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INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
34100 TRIESTE (ITALY) - P.O.B. 586 - MIRAMARE - STRADA COSTIERA 11 - TELEPHONE: 2240-1
CABLE: CENTRATOM - TELEX 460392 - I

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"COLLEGE ON SOIL PHYSICS"

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"Consistence of Soil"

Prof. K.H. HARTGE
Universitat Hannover
Hannover, Fed. Rep. of Germany

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1. Introduction: Consistence as an Aspect of Soil Structure

When soil consistence is mentioned, usually one thinks of Atterberglimits. There are several of them, but the most widely known ones are upper and lower plastic limit. The first of these is frequently called liquid limit.

It is generally known that these limits express consistence in terms of water content of a soil at a specified consistence. These specified consistences are determined empirically and the procedure employed is extremely simple. This simplicity is somewhat fallacious however, since extreme accuracy is needed in handling, in order to obtain reproducable results. Only the apparatus needed is inexpensive.

Sometimes the question comes up: What is the use of these Atterberg values? First answer is that one can not judge Atterberg values other than by comparision because they are extremly empiric. The use to be made of them is the much better the more material is at hand for comparision.

Second answer is that the Atterberg limits are just one measurement to formulate a rather complex property of the soil. The property "consistence" is as complex as the property "fertility" and so one should not try to discribe the whole of it with but one figure.

The original latin meaning of the word consistence is ability of a man or a thing to keep his or its place or form in relation to his or its immediate environment. As all environment in most parts of the soil is soil again, this definition is almost the same as that comonly given for "stability" of structure or of aggregates.

So consistence turns out to be one aspect of the wide object of structure, its changes, the ability of soil to withstand these changes and the way in which a change of the active forces will influence the soil.

2. Background: Easily Observable Facts

Consistence of soil can be felt quite obviously if one walks over it. The difference of feeling when walking on the walking path between two freshly prepared seedbeds and the feeling when accidentally stepping on the bed itself, is obvious. The fact that soil is gaining hardness when it is compacted is an important observation.

The attentive observer may as well feel the difference between the hard consistence of a soil of a park-lawn and the softer consistence of a meadow soil. Even the fact that cattle is treading a soil strongly and regularely can be distinguished from cases, where cattle just occasionally treads the soil.

One feature of consistence can even be seen as well: The soil surface of pathway is generally lower as the one of the soil left and right of it. It can be observed quite generally that soil in the deep trails of heavy vehicles is harder than that besides these trails. There is a third observation easily made: If one watches the wheels of a tractor the behaviour of the soil under a driving wheel is obviously different from the one of a passively rolling wheel. Furthermore the soil under these wheels gives way to a certain extent. Sometimes the result is a hardbottomed trail, sometimes the soil would not become hard and the wheels will sink down puddling it.
All observations have to do with consistence and its effect under various stresses.

3. Consistence as a System of Forces

If we consider the relative movement of particles to each other to be a question of consistence, then we can reduce the system to be observed to just one point or plane of contact.

The simplification is possible, if we consider the rules of addition and combination of forces in forcesystems of several kinds - i.e. planar-central, planar-general, spatial-general.

As in the latter case all momenta and forces can be reduced to give one resulting force and a momentum in a plane, rectangular to that force, one can conclude that for a given particle there is just one contact, where only a normal stress is active. On all other contacts there is some force "not normal" and in contact planes normal to that of the momentum there is no normal force at all. Now we consider one arbitrarily chosen point resp.plane of contact of one soil particle on some other.

We can reduce all forces active at that plane to four of them, if we sum up vectorially all those of equal mechanisms to give one resultant.
These four forces are:

- weight of particle in consideration
- resultant of all weight components from other particles transmitted over the solid phase to the contact in consideration
- resultant of all force components transmitted from the liquid phase
- cohesion and adhesion at the contact.

<u>Fig. 1</u>: If we for simplicity let these four forces give a planar-centric force system, they can be summarized to give one resultant force. This resultant will in most cases not be normal to the plane of contact. So it can be split up to a component normal and a component tangential to that contact plane or surface.

<u>Fig. 2</u>: If now the soil withstands these both components the structure is said to be "stable" or - the consistence is "hard" or "stiff".

As this situation can be described as well in terms of the Coulomb equation, we can reduce one aspect of the term "consistence" to basic physical properties at a contact.

If we accept this statement, we must take into account the fact that a change of any of these four forces will change the resultant and hence the equilibrium situation of the whole system. Therefore we should look a little bit closer to the possibilities to change them.

4. Consistence of a Soil in situ

As is generally known, a soil can be compressed under load. The more compression is already achieved, the less further compression can be obtained by adding another unit of load.

The curve showing this is called a "standard compression curve" or "compression curve" or "compression characteristic". On the abscissa of this curve pressure is plotted. On the ordinate a unit is plotted that is connected with pore space (void ratio or height h)(Fig. 3). This is because usual compression forces is applied uniaxially and horizontal expansion is prevented by the sampleholder the consequence of increased load can be measured as decrase in sample height as well as in void ratio (Fig. 4,5).

This relation calls attention to a fact that is frequently neglected in pedology, namely the change of position of soil surface when pore volume is changed. This means in the end, that porevolume at a given level in a profile is a function of depth under surface (because of natural overburden), of shearing resistance that might develop and of "precompression" that is previous temporary higher load, for instance caused by agricultural machinery. One can say therefore, that pore volume or bulk density of a soil is strongly dependent on consistence as a material-parameter as well as consistence as a parameter of present and previous influences from outside or from geometric enviroment (Fig. 4,5).

Every soil has its own compression characteristic for the whole profile that shows an equilibrium situation between the three factors mentioned. This can be seen from the fate of loosening or deep ploughing actions, if the same management as before this amelioration is applied again after it. It can be seen as well from curves of differently developped soils on same material. And it can finally be seen from a comparison of pore volumes and shearing resistance as related to soil development.

5. How to Measure Consistence

If the wide range of the term "consistence" is accepted in the way as it is used here, then it is obvious that it cannot be characterized by just one figure obtained from one or two measurements.

Classical Atterberg-limits thus prove to be too narrow on one hand, too little defined on the other hand.

The wide scope of methods ranges from those aimed at the material properties like shearing parameters (angle of internal friction and cohesion) obtainable from small samples with laboratory equipment, to properties of packing of the whole soil-body including previous temporary overloads obtainable only from in situ measurements of forces, pressures, stresses and volume changes.

6. Conclusions

What is the importance of soil consistence in view of plant production?
It is well known and generally accepted that water and air regime is of first importance to plants. Nutrition is second only.

This is in agreement with all life on earth. Death from dehydration or from suffocation or drawning respectively is by far quicker than by starvation.

For plant life this means that regular access to water in extractable state and in presence of breathing air for the roots is first growth condition.

This condition can only be met by permanent artificial and highly regulated irregation.

Or ⟶ By providing of a suitable stock.

This was done in past times by carefully selecting soil and its position in topography and climate, because changes in soil properties that govern water regime were generally out of reach.

This has changed drastically in recent time. Equipment can be obtained to change or even "make" soil to an extent that was beyond thought some decades ago. The need to use this chance obviously increases as long as world population grows because the choice for adequate additional production areas is dwindling.

In this situation however new aspects gain weight improving soils, ameliorate their water and air regime properties, even "make them".

In this situation soil consistence is one of the most important aspects.

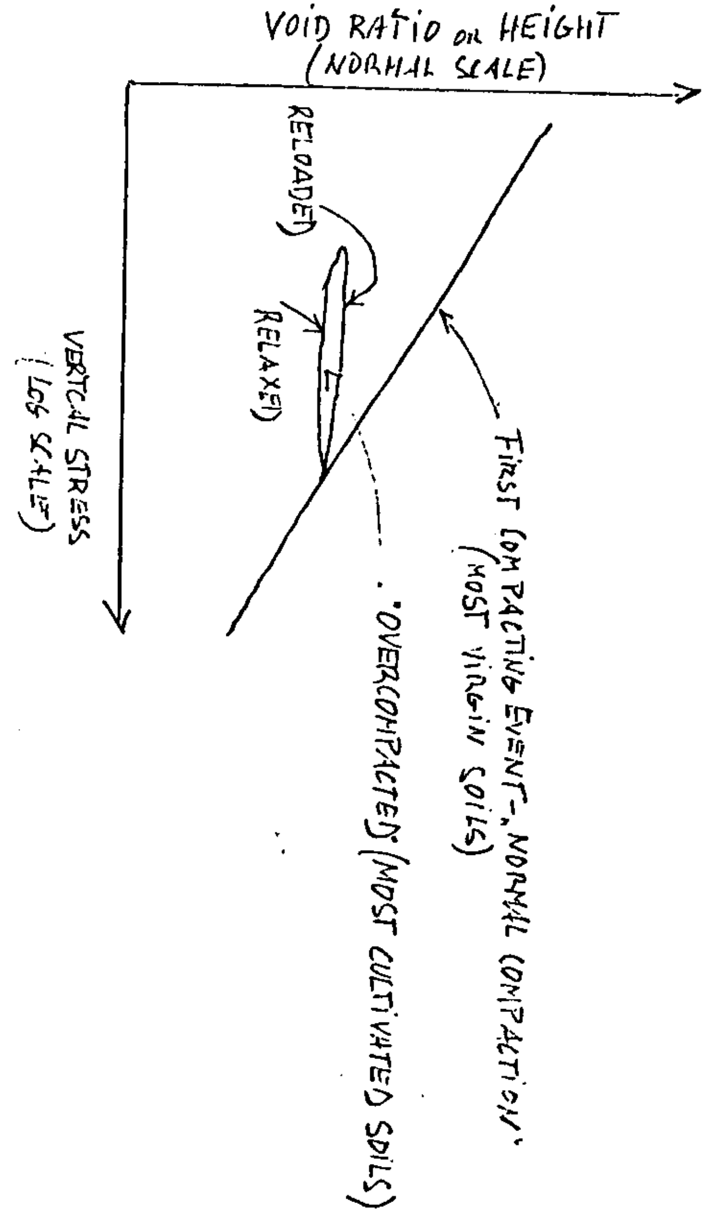

FIG. 3. COMPACTION-CHARACTERISTICS

FIG. 1. FORCES ACTIVE AT ONE PLANE OF CONTACT BETWEEN PARTICLES OR AGGREGATES

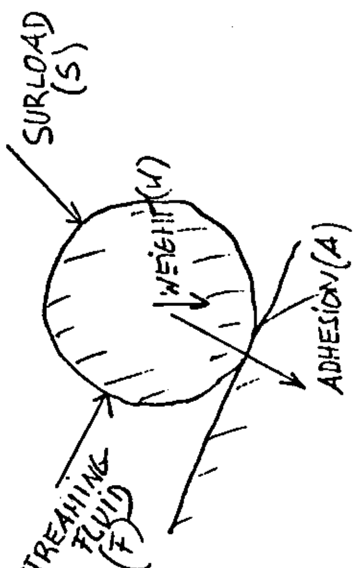

FIG. 2. FORCES A, F, S AND W, THEIR POLYGON AND THE REACTIVE FORCES THA DEVELOP AGAINST THE AKTIVE RESULTANT

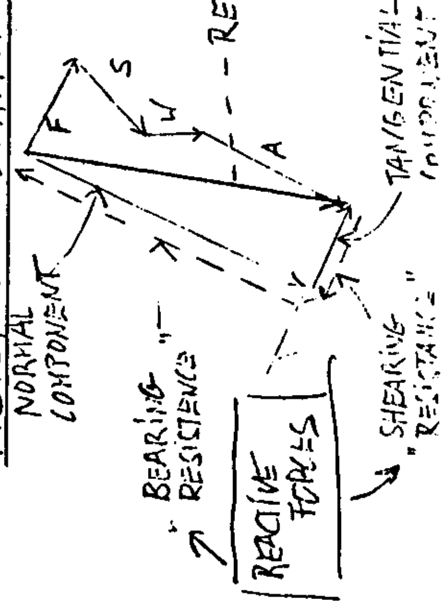

FIG. 4. RELATION BETWEEN LEVEL OF SOIL SURFACE AND CHANGE OF POROSITY (PV) WITH DEPTH (Z)

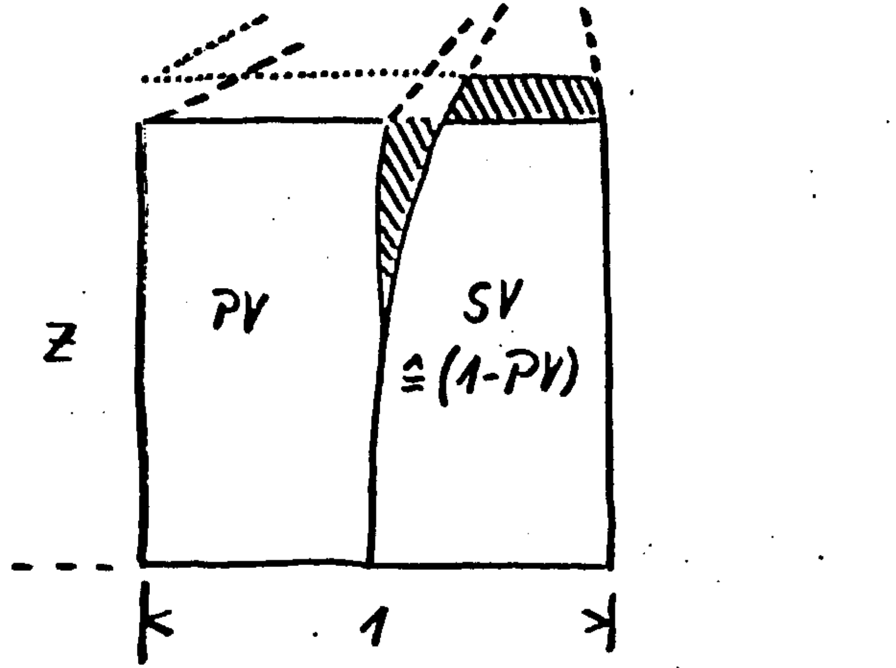

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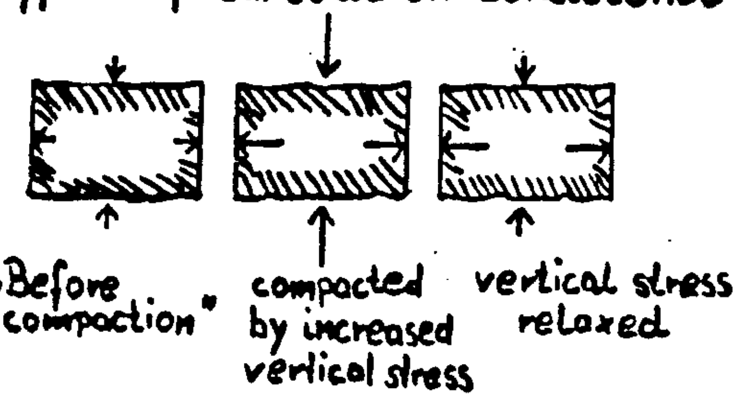
Fig. 5, Effect of surload on consistence



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