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Isotropic assessment of clay soil in terms of volume changes

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Abstract. One of the basic characteristics of heavy soils is their capacity to change their volume in horizontal plane they are represented by formation of cracks and in vertical plane by vertical movement of soil surface. Non-dimensional geometric factor r_s is the ratio of participation in soil volumetric changes of both crack formation and vertical movements. In theory, r_s can acquire values in the interval: $r_s \in \langle 1, \infty \rangle$.

1. Introduction

Heavy soil is characterized by a high content of clay particles. These particles in soil moisture change cause shrinking and swelling processes. These processes occur in three dimensions. In horizontal plane they are represented by formation of cracks and in vertical plane by vertical movement of soil surface. With the formation of cracks, soil environment becomes a two-domain structure, cracks being one domain and soil matrix being the other one. Shrinkage cracks are distributed through the unsaturated zone of a soil profile.

The aim of this chapter is to evaluation of isotropy of soils from the view of volume changes. Evaluating criteria for isotropy was value of geometric factor - r_s.

2. Materials and methods

Soils volumetric change is a three-dimensional process. In nature, drying of soils is partly reflected in cracks formation and partly in the soil surface subsidence. Therefore soil changes are horizontal, caused by opening and closure of cracks, and vertical as soil surface movement. In laboratory, soil volumetric changes are visible as changes in geometric dimensions of an undisturbed specimen of soil [1]. Calculations are based on the following equations (1), (2), (3) (figure 1):

$$\Delta V = \Delta V_v + \Delta V_h \qquad [\mathrm{m}^3] \qquad (1)$$

where

$$\Delta V_v = z_s^2 \times \Delta z \qquad [\mathrm{m}^3] \qquad (2)$$

$$1 - \frac{\Delta V}{V} = \left[1 - \frac{\Delta \mathrm{z}}{\mathrm{z}}\right]^{\mathrm{r_s}} \qquad (3)$$

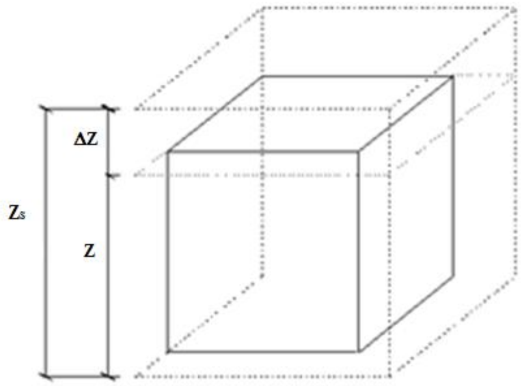

Figure 1. Volume change of isotropic soil sample in shape of cube during drying process, (dashed line express the sample in saturated state (volume Vs), continues line express the sample after shrinkage (volume V)).

From equations (1), (2), (3) and figure 1 apparent a mathematical expression of the relationship between soil volumetric change and vertical subsidence is as follows [1] in the equation (4) :

$$\Delta z = z_s - \left[\left(\frac{V}{V_s}\right)^{\frac{1}{r_s}}\right] \times z_s \qquad [\mathrm{m}] \tag{4}$$

where ΔV - total volumetric change of a soil specimen, [m^3], ΔV_v - vertical volumetric change, [m^3], ΔV_h - horizontal volumetric change of a soil specimen, [m^3], V - soil volume after shrinkage, [m^3], V_s - volume of a saturated soil specimen, [m^3], Δz -change in height of a soil specimen, [m], z_s - height of a saturated soil specimen, [m], z - height of a soil specimen after shrinking [m], r_s - geometric factor [-].

Horizontal volumetric change can be expressed by the following combination of equations (1), (2), (4):

$$\Delta V_h = V_s \times \left[\left(\frac{V}{V_s}\right)^{\frac{1}{r_s}} - \frac{V}{V_s}\right] [\mathrm{m}^3] \tag{5}$$

Non-dimensional geometric factor r_s is the ratio of participation in soil volumetric changes of both crack formation and vertical movements. It can be influenced by external load and possibly by terrain settling process, which occurs when the clay sheet particles are orientated in one predominant direction. r_s can reach the following values:

$r_s = 1$	no cracking process, all soil volumetric changes are vertical;
$1 < r_s < 3$	vertical movement predominates over crack formation;
$r_s = 3$	isotropic shrinking;
$r_s > 3$	crack formation predominated over vertical movement;
$r_s \rightarrow \propto$	all soil volumetric changes are horizontal; i.e. only cracks are formed.

In nature, isotropic shrinking with $r_s = 3$ can occur in most soils. Provided that during drying the vertical change in height of a soil specimen and the volume of water saturated soil are measured, the equation (4) can be used to calculate the geometric factor r_s. This factor can be calculated from the equation mentioned previously in its analytical form:

$$r_s = \frac{log\left(\frac{V}{V_s}\right)}{\log\left[\frac{-(\Delta z)+z_s}{z_s}\right]} \qquad [-] \tag{6}$$

Geometric factor r_s has been studied in selected areas of ESL table 1) on a set of 160 samples [2,3].

3. Results and discussion

Table 1 shows that max r_s was in the locality of Vysoká (13.0) and the smallest in locality Zatín and Pribeník (0.5). These are sites with high and almost the same content of clay. The highest average r_s was in the high (5.7) area and the smallest in the Somotor 2 site (2.3). From the results shown in table 1 indicates that the profile Senné 2000, on average, identified isotropic shrinkage (r_s = 3).

Table 1. Rating profiles the average value of r_s.

Locality	Coordinates	rs in layer				l. fr.	clay	profile rating
		max	min	max-min	avg	< 0,001 mm	< 0,002 mm	
Michalovce	N48° 44,255´ E21° 56,664´	5,3	2,9	2,3	3,9	23,54	26,90	dominated by the formation of cracks
Milhostov	N48° 40,185´ E21° 44,248´	5,9	2,8	3,1	3,9	27,28	29,15	dominated by the formation of cracks
Pribeník	N48° 23,688´ E21° 59,547´	3,4	2,9	0,5	3,1	29,70	31,90	dominated by the formation of cracks
Senné	N48° 39,802´ E22° 02,892´	4,4	2,6	1,8	3,0	51,03	54,84	isotropic shrinkage
Sírnik	N48° 30,538´ E21° 48,830´	4,8	2,7	2,0	3,3	30,55	35,18	dominated by the formation of cracks
Somotor 1	N48° 23,748´ E21° 48,471´	10,0	3,8	6,2	5,3	23,72	25,89	dominated by the formation of cracks
Somotor 2	N48° 23,173´ E21° 48,237´	3,0	1,7	1,3	2,3	18,30	20,15	dominated by vertical movement
Horeš	N48° 22,540´ E21° 53,907´	3,9	2,7	1,2	3,1	41,19	43,74	dominated by the formation of cracks
Kamenec	N48° 21,048´ E21° 48,877´	3,4	2,2	1,2	2,8	29,81	32,11	dominated by vertical movement
Vysoká	N48° 36,796´ E22° 06,898´	13,0	3,0	10,0	5,7	11,27	12,88	dominated by the formation of cracks
Zatín	N48° 28,725´ E21° 54,918´	3,4	2,9	0,5	3,4	28,45	31,55	dominated by the formation of cracks

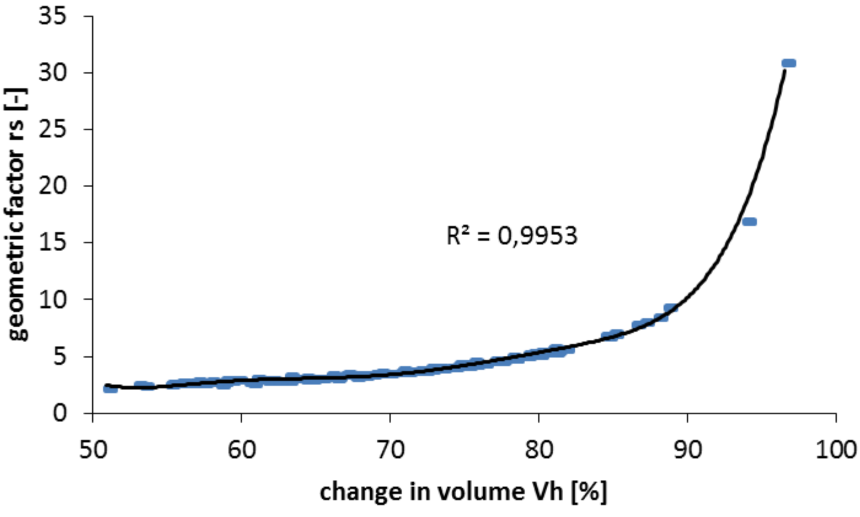

Figure 2. The dependence on the geometric factor r_s from volume changes V_h in the horizontal direction. Volume change V_h is expressed in % of the total measured volume changes.

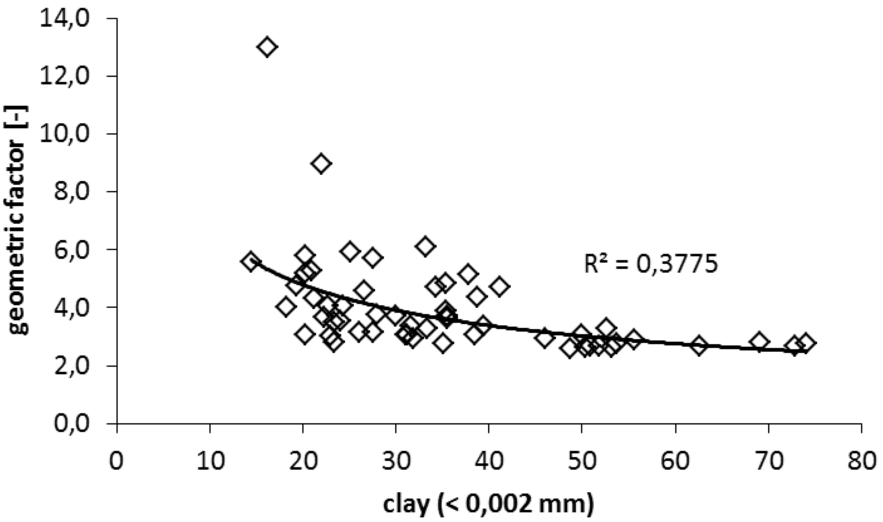

Figure 3. The dependence on the geometric factor r_s from volume changes V_h from the clay content. Volume change V_h is expressed in % of the total measured volume changes.

The dependence of the geometric factor r_s on volume changes V_h in the horizontal direction (figure 2) and on the clay content (figure 3) is shown. Volume change V_h is expressed in % of the total measured volume changes. It is clear from the figure 3 that with the increase in volume corresponding to the horizontal direction, the geometric factor increases. It is clear from the figure 2 that with the increase in volume corresponding to the horizontal direction, the geometric factor increases. It is also clear that with the growth of clay in the soil the variability of r_s is reduced. The geometric factor is approaching 3. This means that the increase in clay content in the soil causes isotropic shrinkage, respectively vertical movement begins to predispose isotropic shrinkage to crack formation.

Conclusions

In the current contribution, the isotopic properties of heavy soils were analyzed in VSN in selected soil profiles in terms of spatial realization of their volume changes. The basis of the analysis was the results of experimental measurements in the field and in the laboratory. The assessment of soil isotropy in relation to their volume changes and based on the geometric factor r_s showed that its values ranged from 0.5 to 13.0. The effect of the horizontal component of volume changes and clay content in the soil on the geometric factor r_s was documented. The results of this analysis will be used in the numerical simulation of the water regime and its prognosis under the conditions of heavy soils under VSN.

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