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The rheological approach in an assessment of interparticle interactions in soils

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Abstract. The rheological parameters were determined by the amplitude sweep test on the MCR-302 rheometer and have shown a behavior specificity of soils of different genesis depending on a texture and organic matter content. Light loamy gley podzolic soils of the northern taiga have a dilatant hardening of interparticle bonds, but their stability is extremely low. Soddy-podzolic soils of the Moscow region have somewhat greater stability, and it is similar to a gley podzolic soils` stability. The typical chernozem has the greatest stability to stresses.

1. Introduction
The rheological approach in the studies of interparticle interactions in soils has recently become increasingly important, since it allows evaluating the soil structure from the standpoint of evaluating the strength of interparticle interactions bonds. This approach enables to obtain quantitative, physically justified characteristics of structural bonds in pressure units [1, 2]. The studies' results of the rheological behavior of upper soil layers by the amplitude sweep test on the rheometer MCR-302 (Anton Paar, Austria) are presented in this paper [1-3].

2. Materials and methods
The study`s objects were a gley podzolic soil of northern taiga subzone of the Komi Republic territory, a soddy-deep podzolic soil of the Moscow region, a typical chernozem of the Kursk region. Some physical and chemical properties are presented in Table 1.

The texture of investigated soils was measured by the laser diffraction analysis of particle sizes on the «Analysette 22 comfort» instrument with a preliminary dispersion of a aqueous soil suspension by a ultrasonic treatment for 5 minites [4]. The samples of a typical chernozem and a soddy-podzolic soil are heavy large-silty loams (Kachinsky`s classification) or silt loams (the international classification of USDA). The sample of a gley podzolic soil is a light loam according to the Kachinsky`s classification. The organic matter content was determined by the dry combustion method on the AN-7529M analyzer [4].

Table 1. Physical and chemical properties of soils

Soil sample	Organic matter content (%)	Physical clay content (particle size <0.01 mm) (%)	Water content of daily capillary swelling (%)
Typical chernozem	6.80	42.50	88.83
Soddy-podzolic soil	1.06	40.84	47.86
Gley podzolic soil	1.09	25.00	38.11

The rheological parameters of the behavior of soil pastes were determined with the condition of the daily capillary swelling (Table 1). The soil samples were previously rubbed with a rubber pestle and sieved through a 1 mm sieve. 3 g of air-dry soil samples was placed in small cylinders with a diameter of 2.5 cm, corresponding to the diameter of the upper plateau of the rheometer. The technical test modes were as follows: the distance between the plateau- h 2-4 mm, the plateau diameter -2.5 cm, the deformation γ - 0.001 - 100%, the frequency s 0.5 Hz, the number of measured points - 30. During all tests a constant temperature of 20^{o}C is regulated by a Peltier unit. In the present study, we have carried out tests with the control of the normal force NF <10 N. The experiments were carried out in three replications.

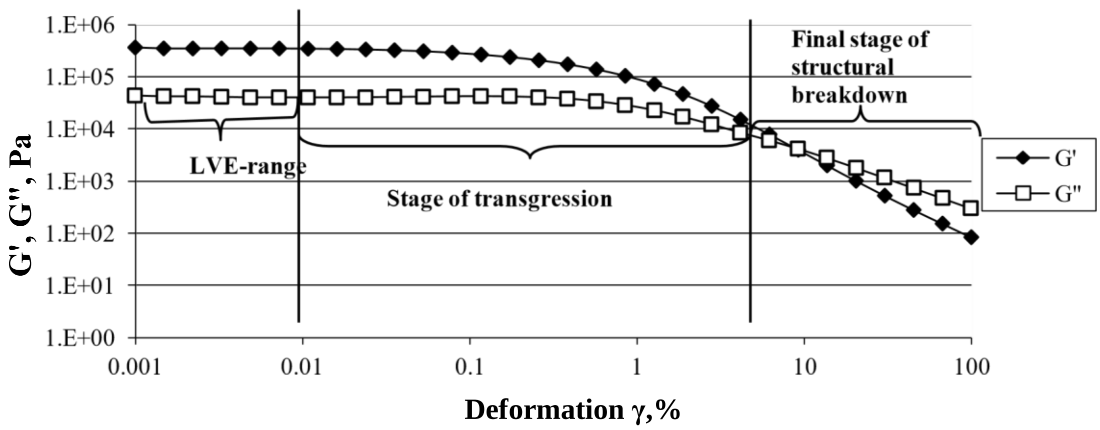

Figure 1. Storage modulus G' and loss modulus G'' of the sample of typical chernozem

The resulting curves of the storage and the loss (viscosity) modulus are presented in Figure 1. The linear viscoelastic range (LVE-range), marked as a range of curves running parallel to each other and parallel to the x-axis, is the area of an elastic behavior of soils. The range of curves from their decreasing to their intersection (crossover) is a transgression area or area of a plastic behavior. A viscous flow (a final stage of a structural breakdown) begins after the intersection of moduli curves; here the storage modulus is less than the loss modulus. Further, we analyze and discuss the obtained parameters.

3. Results and discussion

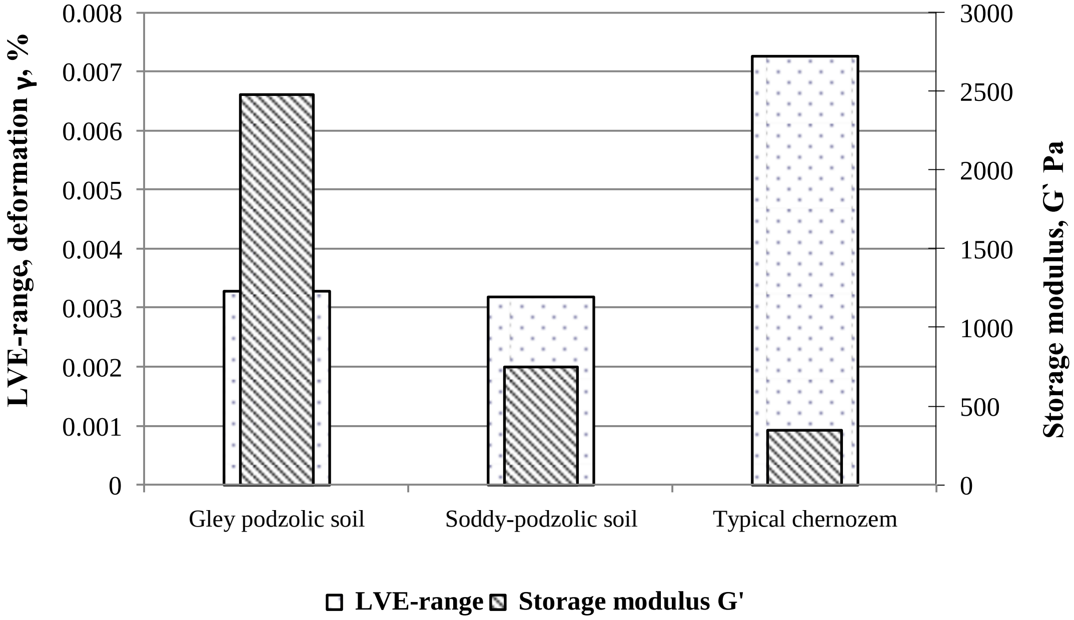

Figure 2. LVE-range and the storage modulus G` in the LVE-range

As can be seen from Figure 2 LVE-range values of gley podzolic and soddy-podsolic soil` samples are approximately less two times than the value of the chernozem`s sample, however the storage modulus of this range of the gley podzolic soil`s sample is considerably more than that of soddy-podsolic soil`s sample or chernozem`s sample. The high value of the storage modulus of the gley podzolic soil`s sample is probably related to the dilatant hardening of coarse soil fractions. The sample of a gley podzolic soil have the low content of organic matter (Table 1), which causes small water interlayers between the particles and accordingly a lower moving possibility relative to each other for them. This is the reason of the low LVE-range value at the high storage modulus`s value. The sample of soddy-podzolic soil has the low LVE-range value similar the value of gley podzolic soil`s sample. However, the storage modulus of a soddy-podzolic soil is low unlike that of a gley podzolic soil. It is possible that the LVE-range value is related to the content of organic matter. The content of OM is 1.09% and 1.06% in samples of a gley podzolic soil and a soddy-podzolic soil respectively. The low storage modulus`s value of a soddy-podzolic soil, unlike that of gleypodzolic soil, is probably due to the heavy texture, correspondingly to a greater water absorption; soil particles are more divided by water interlayers, and an interparticle interaction is weakened. The chernozem`s sample differs from other samples by the larger LVE- range, which is due to the high content of OM (6.8%). Organic matter prevents soil particles from separating from each other with high moisture content. In Figure 3 the deformation values of the moduli curves` intersection (G'= G") are presented. In this area a plastic behavior changes to a viscous one. As can be seen the typical chernozem`s sample has the greatest stability, the gley podzolic soil`s sample has the least stability. The integral zone Z shows the total area of an elastoplastic behavior before a transition to a viscous flow area.

The chernozem`s sample is distinguished by the greatest value of the elastoplastic behavior`s area, the gley podzolic soil`s sample has the least value.

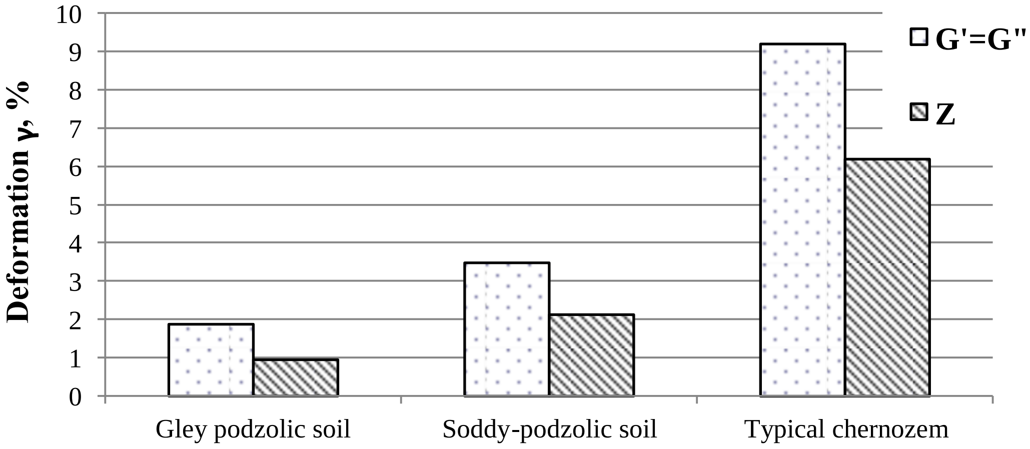

Figure 3. Deformation values of the moduli curves` intersection (G'= G"), the integral zone Z

4. Conclusion

The rheological parameters determined by the amplitude sweep test have shown that the behavior specifity of soils of different genesis depends on the texture and the content of organic matter. Light loamy gley podzolic soil of the northern taiga has the low content of organic matter and shows a dilatant hardening of interparticle bonds in the condition of the daily capillary swelling but the stability of this system is extremely low. Soddy-podzolic soil of the Moscow region has the heavy texture and the low content of organic matter and shows a larger stability. Heavy loamy typical chernozem has the high content of organic matter, the low strength of interparticle bonds and shows a wide range of stability to stresses.

Acknowledgments

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