Investigation on the Effect of Lime and Fly Ash on Hydraulic Conductivity of Soil

Saeid. Amiralian, Amin. Chegenizadeh, and Hamid. Nikraz

***Abstract*—**This paper presents a series of laboratory experiments in order to investigate on the effect of lime and fly ash on hydraulic conductivity of sand. The study were conducted on Baldivis Yellow Concrete Sand (The Western Australian sand) with different percentage of lime (%1, 2%, 3%), fly ash (%5, %10, %15) and composition of lime and fly ash. A few researches carried out in this field however, the result of current study revealed an effective role of lime and fly ash in the reduction of hydraulic conductivity of sand. The obtained results illustrated that, in compared with the other results of lime and fly ash specimens the combination of lime and fly ash had a significant reduction in hydraulic conductivity of sand. Hence, it seems that utilization of the combination of lime and fly ash was more effective than use additives alone (i.e., lime and fly ash).

***Keywords*—**Fly Ash, Hydraulic Conductivity, Lime.

I. Introduction

NOWADAYS one of the critical challenges for geotechnical engineering is making construction on unsuitable soils, which have not sufficient properties of land for engineering projects. In some cases, engineers have to use local soil and handle the problems of inadequate soils during the projects. For this purpose, several geotechnical techniques such as displacement, replacement, reinforcement, and stabilization were implemented [1]. Soil stabilization as a cost-effective and environmental approach was implemented for modifying the mechanical and chemical behavior of soils. In this field, chemical stabilization with lime and fly ash could enhance the soil workability, plasticity, compressibility, and bearing capacity. Lime and fly ash treatment through the pozzolanic reaction leads to improve the engineering characteristics of soil [1]-[3]. Chemical stabilization is sometimes applied for constructing the soil systems such as dams, canals and river levees, however, the research about the consequences and effectiveness of lime or fly ash treatment on hydraulic conductivity of soil is extremely limited and extensively different [2]-[4].

The most common idea is hydraulic conductivity may be associated with the compressibility characteristic of soil [2]. In addition, based on several investigations hydraulic conductivity of soil depends on the compaction procedure. Consequently, in spite of the equivalent dry density and moisture content, the difference in compaction energy could lead to a different result for the same sample [2], [3], [5], [6]. Therefore, progress in the compaction properties of soil due to the chemical and mechanical improvement can effect on the hydraulic conductivity of soil as well. For this reason, the lower dry density of treated soil may be lead to the higher hydraulic conductivity [3], [5]-[7].

On the other hand, some studies demonstrated that, hydraulic conductivity of stabilized soil would be decreased due to reduce the level of consolidation. Moreover, investigations have shown that, increasing the amount of additives and hydraulic conductivity had an inverse relationship together [2], [3].

Hence, regarding to the diverse results and limited research about the effect of chemical stabilization on hydraulic conductivity of soil, this study was carried out to evaluate the effect of lime and fly ash on the soil hydraulic conductivity.

II. Material Characteristics

A. Sand

The soil selected in this research was Baldivis Yellow Concrete Sand (The Western Australian sand). It is known as quartz sand and supplied from Baldivis, 50 km south of Perth (Western of Australia). Baldivis sand is widely used for geotechnical projects in Western of Australia and suitable for mixing or footings and making concrete.

B. Lime

The lime used in this study is an industrial hydrated lime that suitable for engineering applications such as neutralising agent in water and sewage treatment, a binder in mortars, soil stabilization and maintaining alkaline conditions for mineral processing. More than 95 percentage of particle sizes of hydrated lime are less than 75 micrometers. The lime composition is between 80-95% Calcium hydroxide, 0-6% magnesium hydroxide, 0-8% silicon dioxide, 0-1% aluminium oxide and 0-.05% iron III oxide.

C. Fly Ash

The fly ash was considered for this study, collie fly ash that commonly used for concrete additive, bulk filler, fine filler in asphalt and other products, mine paste fill, soil amendment and stabilization, stabilizing agent for liquid wastes, road

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base. Approximately 40 percentages of particles size of fly ash is less than 10 micrometers. The fly ash ingredient is between 10-30% Mullite, 9% crystalline silica and 30-60% amorphous silica.

III. EXPERIMENTAL PROCEDURE

A. Mixture and Specimen Preparation

First, the Baldivis Yellow Concrete Sand was dried in the oven temperature (100±1 ºc) for one day. Then was passed through US Number 4 sieve (4.76 mm aperture) and prepared for the test. The sand specimens were mixed by a calculated amount of additive and moisture content. For investigating the relation between maximum dry density of standard compaction test and hydraulic conductivity of sand, the obtained results of compaction test were applied. The amount of optimum moisture content, maximum dry density and dry weight of sand in hydraulic conductivity test was determined based on the results of standard proctor compaction test TABLE I. Then, the moist soil was stabilized by addition the definite percentage of lime, fly ash, and lime-fly ash. The tests were performed at different percentages of the lime (1-3 %), fly ash (5%, 10%, and 15%) and mixture of each combination based on dry weight of sand. In the final step, after combination, the specimens were sealed in a plastic bag for one hour before the hydraulic conductivity test.

B. Hydraulic Conductivity Test

Hydraulic conductivity test was performed in the permeameter cylinder of 15 cm height and 7 cm diameter applying the falling head method. Each specimen was compacted in four layers into the mould by a mini compaction hammer with 1264 gr weight. The compaction process for each combination was continued until achieved the obtained maximum dry density by standard proctor compaction test. On the other hand, the porous discs were saturated in water for one hour prior to test. Fast flow filter paper (number 4) was placed between the sample and the porous discs. Moreover, the height of specimens after compaction process in the mould and before the running test was 13.5 cm, and during the experiments, the temperature of the room was 22.5 ºc.

IV. RESULT AND DISCUSSION

The results of hydraulic conductivity tests and compaction data for each specimen in this research are illustrated in the TABLE I and Fig 1-3. These tests results may help to evaluate the effect of lime and fly ash on hydraulic conductivity of sand. The main consequence of additive was reduction in the hydraulic conductivity of stabilized sand. As are illustrated by the TABLE I and Fig. 1, after lime-fly ash treatment, the hydraulic conductivity of sand specimens was decreased about 180 times comparison with hydraulic conductivity of pure sand. The maximum change in hydraulic conductivity was happened by the combination of 3 per cent lime with 15 per cent fly ash among the other specimens.

TABLE I
COMPACTION AND HYDRAULIC CONDUCTIVITY DATA

Specimen	Moisture Content (%)	Dry Density (gr/cm3)	Hydraulic Conductivity (cm/sec)
Sand	13.94	1.62	7.67×10^{-3}
% 1L	13.74	1.67	2.07×10^{-3}
% 2L	13.08	1.69	1.53×10^{-3}
% 3L	12.99	1.71	1.17×10^{-3}
%5FA	13.78	1.73	1.83×10^{-3}
%10FA	12.49	1.82	9.65×10^{-4}
%15FA	12.05	1.89	1.19×10^{-4}
%1 L-%5FA	13.79	1.78	4.77×10^{-4}
%1 L-%10FA	12.62	1.85	8.12×10^{-5}
%1 L-%15FA	11.26	1.90	7.34×10^{-5}
%2 L-%5FA	13.87	1.80	7.05×10^{-5}
%2 L-%10FA	13.31	1.84	3.78×10^{-5}
%2 L-%15FA	11.13	1.90	$2.25\times10\text{-}^{5}$
%3 L-%5FA	14.09	1.79	4.32×10^{-5}
%3 L-%10FA	12.91	1.86	1.81×10^{-5}
%3 L-%15FA	10.37	1.91	1.27×10^{-5}

L: Lime; FA: Fly ash; L-FA: combination of lime and fly ash.

It seems that, the mixture of lime and fly ash, can lead to a significant reduction in the hydraulic conductivity of sand comparison with apply other additives alone such as lime and fly ash.

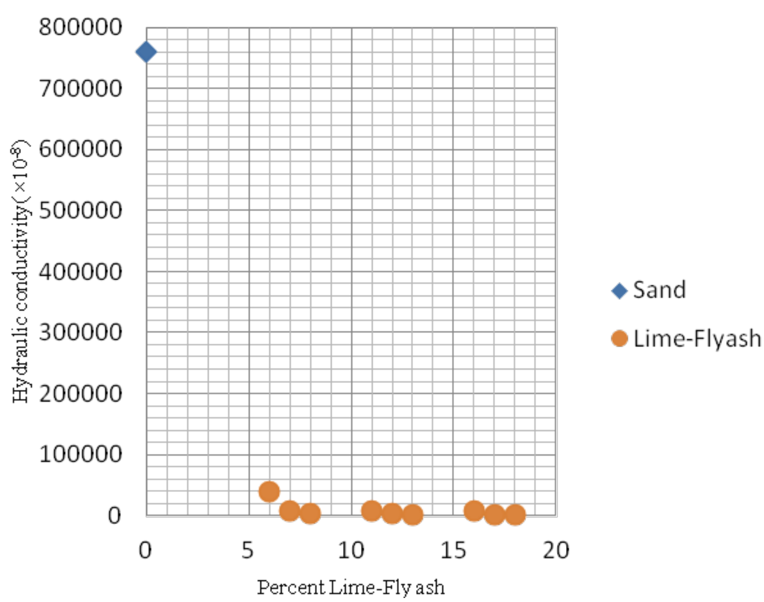

Fig. 1 Lime-Fly ash effect on hydraulic conductivity of sand

Moreover, it can be seen from the Fig. 2 utilization of fly ash for hydraulic conductivity of sand was more effective than sand treatment with lime.

As is shown by Fig. 2 applying fly ash could reduce the hydraulic conductivity of sand roughly 65 times.

Whilst Fig. 3 illustrates that, sand treatment by lime led to just seven fold reductions in the coefficient of hydraulic conductivity of sand nevertheless, this amount is not noticeable compared with fly ash effect.

On the other hand, the given result revealed that maximum decrease in hydraulic conductivity related to the specimen with the maximum amount of dry density. However, this tendency is not constant and systematic for other samples that have high maximum dry density. Based on the results, equivalent increase in the proportion of lime and fly ash may lead to efficient effect on hydraulic conductivity of sand.

Therefore, the data illustrated that increase the percentage of lime and fly ash as an additive may reduce the hydraulic conductivity of sand.

V.CONCLUSION

The large number of geotechnical projects have established on the soft and unsuitable soil. Soil stabilization with lime and fly ash is one method for improving the properties of soil. For this reason, the presented research was focused on the effect of lime and fly ash on the hydraulic conductivity of sand.

A series of hydraulic conductivity tests were performed on 16 sand specimens with variety amount of lime, fly ash, and lime-fly ash. The dry density, moisture content and dry weight of sand samples were defined based on standard proctor compaction test results.

This study demonstrated that, lime and fly ash treatment could reduce the hydraulic conductivity of sand. Investigation on lime, fly ash and lime-fly ash specimens indicated that, the combination of lime and fly ash has been the most significant effect on sand among the other samples. The lime- fly ash stabilization had about 180 folds reductions; however, the hydraulic conductivity of sand was decreased 65 times (by fly ash) and 7 times (by lime).

Therefore, the combination of lime and fly ash could be more effective than use additive alone (i.e., lime and fly ash) in sand stabilization. In addition, it seems that, equivalent increase in the ratio of lime and fly ash may lead to effective reduction in hydraulic conductivity of sand.

In the field of efficiency of lime and fly ash for hydraulic conductivity of sand can be concluded, the reduction in hydraulic conductivity of sand stabilized specimens with fly ash were more than lime treatment.

On the other hand, the obtained result revealed that, the specimen with the maximum amount of dry density had a maximum reduction in hydraulic conductivity (i.e., the specimen with the combination of %3lime and %15fly ash).

Furthermore, the hydraulic conductivity of other specimens with high dry density had a noticeable decrease. However, could not be found a methodical relation between dry density and hydraulic conductivity for sand.

Hence, it seems that applying lime and fly ash and the combination of lime-fly ash for an earth structure in permanent contact with water, such as dams, river levees and canals would be effective for improving the quality of structures.

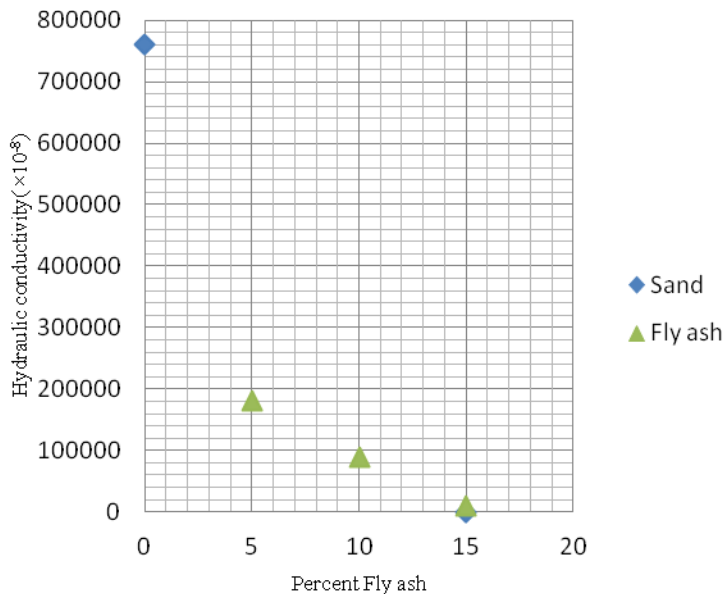

Fig. 2 Fly ash effect on hydraulic conductivity of sand

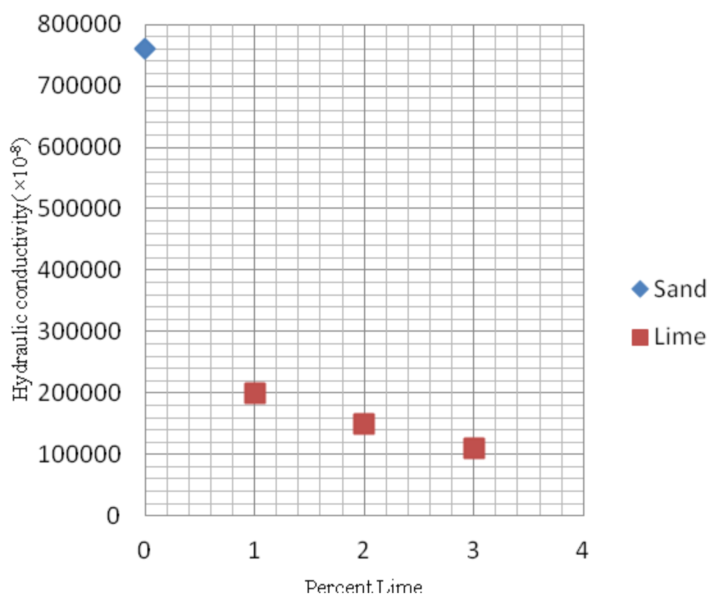

Fig. 3 Lime effect on hydraulic conductivity of sand

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