Scientific Papers. Series E. Land Reclamation, Earth Observation&Surveying, Environmental Engineering. Vol. I, 2012
Print ISSN 2285 – 6064, CD-ROM ISSN 2285 – 6072, ISSN-L 2285 – 6064

SEAWATER INFLUENCE ON THE BEHAVIOR OF THE EXPANSIVE CLAYS

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Abstract

The paper aimed to determine the rate of change in swelling behaviour and liquid limit of clayey soils when exposed to natural seawater with respect to distilled water. The four clayey soil samples were gathered with different mineralogy and plasticity characteristics and tested to determine liquid limit and swelling characteristics in the presence of distilled water, tap water and seawater. The seawater effect is most noticed on the swelling behavior for montmorillonitic soils which have high plasticity.

Key words: *expansive clay, bentonite, free swell, liquid limit, seawater, tap water, distilled water*

INTRODUCTION

Expansive soils are clay soils with high shrink-swell potential. The clayey soils have the property to sensitively modify their volume when moisture changes. As moisture increase, the clay soils increase their volume and they shrink when moisture reduces [5]. These soils have long been recognized as important problem soils in geotechnical engineering, the swelling increase the rate of deterioration of the buildings causing expensive damages.

Numerous reports of expansive soil problems and related damage have been documented in different countries. The Association of British Insurers has estimated that the average cost of shrink-swell related subsidence to the insurance industry stands at over £400 million a year. In the US the estimated damage to buildings and infrastructure exceed $15 billion annually. The American Society of Civil Engineers estimates that one in four homes have some damage caused by expansive soils. In a typical year expansive soils cause a greater financial loss to property owners than earthquakes, floods, hurricanes and tornadoes combined [6].

The focus on this paper is on the behaviour of the plastics and swelling characteristics of different types of clay in presence of seawater, distilled water and tap water.

The studies in the professional literature reported that seawater have a strong impact on the engineering behaviour of clays, especially on the montmorillonitic clay.

Bentonite is very expansive and the dominant clay mineral is montmorillonite. Montmorillonite exhibits an extraordinary potential for volume change with the increase and decrease of water content in the clay.

According to our own studies, the influence of seawater in relation with liquid limits and free swell index was recorded for five types of clay soils, one of this clay is an montmorillonitic clay (bentonite).

MATERIALS AND METHODS

In this study, five clayey soils with different mineralogy were collected.

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

Based on the physical properties and the calculation relations, the following geotechnical parameters were determined: $A_{2\mu}$ - clay ratio with a less than 0,002 mm diameter; PI – plasticity index; AI – Skempton activity index; CP – plasticity criterion; CI – consistency index; LI – liquidity index.

Properties studied in relation to seawater and distilled water are: liquid limit and free swell index.

The liquid limit is measured following the Romanian standard test method (STAS 1913/4-86). The liquid limit represents the water content, in percent, of a soil at the arbitrarily defined boundary between the semiliquid and plastic states. The liquid limit can be determined by the Casagrande apparatus that consists of a semispherical brass cup that is repeatedly dropped on a hard rubber base (Photo 1). The liquid limit is defined as the water content at wich a groove cut into the soil placed in the cup will close over a distance of 10 mm following 25 blows.

Photo 1. The Casagrande apparatus

The free swell index is determined following the Romanian standard test method 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:

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

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

The free swell index can be determined using correlations proposed by O'Neil and Ghazzally (1977), Johnson and Snethen (1978).

Correlations have been a significant of soil mechanics from its earliest days. The correlations are generally semi-empirical based on some mechanics or purely empirical based on statistical analysis. These empirical expressions relate the swelling parameters to the geotechnical parameters that are determined by means of identification tests [9].

The model proposed by O'Neil and Ghazzally (1977) is written as follows:

$$S = 2.77 + 0.131 \cdot LL - 0.27w(\%) \quad (2)$$

While the model proposed by Johnson and Snethen (1978) is written:

$$\log S = 0.036LL - 0.0833w + 0.458(\%) \quad (3)$$

where S – free swell (%); LL – liquid limit (%) and w – natural water content (%).

SOIL CHARACTERISTICS

Table 1 shows the physical characteristics and the geotechnical parameters specifics for each soil sample.

Table 1. Physical characteristics of the soils

	Soil 1	Soil 2	Soil 3	Soil 4	Soil 5
Clay, %	67	63	50	53	100
Silt, %	27	32	36	47	0
Sand, %	6	5	14	0	0
$A_{2\mu}$, %	49	47	44	43	80
w, %	21.32	17.03	18	22.62	-
LL, %	62.19	64.57	43.36	52.65	256.55
PL, %	16.29	16.2	17.95	16.29	54.51
S, %	110	105	80	80	850
PI, %	45.1	48.37	25.41	36.36	202.04
CI	0.91	0.98	0.99	0.83	-
LI	0.09	0.02	0.01	0.17	-
AI	0.92	1.03	0.57	0.845	2.52
PC, %	30.79	32.53	17.05	23.84	172.68

RESULTS AND DISCUSSIONS

The influence of the seawater on the liquid limit is shown in table 2. In presence of seawater the liquid limit decreased.

Table 2. The influence of seawater on the liquid limits and free swell index

Sample #	**Liquid limit (%) / Free swell (%)**		
	Distilled water	Tap water	Sea water
1	62.19 / 110	62.04 / 115	58.33 / 115
2	64.57 / 105	64.38 / 105	61.88 / 110
3	43.36 / 80	43.29 / 75	41.26 / 80
4	52.65 / 80	52.54 / 80	50.48 / 80
5	256.55 / 850	253.17 / 840	120.24 / 400

These trends are quite consistent with diffuse double layer theory. Increasing the salt concentration and the cation valence decreases the inter-particle distances, resulting the decrease of the liquid limit [10].

The swell indexes of the samples were determined in the presence of distilled water, tap water and seawater. The results are shown in table 2 and fig. 1. The swelling characteristics of the soils wich have low liquid limit (LL < 150...200 %) are not significantly affected by seawater. Furthermore, non-swelling soils have slightly higher volume in the presence of seawater than distilled water (Photo 2).

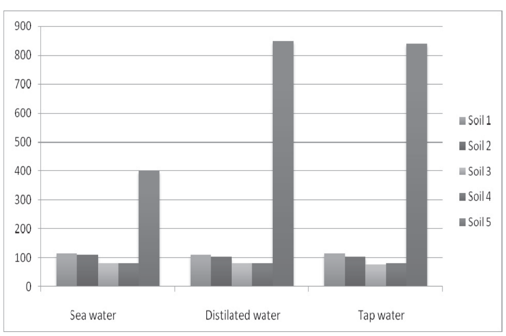

Fig 1. The differences of free swell index

Sridharan (1991) argue that kaolinites have an ability of making edge-to-face particle arrangements because of change in pore fluid chemistry and form flocculated fabrics that govern the engineering properties. The air pockets occurred between the flocculated particles capped the available water during the tests and caused an increase in the liquid limit and sediment volumes of kaolinites. This phenomenon is valid to some extent for mainly kaolinitic and illitic glacial tills. In this regard, the swell volumes of this type of soils can be higher in the seawater because of the flocculated structure [8].

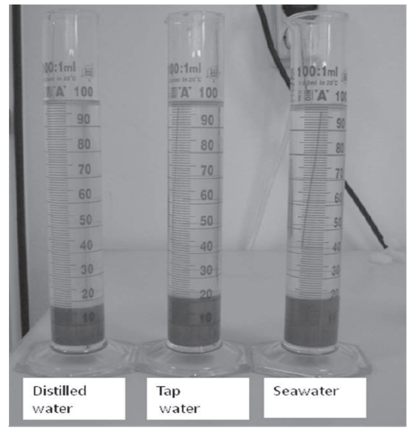

Photo 2. The volume for non-swelling soils in the presence of seawater

The swelling behaviour difference can be clearly seen in Photo 3. The amount of the clay are 12 grams in the three graduated cylinders. In cylinder 1 we have seawater, in the second cylinder we have distilled water and in the third cylinder we have tap water. However, the swell volumes of the samples are extremely different from each other. It should be noted that this difference cannot be seen for non-swelling soils.

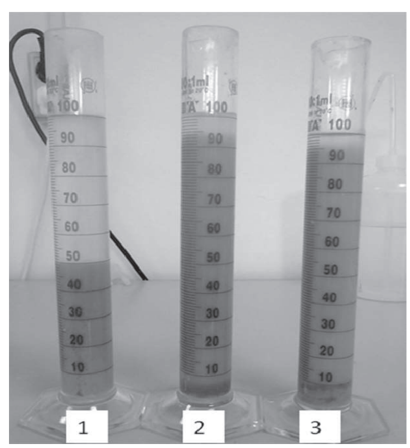

Photo 3. Free swell index determination of the soil 5 (Bentonite)

CONCLUSIONS

In this study, the liquid limit and free swell index were investigated in the presence of seawater, distilled water and tap water.

Based on the laboratory tests regarding the influence of the seawater on expansive soils, the following conclusions may be drawn:

- The differential free swell percent is lower than that in tap water and distilled water for swelling soils (LL > 150...200 %), indicating reduction in swelling potential in seawater;
- The difference in free swell percent between distilled water and seawater is remarkable, between 0% to 200%; zero is for non-swelling soils and 200% is for bentonite;
- The liquid limit decrease in presence of seawater; values of all liquid limits in seawater are lower than those in tap water. This difference can be seen more clearly for the bentonite sample.

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