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On fractal characteristics of the micro-aggregate structure of loess soils

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The idea of loess as a natural multi-fractal was formed in the works of Bird [1], Russell [2]. On the basis of the fractal characteristics of the pore and particle structure, there were obtained theoretical models describing diffusion, deformation of the compaction and the shift of the medium [3], [4]. In [2] the distribution function $N_s(L > d_s)$ of the particles sizes is defined as the number of particles of the size L such that $L > d_s$, where d_s runs over the real numbers. The fractal dimension of the particle size distribution function is defined as follows

$$D_s = \lim_{d_s \to 0} -\frac{\ln(N_s(L > d_s))}{\ln(d_s)}$$

In the presented paper we study subsidence of soils, which are eluvial, eluvial-deluvial loess-like deposits of the Middle-Upper Pleistocene age, lying on the Right-Bank Loess Upland Plain (Middle Dnieper, Ukraine). Under some additional conditions of fractal nature of the loess soil and developing methods introduced in our paper [5] we obtained certain predictive estimations of the coefficient of porosity after the disintegration of micro-aggregates.

. The particles forming the ground may have only a finite set of sizes. We denote these sizes $d_1, d_2, ..., d_{n-1}, d_n$ ranging in decreasing order from the largest. We assume that $\alpha = \alpha_j = d_j/d_{j-1}$, where $2 \leqslant j \leqslant n$, does not depend on j. This assumption corresponds to the idea of the self-similarity of fractal structures. In addition, all known mathematical fractals are constructed on this principle. Then we put $\beta_1 = 1$ and $\beta_2 = (d_j/d_{j-1})^{3-D_s} - (d_j/d_{j-1})^3 = \alpha^{3-D_s} - \alpha^3$, where $2 \leqslant j \leqslant n$ and D_s is the fractal dimension of the particle size distribution function. As the structures formed by particles of a fixed size are self-similar, we also assume that all these structures have the same coefficient of porosity k_p as well as the same porosity $K_p = k_p/(1 + k_p)$. We discovered that under such conditions two different situations may occurred.

Theorem 1. *In the above denotations, two different situations may occurred:*

1. If $K_p > \beta_2$, then

$$e_1 = ((1 + k_p){d_1}^{3-D_s})/({d_1}^{3-D_s} + \beta_2(\sum_{j=2}^{n} {d_{j-1}}^{3-D_s})) - 1$$

is the porosity coefficient after the disintegration of micro-aggregates.

2. If $K_p < \beta_2$, then

$$e_1 = ((1 + k_p){d_n}^{3-D_s} + ({d_1}^{3-D_s} + \beta_2(\sum_{j=2}^{n} {d_{j-1}}^{3-D_s})))/({d_1}^{3-D_s} + \beta_2(\sum_{j=2}^{n} {d_{j-1}}^{3-D_s})) - 1$$

is the porosity coefficient after the disintegration of micro-aggregates.

Applying the obtained estimations for e_1 , we can obtain a predictive estimate of the volume deformation by the following formula: $\varepsilon = e_1 - e_0$, where e_0 is the - coefficient of porosity in the initial (natural) state and e_1 is the predicted value of the porosity coefficient. The results of our experiments and calculations show that on the basis of a new theoretical models and the "Microstructure" technique, having the values of the fractal dimension of the particle size distribution function, it is possible to forecast the volume deformations after the disintegration of the micro-aggregates.. Depending on the type of loess soil and the specific experimental conditions, this may be the amount of subsidence deformation, swelling or suffusion.

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