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THE EFFECT OF THE COLLOIDAL CLAY CONTENT ON THE SWELLING AND PLASTICITY BEHAVIOR

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Abstract

Clayey soils are soils with high shrink-swell potential. This soils have the property to significantly modify their volume when moisture changes. The magnitude of dry contraction and moisture swelling increases with the colloidal clay content. Minerals of the kaolinite group are the least active, while the montmorillonites are the most active. As shown by tests, the swelling potential and the plasticity of clays are high in clay of the montmorillonite type (bentonite) and rise with the fine-fraction content.

Key words: colloidal clay content; clay mineral; free swelling; plasticity index.

INTRODUCTION

The present experimental study has been undertaken to understand swelling behavior of an red clay from Dobrogea, high grade montmorillonite and kaoline clay mixed in different proportions by weight.

The main factors that cause the swelling behavior can be grouped into two categories: **internal factors** – this factors depends on the physicochemical properties of soils and water; and **external factors –** this factors depends on environmental conditions and the formation of the soils.

Clay particles are very small and their shape is determined by the arrangement of the thin crystal lattice layers that they form, with many other elements which can become incorporated into the clay mineral structure (hydrogen, sodium, calcium, magnesium, sulphur). The presence and abundance of these dissolved ions can have a large impact on the behaviour of the clay minerals.

In an expansive clay the molecular structure and arrangement of these clay crystal sheets has a particular affinity to attract and hold water molecules between the crystalline layers in a strongly bonded 'sandwich'.

Because of the electrical dipole structure of water molecules they have an electro-chemical attraction to the microscopic clay sheets. The mechanism by which these molecules become attached to each other is called adsorption. The clay mineral montmorillonite, part of the smectite family, can adsorb very large amounts of water molecules between its clay sheets, and therefore has a large shrink–swell potential (Jones&Jefferson, 2011).

MINERALOGICAL PROPERTIES

In this study were collected three types of clayey soils with different physical and mineralogical properties.

The kaolinite group includes the dioctahedral minerals kaolinite, dickite, nacrite, and halloysite.

The primary structural unit of this group is a layer composed of one octahedral sheet condensed with one tetrahedral sheet. In the dioctahedral minerals the octahedral site are occupied by aluminum; in the trioctahedral minerals these sites are occupied by magnesium and iron. Kaolinite are single-layer structures (Al. Rawas&Groosen, 2006).

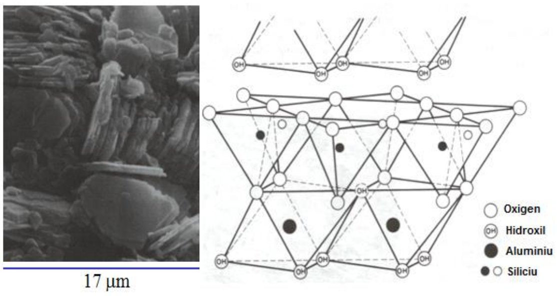

Figure 1. Mineralogical structure of kaolinite (Jones&Jefferson, 2011)

Members of the smectite group include the dioctahedral minerals montmorillonite, beidellite, and nontronite, and the trioctahedral minerals hectorite (Li-rich), saponite (Mg-rich), and sauconite (Zn-rich).

The basic structural unit is a layer consisting of two inward-pointing tetrahedral sheets with a central alumina octahedral sheet.

The layers are continuous, but the bonds between layers are weak and have excellent cleavage, allowing water and other molecules to enter between the layers causing expansion (Al. Rawas&Groosen, 2006).

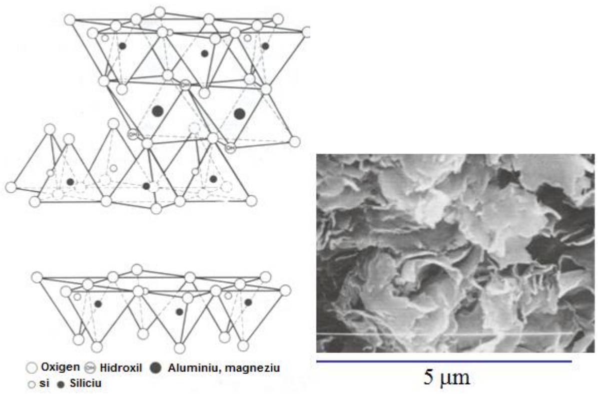

Figure 2. Mineralogical structure of montmorillonite (Jones&Jefferson, 2011)

Table 1 shows the mineralogical composition for an red clay from Dobrogea.

Table 1. Mineralogical composition of red clay in Dobrogea (Siminea, 1986)

Mineral	Content %
Montmorillonite	22
Illite + Muscovite	18
Chlorite + vermicullite	12
Kaolinite	14
Other minerals	14

METHODS

The physical characteristics of these soils were determined according to the Romanian standard in force, specifically: grading – STAS 1913/5-85; plastic limits – STAS 1913/4-86 and free swelling – STAS 1913/12-88.

According to STAS 1913/12-88, the clayey soils were oven dried at 105°C. After drying, the clayey soils were ground using a mortar and pestle until the soil passed the 0.02 mm standard sieve. 90 ml of water were poured into a 100 ml graduated cylinder. Twelve grams of sieved soil were placed in the water in 0.1 g increments. After the 12 grams were added, additional solution was poured to fill the cylinder to the 100 ml and to rinse any particle of soil adhere to the internal sides of the cylinder. After minimum 16 hour of hydration period after the last increment, the final temperature and the volume of swollen soil were measured. The free swell index, measured by this method, is calculated with(Ivasuc, 2012):

$$S = \frac{Vf - Vi}{Vi} \cdot 100(\%) \qquad (1)$$

where: S – free swell (%); V_f – final volume (cm^3) and V_i – initial volume (cm^3).

SOIL CHARACTERISTICS

The swelling grows up in the same time with the growth of the specific surface, which depends on the type of mineral (Table 2).

Table 2. Soil characteristics

	A_2%	W_L%	W_P%	I_P%	U_L%
Montmo-rillonite	100	610	150	460	760
Kaolin	100	52	29	43	32
Red clay	43-93	70	30	40	160

Also the swelling clay soil is influenced by the complex nature of adsorbtion. The presence of Na^+ cations in the absorption complex establish the formation of thick water layers.

If the adsorption complex is composed of monovalent, bivalent and trivalent cations and the moisture water content low range depending on the nature of ions following sequence occurs (Nicolescu, 1981):

$Li^{+} > Na^{+} > K^{+} > Mg^{2+} > Ca^{2+} > Ba^{2+} > Al^{3+}$ (2)

INFLUENCE OF FINE FRACTION CONTENT ON SWELLING POTENTIAL

According to the series mentioned that the size of absorbed water layer decreases with increasing valence cations in the adsorption complex, in Figure 3 we can observe the influence of cations on clay minerals and nature while swelling proces. It is noted that montmorillonite volume has increased more than kaolinite and growth is higher when the adsorption of the same mineral complex cations are Na^{+}.
The particles with fraction less than 2µm are called colloidal clay or ultra clay. Hence the behaviour of fine soil fraction containing clay is influenced by properties of clay minerals.
In order to track the potential inflation depending on the content in the fine fraction we have studied three clays: bentonite (montmorillonite clay type) - B, kaolin (kaolinite clay type) - C and red clay from Dobrogea - A.

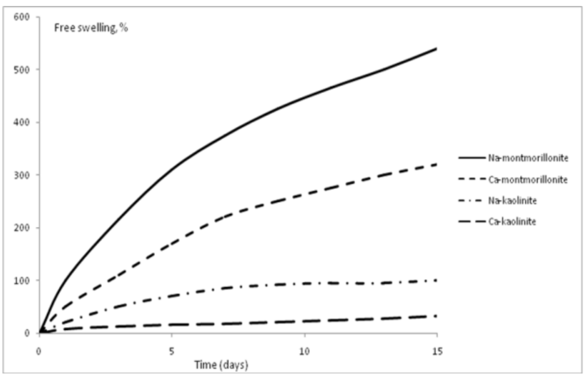

Figure 3. Swelling of montmorillonite and kaolinite

For each clay, swelling behavior was monitored over time (Figure 4). It is noted that bentonite (B) has the highest swelling value and kaolin (C) has the lowest swelling value. The clay (A) has a bigger value of swelling than the kaolin because of the montmorillonite mineral clay content.

The swelling was monitored for mixtures made with bentonite and kaolin, in different proportions, depending on the content of fraction less than 2 µm (Figure 5). The highest value of free swell index is given by montorillonite mineral while the lowest value is assigned to kaolinite mineral.

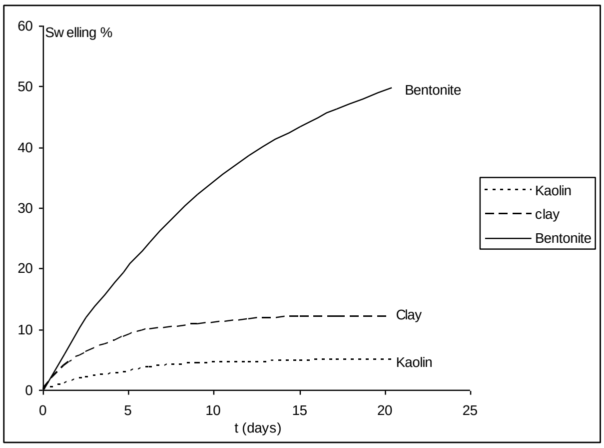

Figure 4. Swelling of bentonite, kaolin, and red clay from Dobrogea

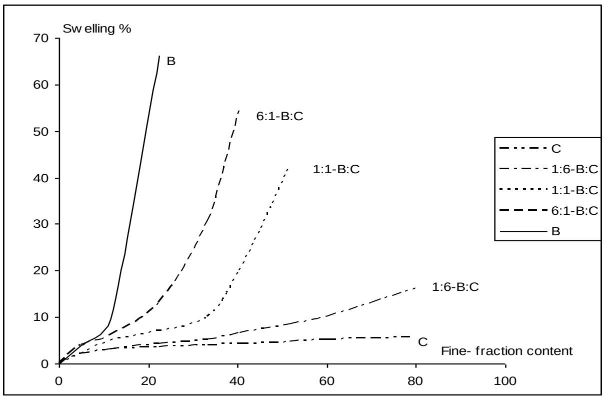

Figure 5. Variation of free swell index

In Figure 5 we can observe the free swelling index variation for different mixtures of bentonite and kaolin.

FINE FRACTION CONTENT INFLUENCE ON SOIL PLASTICITY CLAY

The content fraction below 2 µm influences the plasticity clay properties expressed by the plasticity index I_p (%). The plasticity index I_p result from the difference between the liquid limit (w_L) and plasticity limit (w_P) of these soils:

$$I_P = w_L - w_P, (\%) \qquad (3)$$

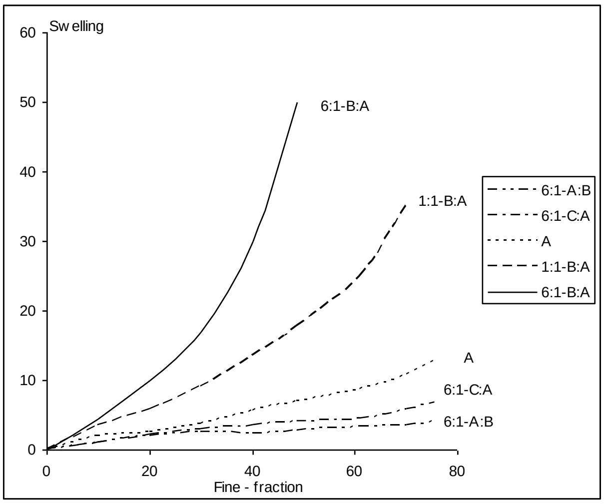

Figure 6. Swelling of mixtures of clay with bentonite and kaolin

The clays plasticity is influenced by the thickness of water layers made around the particles. Liquid limits and plasticity limits depend on the content of clay fraction as the type of mineral (Figure 7).

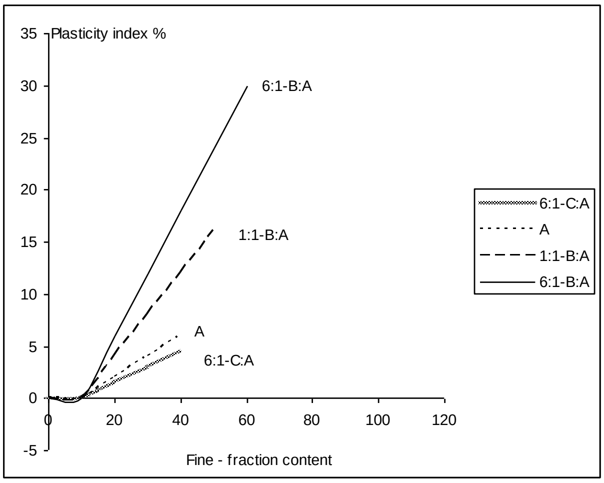

Figure 7. Variation of plasticity index for bentonite and kaolin

For bentonite (B) the plasticity index is higher than for the kaolin (C).

For the mixtures of clay-bentonite and kaolin clays, it can be noticed that the value of plasticity index I_p is a smaller increase due to the red clay of Dobrogea that was included on the mixture.

In Figure 8 we can observe the variation of the plasticity index for different mixtures between red clay from Dobrogea, bentonite and kaolinite clays.

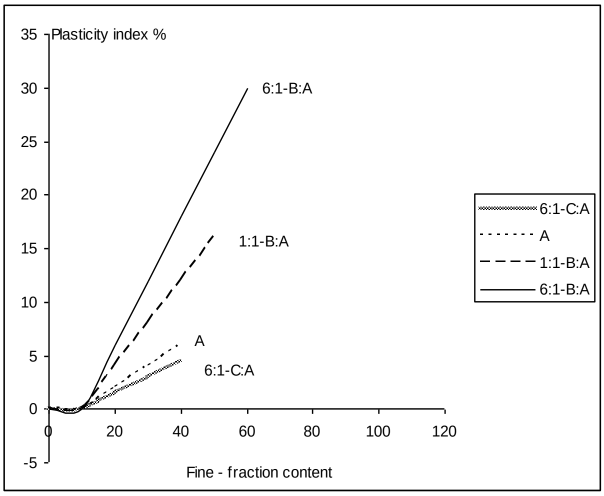

Figure 8. Variation of plasticity index

CONCLUSIONS

The behavior of clayey soils in the presence of water humidity can be estimated using free swell index and plasticity index.

Measured parameters are correlated to the fine fraction content (colloidal clay) and to mineralogical composition of these soils.

For minimize the shrink–swell behavior these soils must be stabilized with inactive materials.

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