Effect of lime and gypsum on stabilization of high plasticity clay, Ankara, TURKEY

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KEYWORDS

Lime, gypsum, swelling percent, swelling pressure, unconfined compression strength

ABSTRACT

Clayey soils may cause swelling, settlement and strength issues when used as foundation or fill material. Various mechanical and chemical techniques are available to stabilise such soils. The Upper Pliocene aged clay with high plasticity is spread out around Ankara (Turkey), especially at Batikent residential area. Several geotechnical problems caused by the high plasticity clay are still reported at this region. The aim of this study is to investigate the effect of lime, gypsum and lime+gypsum additives on the swelling percent, swelling pressure and unconfined compression strength of clay with high plasticity in order to determine the optimum mixture. The optimum water content and dry unit weight of natural clay were determined through standard compaction. Admixtures of 3, 6, 9, 12 and 15% lime, gypsum and lime+gypsum (half/half) were prepared and tested at the end of 90 days. It is concluded that, swelling percent and swelling pressure reduce with increasing additive percent and time, while the unconfined compressive strength increases. The optimum mixture is adding 6% lime which corresponds to a 99.55 % decrease for swelling percent, 98.98% decrease for swelling pressure and 191.87 % increase for the unconfined strength along 90 days.

1. INTRODUCTION

Clayey soils should be specially treated in terms of geological and geotechnical aspects; such as bearing capacity, settlement, swelling, etc. Soil improvement techniques should be applied in case of instability issues. Cement, lime, gypsum, fly ash and bitumen are such materials used for chemical improvement (Van Impe 1989).There exist many studies about the geotechnical properties of Upper Pliocene deposits (Birand 1965, 1977, 1993; Arda 1966; Kasapoğlu 1982; Kiper 1983; Kılıç and Demirbaş 1989; Kılıç 1990; Ergüler et al. 2002). Moreover, Tonoz et al. (2003) showed that, after 28 days of curing time mixtures of Ankara clay with lime columns have increased preconsolidation pressure. The compressive strength of clay increases by adding different amounts of gypsum (Degirmenci, 2008). Yılmaz and Civelekoğlu (2009) concluded that, gypsum has an active role in the improvement process of swelling clayey soils after seven days of curing time. The uniaxial compressive strength of kaolinite increases by 21 times within ten years by adding 4% and 12% of lime by mass (Kavak and Baykal, 2011).

The aim of this study is to investigate the effect of gypsum, lime and lime + gypsum admixtures (half/half) at periods of 90 days on the swelling percentage, swelling pressure and unconfined compression strength of the clay with high plasticity at Batikent residential area.

2. MATERIAL AND METHOD

Reddish brown and gray colored clay with high plasticity within Upper Pliocene Deposits had formed as the weathering products of the volcanic rocks within a lake environment (Erol 1954, Kasapoğlu 1982, Kiper 1983, Ulamış and Kılıç 2009). Clay samples were collected from three different construction sites (Figure 1). Lime and gypsum were provided from Elmadağ and Bala. Mineralogical composition of clay, lime and gypsum were determined through XRD. The index properties, dry unit weight vs. optimum water content were tested using ASTM (2008) standards. Mixtures were prepared by adding 3, 6, 9, 12 and 15 % of lime, gypsum and lime+gypsum by mass. Cylindrical samples were prepared through standard compaction with respect to predetermined γ_{dmax} and w_{opt} values for swelling percent, swelling pressure and unconfined compression strength tests using the average values of three tests along 90 days.

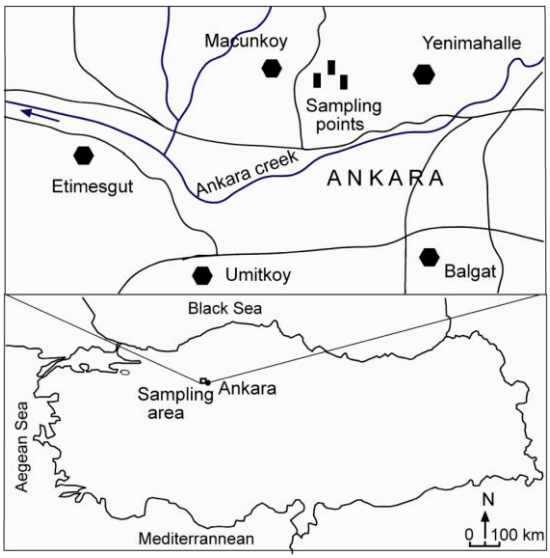

Figure 1. Location of the sampling points

3.GEOTECHNICAL AND CHEMICAL PROPERTIES OF CLAY

Some geotechnical properties of grayish clay samples are given in Table 1. The clay exhibits "high plasticity" due to its liquid limit and plasticity index (Leonards, 1962).Chemical composition of clay is determined (Table 2) and semi quantitative analysis results of clay are given in Figure 2. Clay consists of MgO, Al_2O_3, $Fe_2O_3$and K_2O components which indicate smectite and illite minerals. Existence of SiO_2 with a percent of 48 is a result of quartz within the samples.

Table 1. Mean values of index and mechanical properties of clay

Liquid limit (LL, %)	84
Plastic limit (PL, %)	32
Plasticity index (PI, %)	52
Optimum water content, (w_{opt}, %)	24
Maximum dry unit weight (γ_{dmax}, kN/m^3)	14.75
Unconfined compression strength, q_u (kPa)	438
Swelling percent (%)	17.67
Swelling pressure (kPa)	165.23

Table 2. Chemical composition of clay

Components	%	Components	%
Na_2O	0.37	CaO	0.82
MgO	2.29	TiO_2	0.79
Al_2O_3	12.76	V_2O_5	0.03
SiO_2	48.12	Cr_2O_3	0.01
P_2O_5	0.02	MnO	0.14
SO_3	0.16	Fe_2O_3	5.82
Cl	0.07	Loss on ignition	26.88
K_2O	1.72	Total	100.00

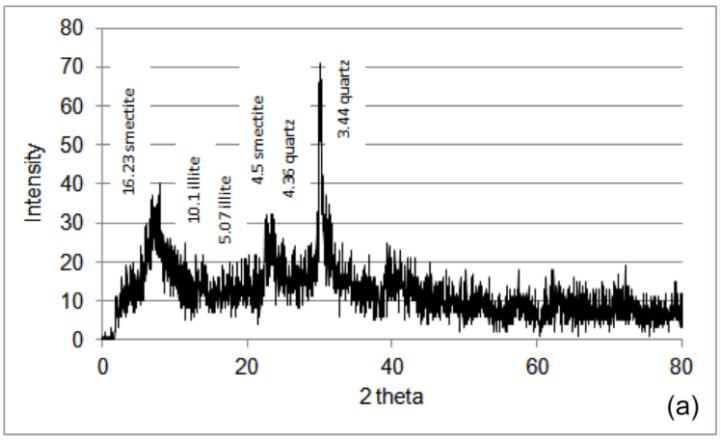

Figure 2. Semi-quantitative XRD scan representing the peaks of clay components

4. THE EFFECT OF ADDITIVES ON THE IMPROVEMENT OF CLAY

Lime ratio vs. swelling percent and swelling pressure relations obtained at 90 days are given in Figure 3. Swelling percent decreases by increasing ratios of lime along all time periods. Here, after a distinct reduction at 3% lime ratio, the 6% can be concluded as the optimum mixture ratio to stabilize the swelling percent. The 6% ratio seems to be the optimum boundary to reduce the swelling pressure (Figure 3).

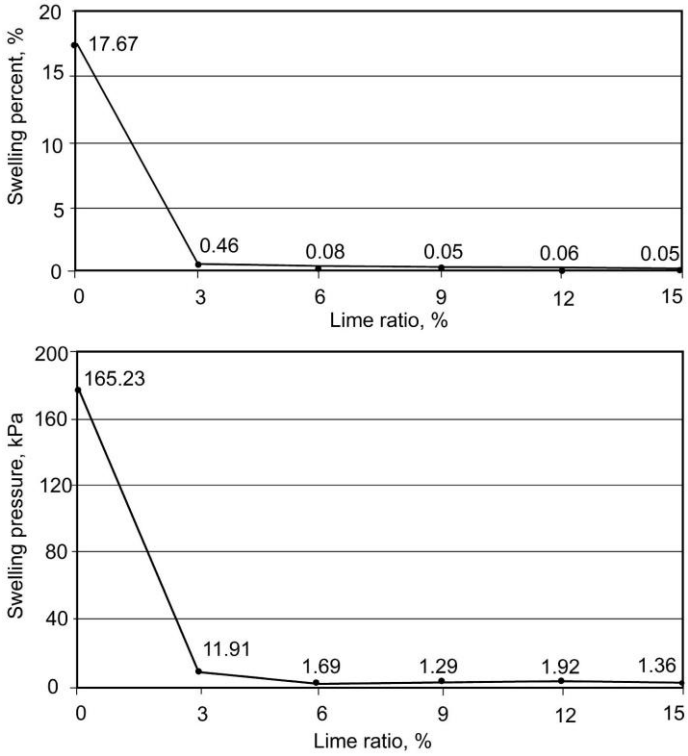

Figure 3. Lime ratio vs. swelling percent and swelling pressure at 90 days

Gypsum ratio vs. swelling percent and swelling pressure obtained at 90 days are given in Figure 4. Gypsum reduces the swelling percent just like the lime, however the reduction ratio is lower than that of lime additive. Unlike lime, adding 3% of gypsum could be the optimum ratio for swelling percent. Adding 15% of gypsum decreases the swelling pressure by 74.75% at 90 days (Figure 4).

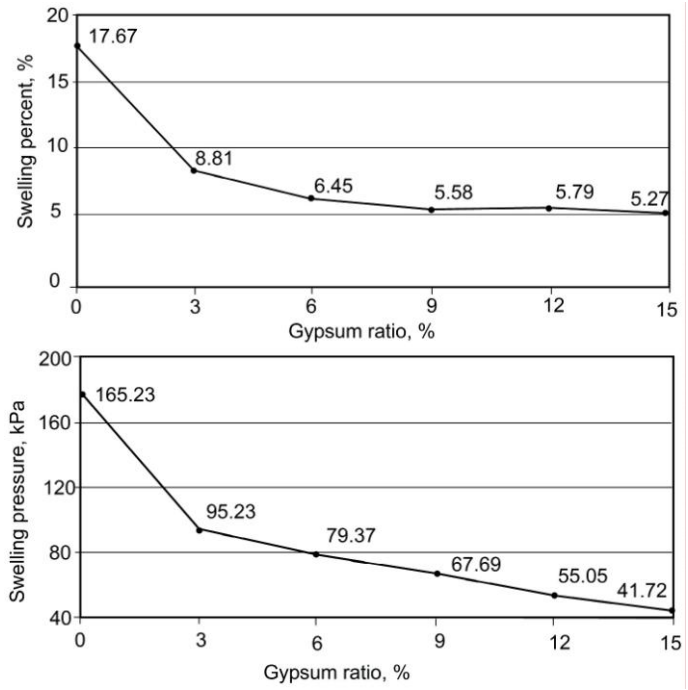

Figure 4. Gypsum ratio vs. swelling percent and swelling pressure at 90 days

Lime+Gypsum ratio vs. swelling percent and swelling pressure relations obtained at 90 days are given in Figure 5. Adding lime+gypsum at all the ratios decrease the swelling percent and there is an obvious reduction at 6%. Adding 15 % of lime+gypsum, the swelling pressure decreases by 91.38 % at 90 days (Figure 5).

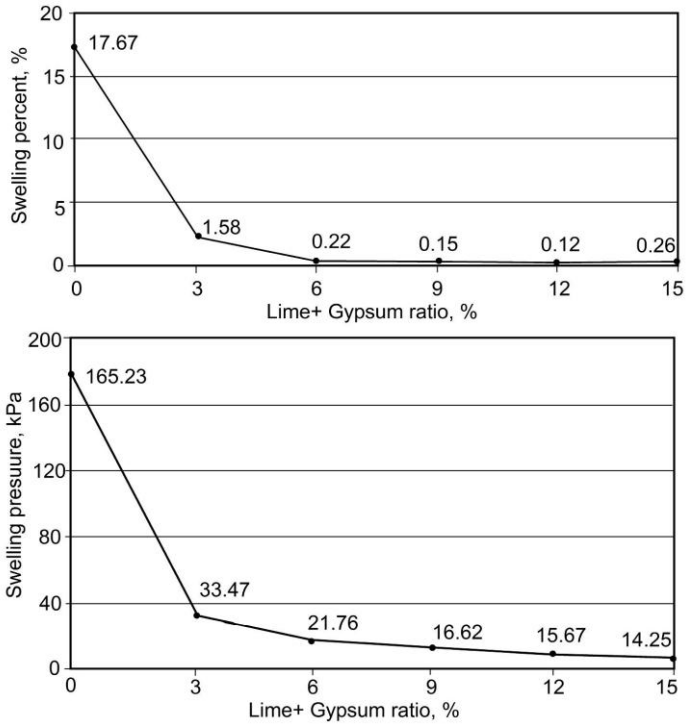

Figure 5. Lime + Gypsum ratio vs. swelling percent and swelling pressure

Lime, gypsum and lime+gypsum ratios vs. unconfined compression strength obtained at 90 days are given in Figure 6. For all the mixture ratios and periods, the effect of gypsum on compressive strength is not accurate as to the swelling percent and pressure. Adding 15% of lime for 90 days seems to stabilize the strength which is 7 times higher than the original value. Similar to the lime alone, lime+gypsum increases the strength for all the ratios and time intervals.

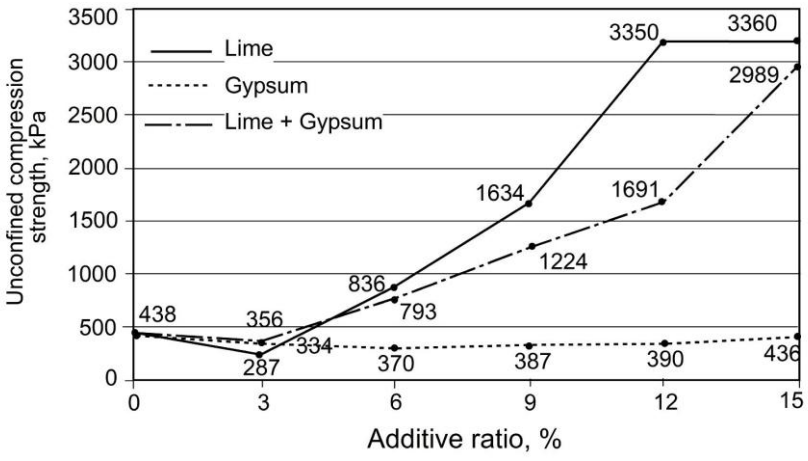

Figure 6. Additives vs. unconfined compression strength

5. RESULTS AND DISCUSSIONS

Clay consists of 48.12% SiO_2, 12.76% Al_2O_3, 5.82% Fe_2O_3, 2.29% MgO, 1.72% K_2O, 0.82% CaO and 0.37% MgO according to order of abundance. According to XRD analysis, Na-smectite exists in the clay.

Na-smectite exists within the investigated clay which involves high swelling percent and swelling pressure potential. In case lime is added to clay, Na replaces with Ca, transforming Na-smectite into Ca-smectite which has low swelling percent and swelling pressure.

Since it seems hard to obtain a homogenous mixture of lime and gypsum and cost would be high, stabilization with lime might be more favorable. The highest improvement rate is for the 15% lime addition at the end of 90 days however, there is a negligible difference from the 6% ratio

The time period is limited with 90 days in this study. It must be considered that, the swelling percent and swelling pressure will decrease while the unconfined compression strength will increase with progressing time.

It is concluded that, using 6% of lime would be enough to stabilize the high plasticity clays in order to deal with the swelling, settlement and bearing capacity problem for the constructions around Batikent area. It is appropriate to determine the thickess of the filling material and the loading vs. deformation relations of such layers might be tested by plate loading and California bearing ratio tests.

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