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Improvement of the Strength of Ankara Clay with Self-Cementing High Alkaline Fly Ash

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Abstract

Turkey's plants are fired by lignite, producing class C fly ash containing a high percentage of lime. Sulphate and alkali levels are also higher in class C fly ashes. Therefore, fly ash is, commonly, unsuitable as an additive in cement or concrete in Turkey. In this study, highly alkaline fly ash obtained from the Yenikoy thermal power plants is combined with soil samples in different proportions (5%, 15%, and 25%) and changes in the geomechanical properties of Ankara clay were investigated. The effect of curing time on the physical-mechanical properties of the fly ash mixed soil samples was also analyzed. Free swelling index values showed a decrease of 92.6%. The California bearing ratio has seen a more drastic increase in value (68.7 times for 25% fly ash mix).

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Keywords: Fly ash, Ankara clay, cohesion, internal friction angle, California bearing ratio;

1. Introduction

Turkey is the main source of energy for forming the low thermal valuable lignite thermal power plants. There are 16 coal-burning thermal power plants currently operated. This number is expected to rise to 46 in the future. The ash is removed from the existing thermal power plants in Turkey, but a small proportion of it, 2%, is recyclable. Turkey's plants are only fired by lignite, a class C fly ash containing a high percentage of lime. Sulphate and alkali contents are also higher in class C fly ashes. Therefore, fly ash is, generally, unsuitable as an additive in cement or concrete in

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Turkey. Fly ash is used to stabilize the fine-grained soils so that a stable working platform can be provided for highway construction equipment [1,2]. Many studies on the performance of the fly ash mixed soil have claimed that class C fly ashes are very useful to ameliorate physical-mechanical properties of cohesive soils [3, 4, 5].

Ankara Clay consists of a sequence of lacustrine sediments that comprises the surface of the Ankara Valley and extends in places down to 100 m. These expansive soils are found in central, western, and southern parts of Ankara, the capital of Turkey. During the past decades, the rapid expansion of the city and its population because of internal migration from different regions of Turkey have led to the intensive construction of various kinds of structures, especially low-cost and one-story buildings in suburbs, and have resulted in expanded networks of streets and buried utilities. Because of the expansive nature of this clay, damage to the roads and low-rise buildings caused by differential volume change of the clay occurs, particularly in the southern part of the city. This damage caused by the swelling has been deliberately ignored in both design and construction, however, because of limited budgets, poor construction methods, poor quality control, inadequate water drainage, and ineffective remedial measures [6].

In this study, highly alkaline fly ash obtained from Yeniköy thermal power plants are mixed with soil samples in different proportions (5%, 15%, and 25%) and changes in the geomechanical properties of Ankara Clay were investigated.

2. Materials

Three block samples of the expansive clay have been extracted in the vicinity of Ankara (Turkey) (Fig. 1). That expansive soil has been named Ankara Clay (AC) in literature. The colour of AC is red, and it includes lime bands.

AC was analysed in the laboratory and found to have a plastic limit (PL) of 35%, a liquid limit (LL) of 88.7% and plasticity index (PI) of 53.7%. The soil sample was classified as "CH" by the unified soil classification system. Furthermore, it has high activity (A=1.49>1.24). It includes 36% clay, 47% silt and 17% sand-sized materials.

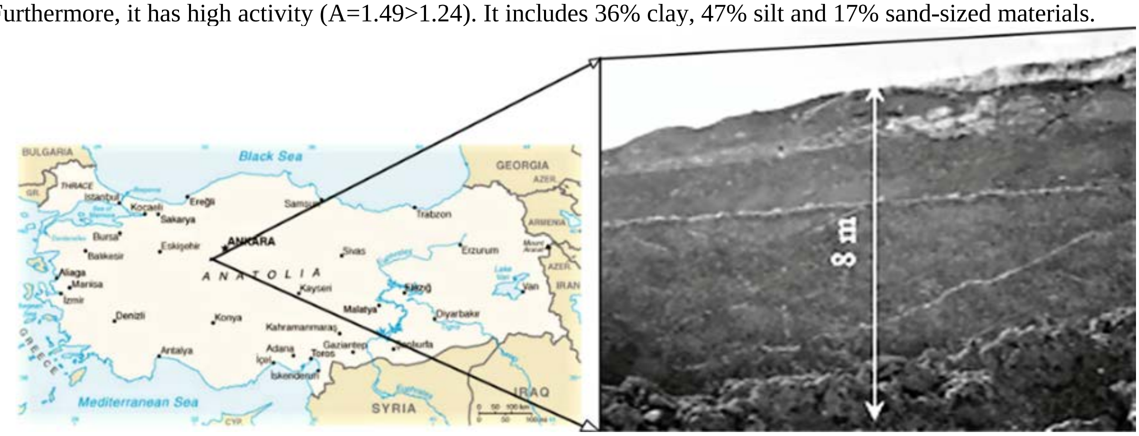

Fig.1. The sampling area of AC.

Fly ash was obtained from the second unit of Yeniköy Thermal Power Plant. XRF analyses were realized to be classified fly ash. Yeniköy fly ash (YFA) is over 10% reactive lime (21.80%) due to TS EN 197-1 [7], and W class (calcareous fly ash). The morphological analysis results show that usually, semi-spherical and spherical glass beads have a grain size between 2.1-16.89 μm as well as rough surfaces, both perfectly balls shaped and irregularly shaped particulate. XRD diffractograms show that YFA includes quartz, free lime, anhydride, gehlenite, hematite, calcite.

3. Method and Results

This study determined effects of the fly ash additives on the strength of clay soil. AC was mixed with fly ash in 5%, 15%, and 25% proportions. Mixtures were cured at 1, 7, and 28 days. During the curing periods, samples were stored in rooms with 90 RH%. The California bearing ratio (CBR), and swelling index tests were used on the cured samples, all tests to ASTM (D1883) and Indian (IS2720) standards [8,9].

3.1. CBR tests

CBR tests were carried out in 98% modified proctor stiffness. All CBR test samples were prepared at the optimum water content (6.4%). During cure periods, prepared CBR samples have waited under load (7 kg), which present overburden pressure of the sampling depth of AC. The results of CBR tests show that curing period is active in CBR values. All samples, including FA, present a high increase in CBR values after seven days curing (Fig. 2). However, declines were observed in the CBR results of the samples, not including FA. This is due to curing condition. AC samples started to swell when taking in water in the humidity cabinet. Therefore, they have begun to lose their stiffness and CBR after one-day curing. In contrast, other samples containing FA grew stiffer with curing time. The most increment ratio (68.7 of 25% FA at the 28 days) on the CBR values were observed in the samples that include 25% FA (Fig. 3). Increment ratio was calculated by CBR value of FA mix was divided by CBR value of AC.

Furthermore, some physical changes were observed on the 25% FA mixtures. Although the colour of AC is claret red, 25% FA mix colour was changed to brownish green. As well, 25% FA mix samples have shown brittleness.

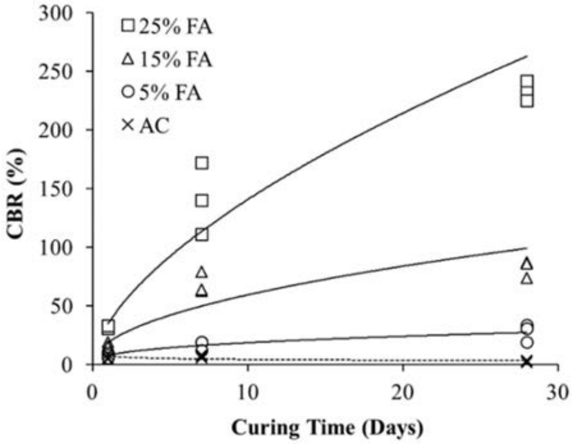

Fig. 2. The effects of the curing period and FA content.

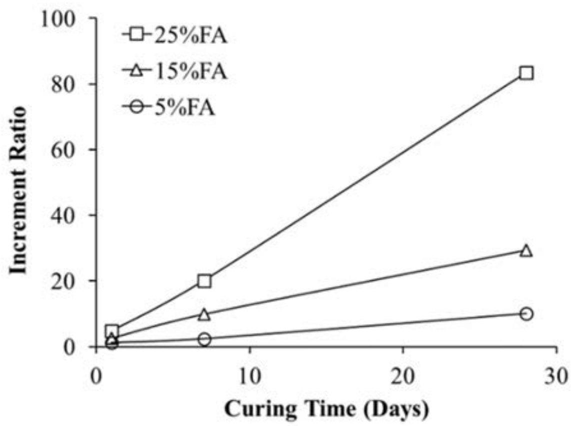

Fig. 3. Increase at the CBR values.

3.2. Free Swell Index

Free swell is the increase in the volume of soil, without any external constraints, on submergence in water. The possibility of damage to structures due to swelling of expansive clays needs to be identified, at the outset, by an investigation of those soils likely to possess undesirable expansion characteristics. Inferential testing is resorted to reflect the potential of the system to swell under different simulated conditions.

The actual magnitude of swelling pressures developed depends on upon the dry density, initial water content, surcharge loading, and several other environmental factors. Tests were carried out as to the Indian standard (IS: 2720). The views of samples at the end of tests were given in Fig. 4. The first tube included kerosene and sample, and the second water and sample. Some tubes which contained water and sample were losing intensity depend on some fly ash additives.

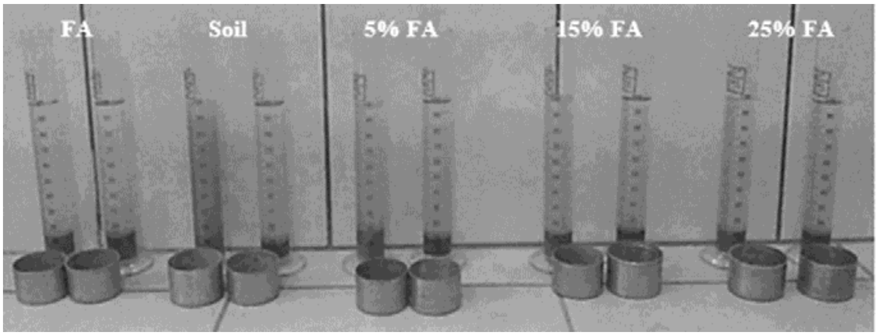

Fig. 4. Tubes of free swell index tests.

Free swell index values of soil samples were decreased with the amount of fly ash in the mix (Fig. 5). The free swell value of 25% of fly ash mixed soil sample was close to 0%. With 5% FA mixed soil samples, the swelling ratio decreased by 27% in value as well as with 25% FA; it declined by 93% (Fig. 6). Clayey soils, even with a very low rate of participation in the fly ash, can considerably reduce swelling potential. No level change appeared in the free swell test of Yeniköy FA. Therefore, we set free swell index at 0%.

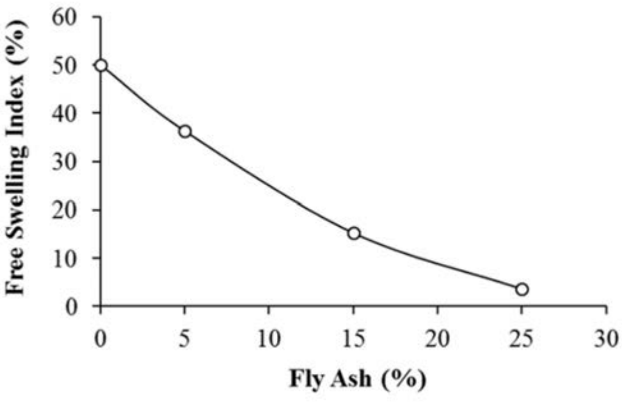

Fig. 5. Free swelling index vs. the amount of FA content.

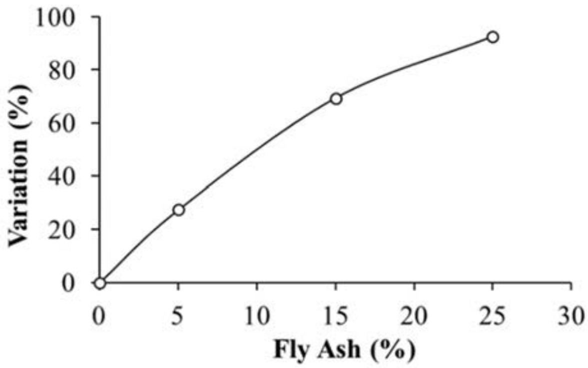

Fig. 6. Free swelling index variation vs. the amount of FA content.

4. MLR evaluation

Multiple regression analyses were realized to obtain the relationships between curing periods (d, days) and fly ash content (FA, %). XLSTAT of Addinsoft was used to create the regression models. The best model (R^2:0.70) for CBR values were presented in the Equation 1 (Fig.7).

$$CBR\ (\%) = -31.85 + 2.39*d + 5.16 * FA \tag{1}$$

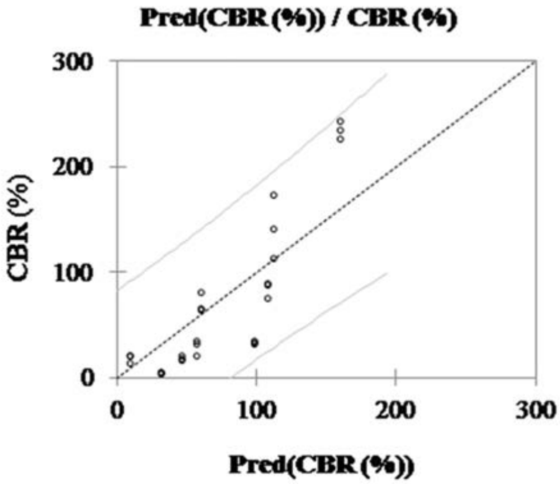

Fig. 7. Measured and predicted CBR values derived from Eq.1.

5. Conclusions

On the basis of the work reported in this paper, the following conclusions have been drawn:

1. CBR values of AC were drastically increased with fly ash additive. Furthermore, soil samples, including a high percentage if FA showed stiff view and brittle behaviour.
2. There is a robust relationship between shear strength parameters and curing periods with fly ash content. Furthermore, the same inference was determined for CBR values.
3. The values of the swelling index were dramatically decreased with fly ash additive.
4. As to this study, Ankara Clay could be stabilized successfully with about 10% or more of Yenikoy fly ash.

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