THE EFFECT OF CEMENT AND FLY ASH ON THE UNDRAINED SHEAR STRENGTH OF CLAYS

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SUMMARY

The study takes into consideration the effect of chemical agents in stabilizing soils considered to be of weak properties. The methodology is based on the procedure of mixing the soil with chemical agents in various proportions, namely, cement as 1%, 3% and 5% of the dry mass of soil, as well as its combination with fly ash in the following proportions: 1.5C-8FA, 3.5C-8FA, 5.5C-8FA, 3.5C-6FA and 3.5C-10FA. The clay material used for this purpose was collected in the area of Currila, Durrës, and the tests determined the effect of these chemical agents in changing the undrained shear strength of the soil.

Key words: chemical agents, weak soils, undrained shear strength.

INTRODUCTION

In analyzing the problem encountered with Pliocene clays in Currila hill in Durrës, Albania, a significant role is identified in the undrained shear strength parameter for increasing the stability of the slope. The location chosen lies along the western coast of Albania and it is affected by periodical landslides occurring along the slope as a result of a weathering process of the clay material, followed by the development of a system of crevices that over time accumulate water, thus lowering the mechanical strength parameters of the clay. One of the methods employed for the treatment of clayey soils is mixing them with various percentages of chemical agents, such as cement and fly ash. This procedure was computed last year with significant results.

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In this study, the effect of such agents is considered in changing the undrained shear strength parameter of the soil, thus influencing the stability of the slope. The calculations of this parameter were made possible by taking into account the results obtained from the fall cone test, as well as from parameters that were derived from this test, such as the Liquid Limit and Liquidity Index of the clay.

METHODOLOGY

The undrained shear strength parameter is usually determined via the unconfined compressive strength (UCS) test and triaxial test, but also using a number of empirical formulas from literature that relate the fall cone test with this parameter (Strozyk & Tankiewicz, 2013; Nagaraj et al., 2012; Tanaka et al., 2012). The fall cone test procedure, according to BS EN ISO 17892-6:2017, determines the liquid limit of the soil through the penetration of a standard cone dropped for 5 seconds from a position where the tip is in contact with the soil surface. The penetration of the cone for 20 mm inside the soil that fills a cylindrical vessel of standard dimensions corresponds to the liquid limit of the soil. Hansbo (1957) suggests a relation between the undrained shear strength of the soil and cone penetration given in Equation 1:

$$c_u = K\frac{mg}{d^2} \qquad \text{(Eq.1)}$$

where: c_u – undrained shear strength (kPa); K – constant (no units); m – mass of the cone (g); g – ground acceleration (m/s^2); d – cone penetration (mm).

The dimensions and weight of the cone may vary, but for this study a standard cone of 80 grams and 30 degrees tip angle was used. For such characteristics, the value of K is considered as 0.867 (Vardanega & Haigh, 2014). Taking into account the various cone penetration measurements (in millimeters) obtained from this test for mixtures of clay with 1%, 3% and 5% cement, as well as the combinations of cement-fly ash of 1.5C-8FA, 3.5C-8FA, 5.5C-8FA, 3.5C-6FA and 3.5C-10FA – cured for 24 hours – Table 1 shows the values of undrained shear strength calculated with this formula. For every mixture, four different water content (w) values were considered, thus also calculating the Liquidity Index I_L based on the values for Liquid Limit (LL) and Plastic Limit (PL), shown in Equation 2 according to Atterberg (1911):

$$I_L = \frac{w - PL}{LL - PL} \quad \text{(Eq.2)}$$

The above parameter made possible the comparison of these results calculated according to Hansbo (1957) with the calculations of the undrained shear strength according to the formula proposed by Leroueil et al. (1983), which relates this parameter to the Liquidity Index, given by Equation 3:

$$c_u = \frac{1}{(I_L - 0.21)^2} \quad \text{(Eq.3)}$$

Table 1: Cone penetration results for various admixtures cured for 24 hours and undrained shear strength calculated according to Hasbo (1957)

	LL	PL	w	d (mm)	I_L	Cu (kPa)
1%C	55.2%	24.6%	48.2%	14.4	0.77	3.29
			51.4%	16.9	0.88	2.39
			54.1%	18.8	0.96	1.93
			58.4%	22.6	1.10	1.33
3%C	56.5%	27.8%	47.0%	12.3	0.67	4.50
			52.8%	17.4	0.87	2.24
			55.2%	18.9	0.96	1.90
			59.8%	22.7	1.12	1.32
5%C	55.7%	30.3%	49.8%	14.3	0.77	3.32
			52.9%	17.1	0.98	2.32
			56.5%	20.5	1.12	1.62
			59.8%	24.4	1.25	1.14
3.5C/6FA	54.3%	26.6%	50.1%	16.2	0.85	2.59
			52.1%	17.6	0.92	2.20
			56.3%	21.5	1.07	1.47
			58.5%	24.6	1.15	1.13
3.5C/8FA	54.4%	26.8%	50.6%	15.8	0.86	2.71
			53.9%	19.9	0.98	1.71
			56.5%	22.2	1.08	1.38
			60.3%	26.1	1.21	1.00
3.5C/10FA	55.3%	29.2%	50.5%	14.8	0.82	3.10
			55.0%	19.7	0.99	1.75
			57.1%	22.4	1.07	1.36
			59.4%	24.7	1.16	1.11
1.5C/8FA	52.9%	24.3%	48.3%	15.6	0.84	2.78
			52.4%	19.4	0.98	1.81
			53.8%	20.9	1.03	1.56
			57.6%	24.7	1.16	1.12
5.5C/8FA	0.5347	0.285205	47.9%	13.8	0.78	3.55
			51.1%	16.7	0.91	2.43
			56.8%	24.1	1.14	1.18
			58.1%	25.5	1.18	1.05

Another formula proposed by Federico (1983) relates the undrained shear strength parameter to the Liquid Limit and the water content of the mixtures. Just like in the example above, this parameter relates to soil consistency depending on the value of the water content. Federico (1983) relation is given by Equation 4:

$$c_u = e^{[5.25(1.161 - w/_{LL})]} \qquad \text{(Eq.4)}$$

The calculations were based on the values of the Liquid Limit parameter for the admixtures of cement and cement-fly ash cured for 1, 24 and 48 hours.

RESULTS

Figure 1 shows the comparison between the results obtained. The blue line in the graph denotes the relation proposed by Leroueil et al. (1983), whereas the various symbols represent the values of the undrainsed shear strength calculated according to Hasbo (1957), in admixtures cured for 24 hours. The results clearly indicate a significant compatibility between the formulas used by the two authors. The values for undrained shear strength fluctuate from 1 kPa to 4.5 kPa, according to the consistency of the soil.

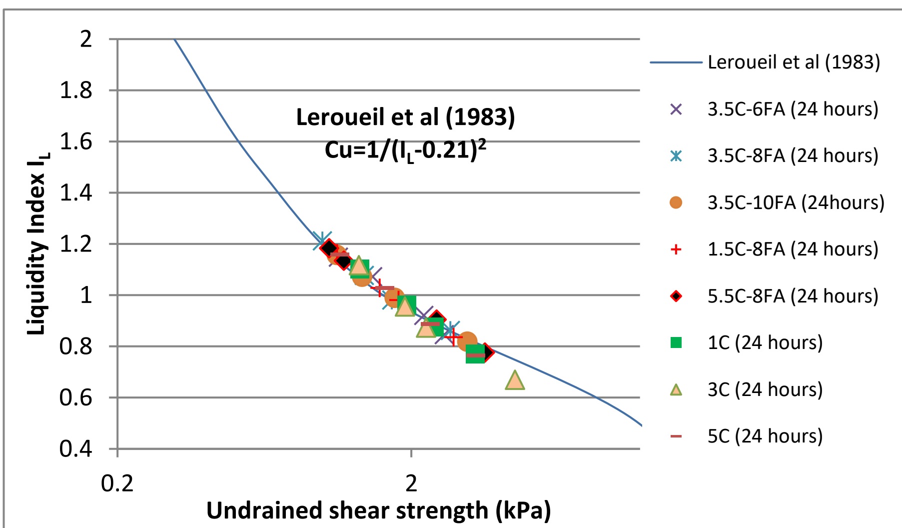

Figure 1: Comparison of undrained shear strength values according to Hansbo (1957) dhe Leroueil (1983)

For the formula proposed by Federico (1983), the reference value considered for the water content parameter was the one corresponding to the liquid state of the clay. This is because site surveys have shown that this is the consistency of the clay when slope failure occurs during the rainy season. The Liquid Limit for the natural soil was determined to be 55%, as shown in Figure 1:

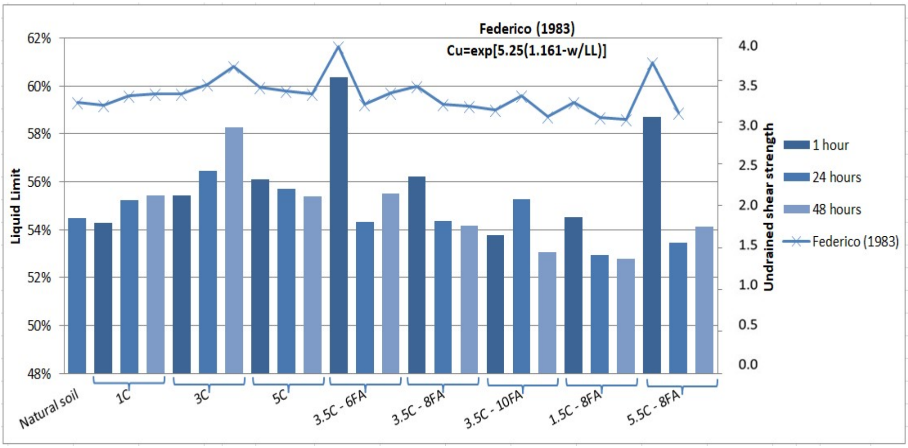

Figure 2: Fluctuation of undrained shear strength values according Federico (1983)

The vertical axis on the left side of the graph shows the values reached by the Liquid Limit parameter (the bars of various shades of blue, according to the curing period), whereas the right side of the graph vertical axis shows the values of the undrained shear strength in kilopascals (relating to the blue line at the top). As it can be observed by the graph, the obtained values for undrained shear strength are similar to those obtained in the previous case.

CONCLUSIONS

From the results obtained by the fall cone test regarding the values of the Liquid Limit of the clay mixed with various chemical agents, the undrained shear strength values were obtained based on correlations from empirical formulas. The results demonstrated a concordance between the formulas proposed by Hansbo (1957) and Leroueil et al. (1983). The values of the undrained shear strength fluctuate from 1 kPa to 4.5 kPa, depending on the consistency of the soil. According to Table 1, the highest consistency was achieved for a mixture with 3% cement after a 24-hour curing period. These values were also compared to an analysis proposed by Federico (1983), thus obtaining similar results, pointing to the fact that the presence of water in the soil accounts for significant fluctuations of the undrained shear strength parameter based on its consistency.

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