughing layer if the soil is wet. The plasticity of this soil is then so great, that very weak mechanical forces (e.g. the weight of the overlying soil) seem to be able to deteriorate soil structure and to give a very compact soil.

These observations suggest the importance of the mechanical deformation of clay soil aggregates under moist conditions. Hence soil structure would depend on the possibilities for the appearance of plastic soil consistencies, ergo on the relation between soil consistency and moisture percentage and on the moisture percentages occuring under field conditions.

Method for evaluating structure of clay soils

A well known method for characterizing soil consistency in relation with moisture percentage is given by Atterberg (1911, 1912). He introduced the lower plastic limit, the sticky point and the upper plastic limit. The lower plastic limit represents the moisture percentage at the change from the friable to the plastic consistency. The sticky point is the moisture content at which the soil sticks no longer to a foreign (metal) object. At a moisture percentage given by the upper plastic limit the soil will barely flow under an applied force.

Until now these Atterberg limits were used mostly for the classification of soils (see e.g. Mohr, 1915 and Doeglas, 1954). In soil mechanics, however, they are used too. Terzaghi (1926) reports that compression of a soil increases rapidly above the lower plastic limit.

Therefore it will be clear that the Atterberg limits alone cannot give adequate information on soil structure, but must be completed with data characterizing the moisture percentages under field conditions. Determination of field capacity or a moisture percentage in the neighbourhood of field capacity seemed to be the simplest way to obtain this completion. For this purpose the moisture percentage at pF 1.9 was determined by means of a suction method.

Determination of the lower plastic limit was done according to the prescription of the American Society for Testing Materials (1950), that of the sticky point with a slight modification of a method described by Keen and Coutts (1928). The upper plastic limit was determined according to Casagrande (1932).

The ratio (moisture percentage at pF 1.9 minus lower plastic limit) : (sticky point or upper plastic limit minus moisture percentage at pF 1.9) has been used as a measure for the location of the moisture content at pF 1.9 on the moisture percentage scale with regard to the Atterberg limits and consequently was supposed to be an index for soil structure.

It will be obvious, however, that high groundwaterlevels or a dense horizon below ploughing depth are able to increase the moisture percentage of the topsoil above field capacity for a longer period and to stimulate in this way the deterioration of soil structure. In such a case the moisture percentage under field conditions must be measured directly.

RESULTS

Fig. 1 shows the results for different clay soils and treatments. The Zuurdijk clay (no. 1), mentioned in the second section and having a poor structure, has a field capacity lying at a relative short distance from sticky point and upper plastic limit.

Consequently the $A : B$ and $A : (B + C)$ ratio's are relatively great. On the other hand, the Reiderwolderpolder clay (no. 4), having a rather good structure, shows a field capacity in the neighbourhood of the lower plastic limit and low $A : B$ and $A : (B + C)$ ratio's.

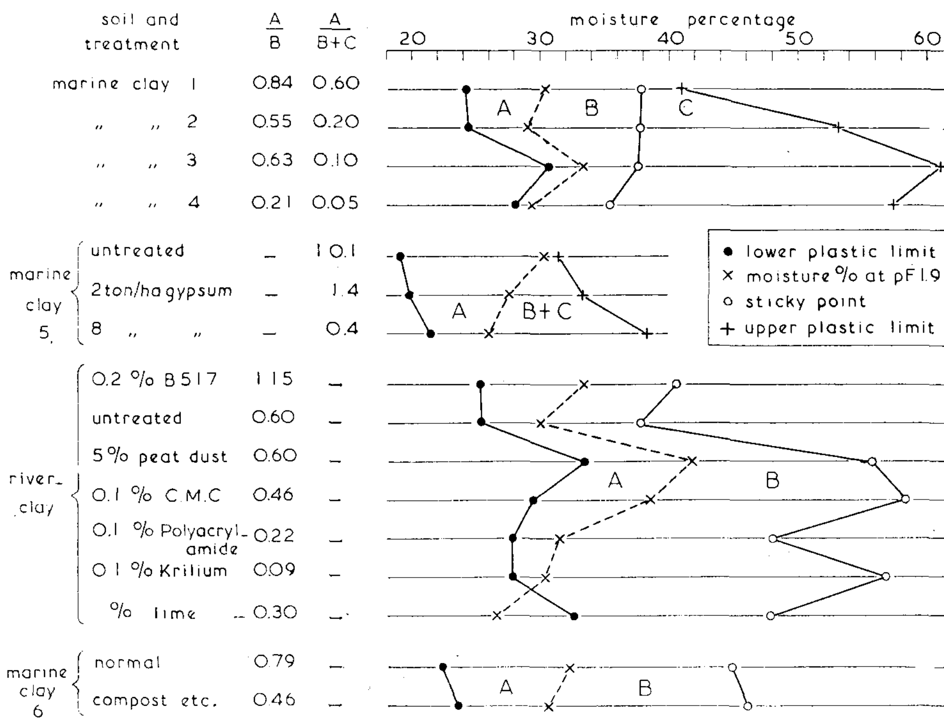

FIG. 1. ATTERBERG LIMITS, MOISTURE PERCENTAGES AT pF 1.9 AND STRUCTURE INDICES DERIVED FROM THEM FOR 7 CLAY SOILS, PARTLY WITH DIFFERENT TREATMENTS.
1–4 : soils from Zuurdijk, Feerwerd, Nw. Beerta and Reiderwolderpolder respectively. The Zeeland-clay no. 5 has been inundated with sea water in Febr. '53. The marine clay 6 is from N.W. Brabant. A = moisture percentage at pF 1.9 minus lower plastic limit. B = sticky point minus moisture percentage at pF 1.9. C = upper plastic limit minus sticky point.

The improvement by means of dressings with gypsum of a clay soil (no. 5), which has been flooded with sea water, is illustrated by Fig. 1 in the same way. The lowest part of this figure shows the improvement of soil structure in consequence of heavy dressings with organic material. The results of the laboratory experiments with a river clay soil, treated with various soil conditioners, peat dust and lime, are illustrating the deteriorating effect on soil structure of the "soil conditioner" B 517, the inactivity of 5% peat dust and the obvious amelioration of soil structure by Krilium and lime.

The correlation between $A : B$ ratio and soil structure is indicated more directly by Fig. 2. The data are obtained from a lime-gypsum experimental field. It is obvious that the more there are big aggregates in the soil (this means decreasing soil structure), the greater the $A : B$ ratio.

These results prove the possibility of using the location of the point pF 1.9 on the moisture percentage scale in respect of the ATTERBERG limits as an index for the soil structure of clay soils.

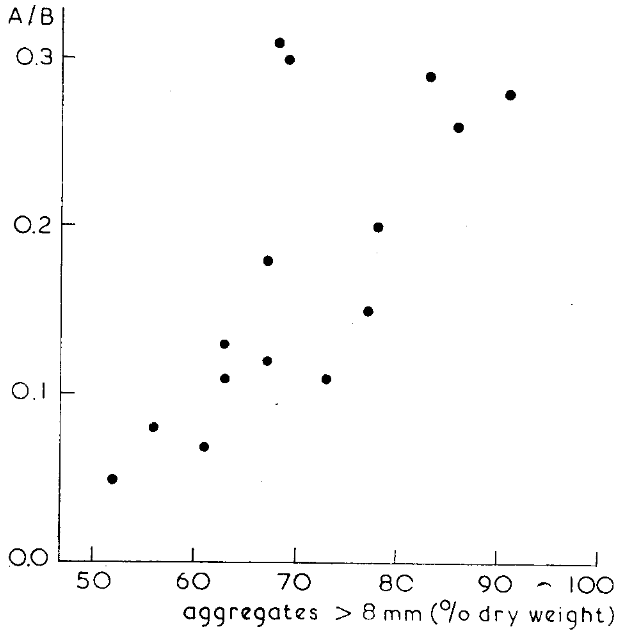

FIG. 2. THE RATIO (MOISTURE PERCENTAGE AT pF 1.9 MINUS LOWER PLASTIC LIMIT) : (sticky point minus moisture percentage at pF 1.9) as related to the percentage aggregates > 8 mm in a marine clay soil (Pr 842).

REFERENCES

American Society for Testing Materials. Procedures for testing soils. Philadelphia 1950, 56–60.

ATTERBERG, A. : Die Plastizität der Tone. *Int. Mitt. für Bodenk.* 1 (1911) 10–43.

— — : Die Konsistenz und die Bindigkeit der Böden. *Int. Mitt. für Bodenk.* 2 (1912) 149–189.

CASAGRANDE, A. : Research on the ATTERBERG limits of soil. *Public. Roads* 13 (1932) 121–130.

DOEGLAS, D. J. : Graphic presentation and discussion of MOHR and ATTERBERG values of soils from East Central Java. *Report Inst. for Soil Research,* Bogor, June 1954.

KEEN, B. A. and J. R. H. COUTTS : "Single value" soil properties : a study of the significance of certain soil constants. *J. Agric. Sci.* 18 (1928) 740–765.

MOHR, E. C. J. : De methoden van ATTERBERG ter bepaling van consistentiecijfers en uitkomsten daarmede verkregen aan gronden van Java en Madoera. *Meded. Lab. voor Agrogeologie en Grondonderzoek* 1 (1915).

PEERLKAMP, P. K. : Het meten van de bodemstructuur. *Landbouwk. Tijdschr.* 60 (1948) 321–338.

TERZAGHI, C. : Simplified soil tests for subgrades and their physical significance. *Public Roads* 7 (1926) 153–162.