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STRENGTH PROPERTIES OF MICROFINE CEMENT STABILIZED HIGHLY PLASTIC CLAY

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Summary:
In this experimental study, strength properties of microfine cement stabilized high plasticity clay was investigated. The results showed that the physical and mechanical properties of high plasticity clay such as consistency limits, compaction behavior, unconfined compressive strength were influenced. Decrease in cement particle size decreased the liquid limit and dry unit weight but increased the wet unconfined compressive strength of high plasticity clay. In addition, the curing environment had an effect on the strength and consistency limits of microfine cement stabilized high plasticity clay such that UCS and plastic limit increased but the liquid limit decreased.

Keywords:
stabilization; cement grain size; clay; strength; consistency limits

1. INTRODUCTION

High plasticity clay occures in many parts of the world. Their significant characteristics include high plasticity, low strength, high swelling and shrinkage potential. These soil properties often result in bearing capacity problems in building foundations, buried utilities, highways and airfield pavements [23]. The annual cost of damage to buildings, structure and roads caused by expansive soils is estimated at £150 million in the UK, $1000 million in the USA and many billions of ponds worldwide[16]. In order to overcome these problems, there are many treatment methods for stabilising natural expansive soils that have been suggested by various researchers. These methods generally include mechanical and chemical stabilisations. Chemical stabilization mostly includes the addition of additives such as lime, cement and fly ash. They cause a chemical reaction to occur in soil water system that finally stabilises the soil.

Cement stabilization of clay soils to improve their engineering properties is well known and practiced worldwide. Cement stabilization reduces the plasticity of soil thus making it more workable. Inaddition, its compressive strength and load bearing properties are improved by a number of chemical processes that occures in the presence of cement [13]. Such factors as types and plasticity of soil, amounts of cement, mixing and compaction methods, curing conditions, gradation and pulverization, etc., affect the performance of stabilized soil. These issues were investigated and discussed in detail by several authors [1, 11, 12, 15, 17, 21, 22, 24, 25, 28]. However, the effect of cement particle size on engineering characteristics of clay soils has not been taken into account so far. In this research, which is part of comprehensive study, the aim was only focused on the effect of cement particle size on the unconfined compressive strength of cement stabilized highly plastic clay.

2. MATERIALS USED

2.1. Clay

The soil used in this study was obtained from Golbası region in Ankara, the capital city of Turkey. A nearly 0.5 m thick layer of agricultural loam comprising the top soil was clearly removed and block samples were taken at depths varying from 1.0 m to 1.5 m. No ground water table was observed at these depths. The disturbed soil with a blocky and friable structure was transported to the Soil Mechanics Laboratory of Gazi University and devided into small pieces, sprayed over the floor and exposed to air at room temperature until it dried.

The particle size distribution (Chart 1), consistency limits, specific gravity, organic content were determined (Table 1) with respect to ASTM D 422-63 [3], ASTM D 4318-10e1 [4] and ASTM D 854-02 [5], respectively. The soil was classified as high plasticity clay (CH) (Table 1) according to Casagrande plasticity chart [6].

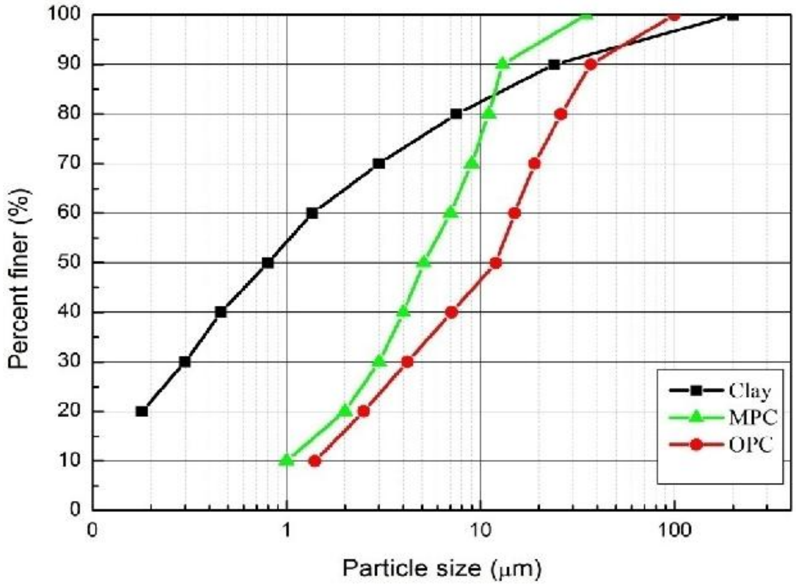

Chart 1. Particle size distribution of Clay, OPC and MPC

Table 1. Properties of soil

Basic characteristics and description	Values
Specific gravity	2.80
Passing No. 200 sieve (<0.075 mm) (%)	98.6
Plastic limit (%)	32
Liquid limit (%)	104
Plasticity index (%)	72
Free Swell (%)	17.7
soil class (USCS)	CH
Organic material (%)	2.29

2.2. Ordinary Portland and Microfine Portland Cements

Cements used in this study were Ordinary Portland Cement (OPC) and Rheocem 650 named as Microfine Portland Cement (MPC). Rheocem 650 is a well-graded cement milled from pure Portland cement clinker. The grain size distributions of both cements were obtained from Laser Particle size Analyzer and shown in Chart 1. As seen from Chart 1, the particle sizes of Rheocem 650 were much smaller than those of Ordinary Portland cement. The grain size distribution of high plasticity clay was also given in Chart 1 in comparision with those of cements. Furthermore, the properties and chemical composition of the cements were summarised in Table 2.

Table 2. Pysical and Chemical properties of OPC and MPC

	OPC	MPC
SiO_2	18.8	19.8
Al_2O_3	4.0	4.2
Fe_2O_3	5.3	4.1
CaO	62.2	62.5
MgO	2.0	2.8
SO_3	3.25	2.1
D_{50} (μm)	12	5.1
D_{95} (μm)	60	11.2
Specific Gravity	3.19	3.10
Fineness (cm^2/g)	3.836	6.250

3. TESTING PROGRAME

3.1. Sample preparation

The mixture design of either OPC or MPC amended clay samples was based on dry weight percentages of OPC or MPC in the clay matrix, respectively. OPC and MPC dosages were selected as 8%, 10% and 12 % in this experimental study. High plasticity clay specimens passed through a No.4 (4.75 mm) USA standard sieve and stabilized with either OPC or MPC were tested in exactly the same manner.

3.2. Determination of consistency limits

The consistency limits for cement treated and untreated high plasticity clays were determined according to the ASTM D4318-10e1 [4] standart in which soil samples were passed through no. 40 U.S. standard sieve. Chart 2 shows the results of the consistency limit tests on untreated and cement-treated soil samples prepared according to the above mentioned standart.

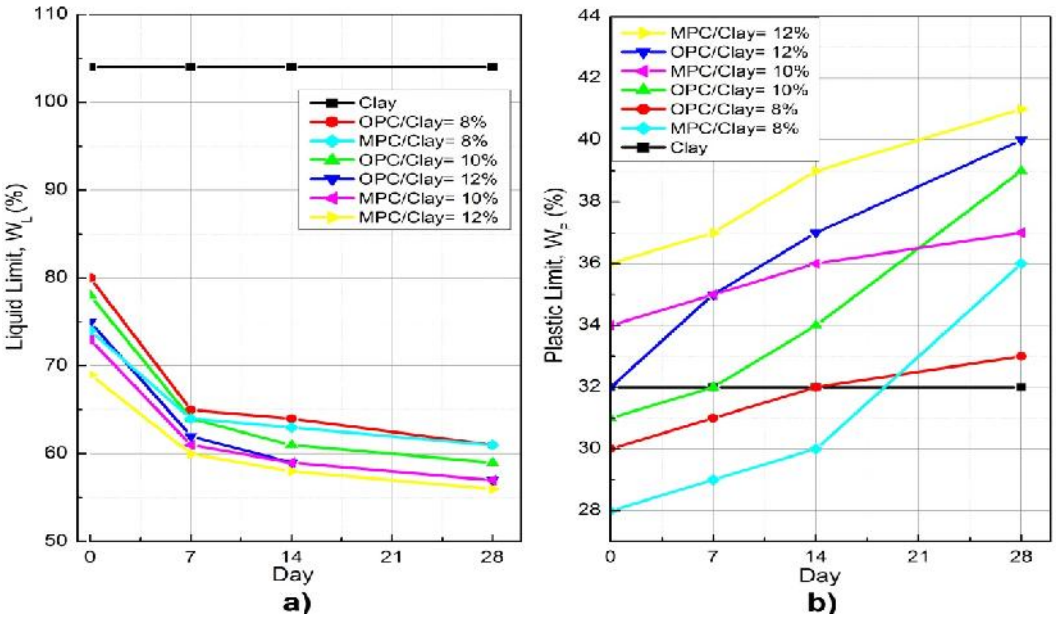

Chart 2. The relationship between liquid limit, plastic limit and curing time

3.3. Compaction test

Maximum dry unit weights of OPC–Clay and MPC–Clay mixtures were achieved by applying an energy level of 600 kN-m/m^3, which is equivalent to the [7], the recommended standard compactive effort. During these tests, dry cement was mechanically mixed with dry clay prior to compaction until homogenous OPC–Clay and MPC–Clay mixtures were obtained. All mixtures were then initially mixed with a certain amount of water, i.e. 15% –20% for the first compaction tests. Henceforward, samples were remixed with suitable amount of additional water for each succeeding compaction test. The samples of both OPC–Clay and MPC–Clay mixtures were formed in a standard mold measuring 101.6 mm in diameter and 116.4 mm in height. Inside the mold, each sample was compacted in three equal layers by dropping a 24.4 N rammer at a distance of 305 mm. Each layer was then subjected to 25 blows according to Method B of [7]. The compaction test results are given in Chart. 3.

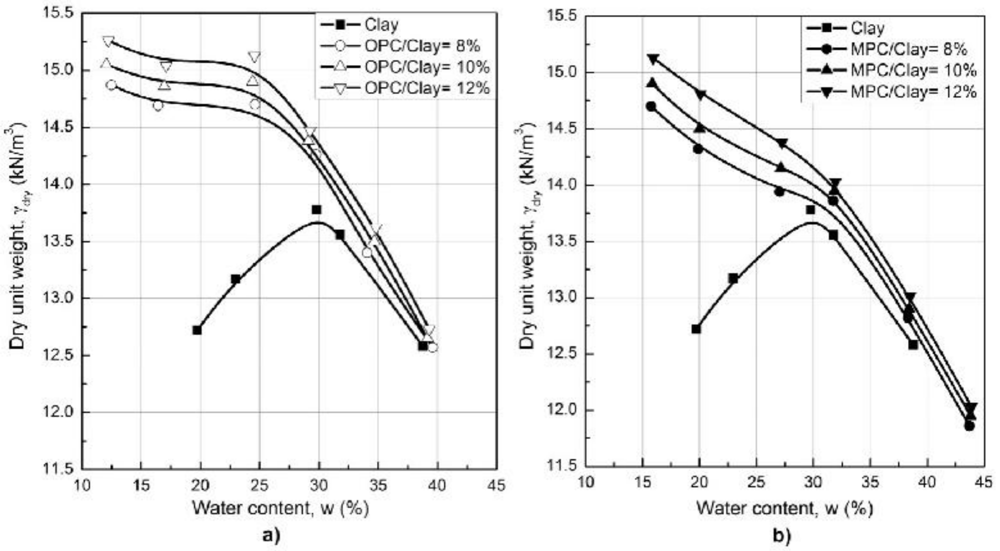

Chart 3. Effect of cement type and cement content on the OMC and Maximum dry unitweight

3.4. Preparation of OPC-Clay and MPC-Clay samples for Unconfined Compression Test (UCS)

For sample preparation, a compaction mold was used and cement stabilized clay specimens were compacted at OMC and maximum dry unit weight of high plasticity clay. The mold was designed to fit the requirement of UCS specimens with a height-to-diameter ratio of 2.01. The mold was made of stainless steel, and longitudinally split into two parts. Before compaction, the inner surface of the mold parts were slightly lubricated to minimize the sample disturbance while removing. Next, the mold was assembled and soil sample was placed into the mold in three equal layers. Each layer was compacted to a height of 33.5 mm with a stainless steel dolly to achieve the desired maximum dry unitweight before placing the next layer. After placing the final layer, the top and bottom end-rings of the compaction mold were disassembled. Finally, the two longitudinal split parts were separated from one another, and the cylindrical sample was gently removed. All specimens were 50.0 mm in diameter and 100.50 mm in height. The cement stabilized soil samples prepared in a way as mentioned above were stored in two different conditions. Some of them were preserved in sealable plastic containers to prevent moisture loss in a humudity room of 20 ^{0}C and others were air dried until the day of testing.

Thereafter, the UCS tests with reference to ASTM D 2166-00 [8]were run on wet and air dried cement stabilized clay samples at different time intervals of 1, 3, 7, 14, 28, 56 and 112 days. The related results are shown in Chart 4.

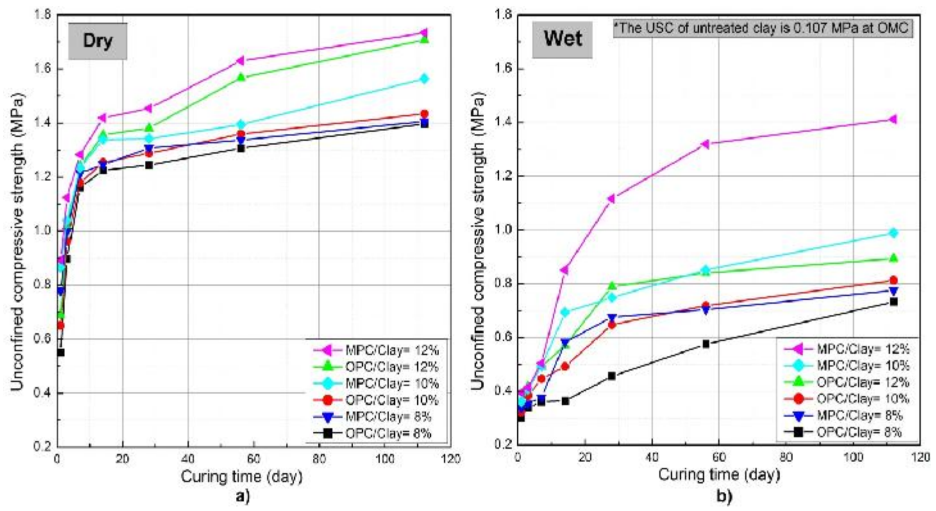

Chart 4. Unconfined compressive strength of stabilized clay; a) Dry, b) Wet

4. RESULTS AND DISCUSSIONS

4.1. Consistancy limits

The results of liquid and plastic limits for the soil with different types and percentages of cements are shown in Chart 2. The results for the mixture of high plasticity clay and cements show that liquid limit decreases and plastic limit increases in general. Although some specimens' plastic limits showed decrease initially but they increased finally. As the percentage of cement increased, liquid limit decreased and plastic limit increased. Similar findings were also reported by Horpibulsuk et. Al (2010)[18]. In addition, liquid limit decreased but the plastic limit increased as the cement size decreased. Furthermore, liquid limit decreased but plastic limit increased with time.

4.2. Compaction characteristics

The characteristic compaction curve for clayey soil could not be obtained from cement stabilized clay samples. Therefore, OMC of pure clay was taken as a reference to add cements to clay specimens and then compaction process was carried out accordingly. Generally, as the cement content increased the dry unitweight increased whether the cement type used was OPC or MPC (Chart 3). Similar findings were also reported by Richardson (1994)[26], Horpibulsuk et al. (2010) [18]and Aniculăesi et al. (2011)[2]. In addition, dry unitweight of cement stabilized clay samples decreased with the decrease in cement particle size. This might be due to the effect of increase of specific surface area of microfine cement.

4.3. Strength

As shown in Chart 4, the results show that the UCS values increase with an increase in OPC and MPC contents and curing time regarding wet and dry cement stabilized high plasticity clay specimens. The dry and wet strengths of OPC stabilized specimen at 8%, 10% and 12% of OPC contents are 1.40, 1.43 and 1.71 MPa and 0.73, 0.81 and 0.89 MPa at the end of 112th day repectively. The dry and wet strengths of MPC stabilized specimen at 8%, 10% and 12% of MPC contents are 1.41, 1.56 and 1.73 MPa and 0.78, 0.99 and 1.41 MPa at the end of 112th day repectively. The rate of strength increase of wet and dry cured samples was high up to 28th day but decreased sharply after that. Several researches [10, 14, 17, 19, 20, 27] also reported strength increase with cement content and curing time. In addition, at the end of 112th day, the OPC stabilized dry specimens gained 87 and 93 percent of their maximum strength within 28th and 56th days respectively. Furthermore, the OPC stabilized wet samples gained 77 and 87 percent of their maximum strength within 28th and 56th days respectively (Chart 4). On the other hand, at the end of 112th day, MPC stabilized dry samples gained 88 and 93 percent of their maximum strength within 28th and 56th days respectively. The MPC wet samples gained 81 and 90 percent of their maximum strength within 28th and 56th days respectively (Chart 4).

The dry UCS of OPC stabilized specimens is about 1.86 times higher than that of wet UCS of OPC stabilized specimens. Similarly, the dry UCS of MPC stabilized specimens is about 1.48 times higher than that of wet UCS of MPC stabilized specimens. It was seen that the dry UCS of MPC stabilized specimens was nearly the same as the dry UCS of OPC stabilized samples. Nevertheless, the wet UCS of MPC stabilized specimens is about 1.30 times higher than that of wet UCS of OPC stabilized samples. It seemed that fineness of cement particle was only effective in increasing the UCS of cement stabilized specimens at wet condition. In general, as the UCS of OPC stabilized specimens was increased by about 14 times than that of UCS of unstabilized clay, the UCS of MPC stabilized specimens was increased by about 15 times than that of UCS of unstabilized clay at the end of 112th day at dry condition. While the UCS of OPC stabilized specimens was increased by about 8 times than that of UCS of unstabilized clay, the UCS of MPC stabilized specimens was increased by about 10 times than that of UCS of unstabilized clay at the end of 112th day at wet condition.

5. CONCLUSIONS

The main conclusions drawn from this study are as follows:

- Liquid limit decreases but the plastic limit increases as the cement particle size decreases. In addition, liquid limit decreases but plastic limit increases with time.
- As the cement content increases, the dry unitweight of cement treated high plasticity clay increases regardless of cement particle size. However,the dry unitweight of stabilized clay decreases with the decrease in cement particle size.
- Dry UCS of MPC stabilized specimens is nearly the same as the dry UCS of OPC stabilized clay samples. Nevertheless, the wet UCS of MPC stabilized specimens is about 1.30 times higher than that of the wet UCS of OPC stabilized clay samples.
- It seems that fineness of cement particle is only effective in increasing the UCS of cement stabilized highly plastic clay at wet condition.

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