Laboratory Investigation on the Compaction Properties of Lime and Fly Ash Composite

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

***Abstract*—**Soil stabilization has been implemented for improving soils, which have inadequate engineering properties. Chemical stabilization method is mixing additives, such as lime and fly ash with soil to modify soil characteristics. This paper describes a research that carried out to study the effects of lime and fly ash in compaction properties of sand based on the seven specimens (i.e., 1 sand, 2 lime, 2 fly ashes and 4 mixture of lime-fly ash). The effectively of lime (%1 and %2), fly ash(%5 and %10) ash and the combination of each mixture were investigated in this research study in order to evaluation the maximum dry density and optimum moisture content of sand. The given result of lime and fly ash specimens illustrated that fly ash stabilization is more effective than lime treatment alone. However, utilization of combination of additives leads to optimum effect on compactability property of sand.

***Keywords*—** Compaction, Fly ash, Lime, Stabilization.

I. Introduction

THE critical factors for designing and implementing a geotechnical construction such as embankments, structures and roadworks are, characteristics of available soil, economic and environmental aspects of the project.

It can be seen that adequate engineering properties of soil serves a pivotal role in engineering project. However, regarding to reduction of suitable resources in many sites and the cost of prepare high quality material for geotechnical projects, engineers have to use the local soils. In some cases, poor engineering properties of soils create problems for engineering during the project. For example, subgrade soils is a main factor in highway structures and create roads on the soft and insufficient soil is one of the most common problems for roadways construction. Although replace the weak soils with stronger soil were applied for modifying in situ soil, due to uneconomical cost of this technique, engineers tend to find alternative methods that are cost effective and environmentally friendly[1]-[7].

For this reason, in 1904 the process of “soil stabilization” was introduced at the first time in the USA. Chemical stabilization is applied by a variety of stabilizers with the main purpose to improve the specific engineering properties of soil. This technique is an economical approach to strengthen the earth for building purposes. The mechanical and chemical characteristic of soil such as durability, strength and load bearing capacity of soil that unsuitable for geotechnical projects can be developed through adding binder or by-products like cement, lime, fly ash, bottom ash, silica fume, and rice husk ash to soil[1],[2],[4],[5],[7]-[11].

Compaction parameters are known as one of the main characteristic of soil. The ability of a soil to achieve the Maximum Dry Density (MDD) in Optimum Moisture (OMC) content is called soil compactibility. Through the chemical stabilization could be developed the compaction properties of soil. In this field, due to the lower cost and availability of by-products the usage of these materials in chemical stabilization is progressed. The large numbers of researches are established about soil stabilization effect on compaction properties of soil; nevertheless, it seems that the archived results are different in some cases and need to more consider.

Therefore, with regard to the various results and limited research about the effect of chemical stabilization on soil compactibility, this study was carried out to evaluate the effect of lime and fly ash on the compaction properties of soil.

II. Experimental Study

One of the pivotal factors in the building of roads and airport, structure’s foundation and embankments is compaction property of soil. The main reasons for soil compaction are increasing the shear strength of soil, lessen soil’s permeability, reduce the subsequent settlement of structures and boost the stability of slope embankments. Soil treatment with lime and fly ash is often applied for generating a soil with well-controlled and superior properties.

A. Literature Review

Since the Roman times lime has been widely utilized for developing the characteristic of soils. Through the reaction between lime and water of the soil, calcium cation (Ca^{2+}) and hydroxylanions (OH^-) are released in stabilized soil. Then cation substitution, particle flocculation and agglomeration are lead to modification the soil properties [6],[12][6, 12].

Some researchers have been established that, the effect of lime effect on compaction parameters was not sufficient; nevertheless, in compared with other binder lime create a rapid and wide chemical reaction with soil particles. Changing the characteristics of soil as a result of chemical interaction

Saeid. Amiralian is Master candidate in Department of Civil Engineering, Curtin University (e-mail: saeid.amiralian@postgrad.curtin.edu.au).

Amin. Chegenizadeh, is Lecturer in Department of Civil Engineering, Curtin University (e-mail: Amin.Chegenizadeh@curtin.edu.au).

Hamid. Nikraz is Professor and Head of Department of Civil Engineering, Curtin University (e-mail: H.Nikraz@curtin.edu.au).

lead to improvement in the soil properties, such as compaction and strength characteristics of soil[1],[5],[13]. In comparison with un-stabilized soil, lime treatment not only form a notable increases in optimum moisture content, but also the studies shown the maximum dry density after lime stabilization was decreased[1],[4],[11],[14],[15].

On the other hand, about 480 million metric tons ash is produced by the combustion of coal in each year in all around the world. Approximately two thirds of ashes are in the form of airborne particles that are called fly ash. Fly ash as a kind of fine-grained, dusty material consists of SiO_2, $Al2O_3$, CaO (quicklime), and other minor components, which are generated by electricity power[16].

Several studies about the effect of fly ash on compaction characteristic of soil [7],[17]-[19] have established that, adding fly ash to soils changed the range of porosity and void ratio of soils. The ability of water attraction of soil particles could be increased after fly ash treatment. This interaction directly leads to an increase in optimum moisture content and a decrease in maximum dry density [11].

B. Material Characteristics

Representative soil samples in this research were Baldivis Yellow Concrete Sand. The local sand used in this study has been collected from the Baldivis, 50 $_{km}$ south of Perth (Western of Australia) and known as quartz sand. Baldivis sand is extensively applied as a suitable material for mixing, footings, making concrete and mortar in geotechnical construction of Western of Australia.

The lime utilized in this study was an industrial hydrated lime, which, appropriate for engineering applications such as neutralising agent in water and sewage treatment, a binder in mortars, soil stabilisation and maintaining alkaline conditions for mineral processing. More than % 95of particle size of hydrated lime is less than 75 micrometres. The lime composition is between %80-95 Calcium hydroxide, %0-6 magnesium hydroxide, % 0-8silicon dioxide, % 0-1aluminium oxide and % 0-.05iron III oxide.

The Fly ash was applied for this study, collie fly ash, which usually used for concrete additive, bulk filler, fine filler in asphalt and other products, mine paste fill, soil amendment and stabilisation, stabilising agent for liquid wastes, road base. Roughly %40 of particles size of fly ash is less than 10 micrometres s. The fly ash ingredient is between %10-30 Mullite, %9 crystalline silica ,and %30-60 amorphous silica.

C. Laboratory Compaction Test

Compaction is the densification of soil via applying mechanical energy in order to remove air from the soil mass. In this study “standard compaction test” were applied for investigation the effect of different combination of lime and fly ash on sand behaviour.

Standard compaction test method given in the *AS1289.5.5.1 (ASTM D-698 2000)* is performed to determine the maximum dry density (MDD) and the optimum moisture content (OMC) of the soils. Samples were compacted in a 105_{mm}-diameter mold applying for the standard proctor effort. Dry unit weight and moisture content for each sample were obtained by the achieved unit weight in optimum moisture point, which was obtained by the intersection of slopes drawn from the wet-side and dry-side soil of the compaction curve of at least five compaction tests.

In sample preparation step, for removing the natural moister of Baldivis Yellow Concrete Sand that was dried in the oven temperature (100±1 ºc) for 24 hours and was passed through US Number 4 sieve (4.76_{mm} aperture). The first series of compaction tests were intended to determine the compaction properties of the non-stabilized soils. Then, based on dry weight of sand, other specimens were mixed by various percentages of the lime (%1 and %2), fly ash (%5and %10), and mixture of each combination. In the last step after combination, the specimens were wrapped up with in plastic bags for one-hour curing time before running the standard compaction test.

III. Result And Discussion

The sand particles are reorganized during the compaction process through water, additives and the external energy. Fig 1-9 are illustrated the compaction properties of sand, lime, fly ash and lime-fly ash mixtures. Investigation on the compaction curves of sand and other additives may evaluate the effect of stabilizer on MDD and OMC of soil.

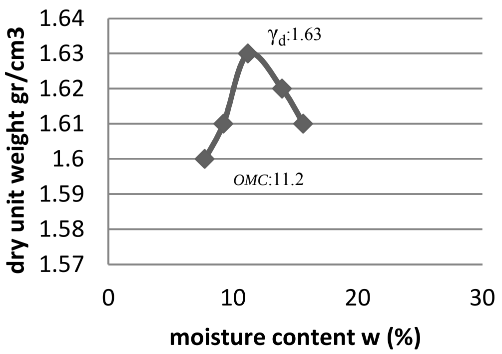

Fig. 1 Compaction curve of pure sand

At the first glance, soil treatments with additive were effected on the compaction characteristics of soil by increasing the OMC and MDD.

In all of the lime, fly ash, and lime-fly ash samples optimum moisture content was increased; nevertheless, the amount of increment in samples that fly ash exist as an additive is lower than just utilization lime for stabilization (TABLE I).

TABLE I
OPTIMUM MOISTURE CONTENT AND MAXIMUM DRY DENSITY(FA: FLY ASH, L: LIME)

Specimen	Moisture Content (%)	Dry Density (gr/cm3)
Sand	11.20	1.63
% 1L	13.74	1.68
% 2L	13.08	1.7
%5FA	12.98	1.75
%10FA	12.49	1.82
%1 L-%5FA	13.79	1.78
%1 L-%10FA	12.62	1.85
%2 L-%5FA	13.87	1.80
%2 L-%10FA	12.75	1.85

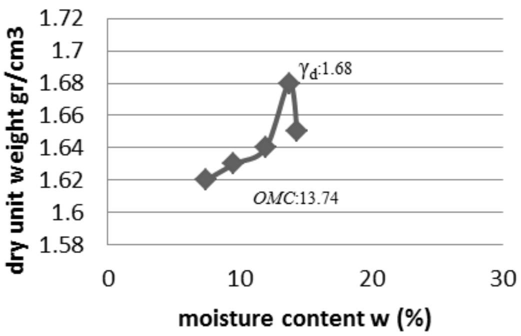

Fig. 2 Compaction curve of %1 lime

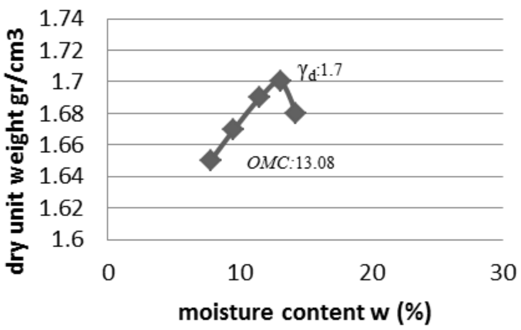

Fig. 3 Compaction curve of %2 lime

The maximum amount of the OMC related to sand combinations, which lime was applied as an additive. As is shown by "TABLE I "the optimum moisture content of sand stabilized sample with %1 and %2 of lime were more than optimum moisture content of fly ash treated specimens. Moreover, the achieved data indicate that sand treatment with lime and fly ash lead to a remarkable increase in the OMC of sand specimens.

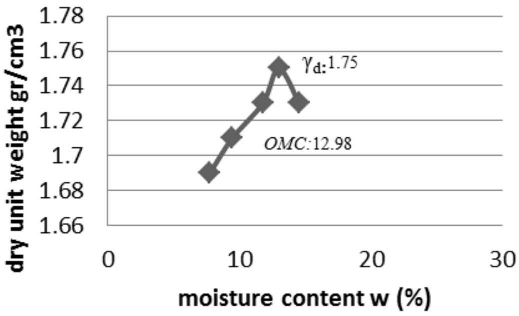

Fig. 4 Compaction curve of %5 Fly ash

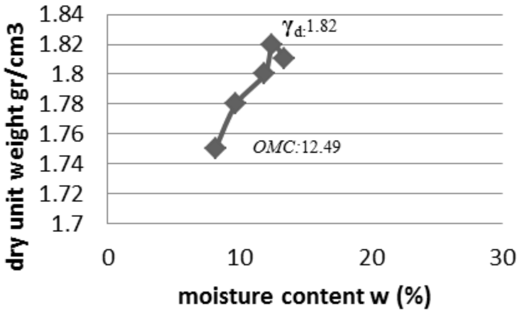

Fig. 5 Compaction curve of %10 Fly ash

However, it seems that fly ash treatment can more effective than lime stabilization for improvement the maximum dry density of sand. At the same time, the maximum dry density of lime samples had not a noticeable increment in comparison with fly ash and lime fly ash specimens. In addition, the sand with 10 percentage of fly ash has lower moisture content in contrast with stabilized specimens by 5 percent of fly ash.

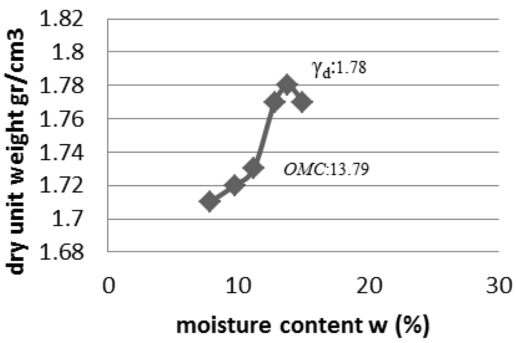

Fig. 6 Compaction curve of %1Lime+%5Fly ash

Fig 6-9 are illustrated the compaction curves of combination of lime and fly ash, which lead to increase in optimum moisture content and maximum dry density. In these combinations the optimum moisture content of specimens with just 5 percent of fly ash and lime, were increased in compared with samples that had 10 percent of fly ash and lime.

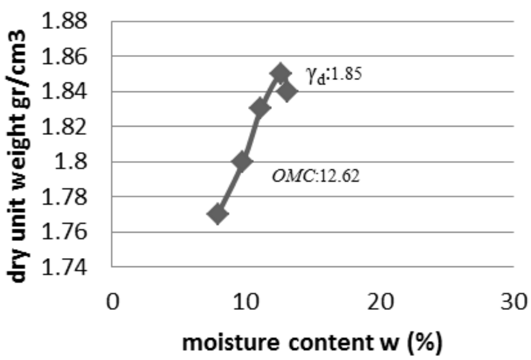

Fig. 7 Compaction curve of%1Lime+ %10 Fly ash

On the other hand, Fig 7 and Fig 9 are revealed that, the most effective result related to the combination of one and two percentage of lime with ten percent of fly ash, which have the most MDD between other samples. However, it seems that lime addition in this combination led to increasing the amount of moisture content compared with ten-percent fly ash only. Moreover, this effect it can be observed in other mixture of lime and fly ash tendency as well.

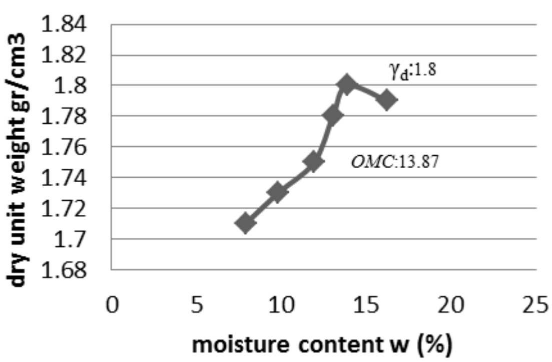

Fig. 8 Compaction curve of %2Lime+%5 Fly ash

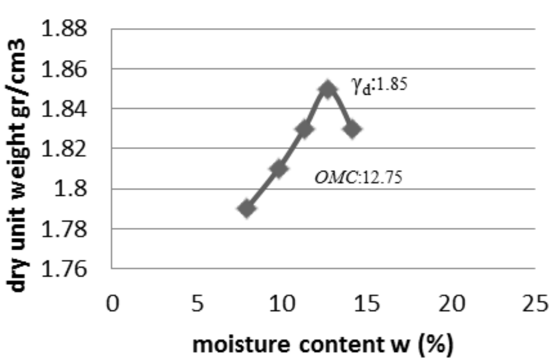

Fig. 9 Compaction curve of %2Lime+ %10 Fly ash

Thus, although utilization of lime and fly ash as an additive led to increase moisture content, due to increase in the maximum dry density of sand, lime and fly ash could be an appropriate stabilizer for improvement the compaction properties of sand.

IV. CONCLUSION

Soil stabilization as a cost-effective and environmentally method is utilized in order to improve the properties of poor soil by adding the binder and by-products. The experiments conducted to study the effect of lime and fly ash addition on the geotechnical behaviour of sand. Despite the probable limitations in the laboratory tests, the following conclusion can be drawn from the experimental results of seven specimens, which are separated based on the materials (i.e., Sand, lime %1 and %2, fly ash %5 and %10, and four lime-fly ash combination).

The results indicate that, the compaction properties of all stabilized specimens are improved in contrast with pure sand. It seems that, utilization of fly ash is more effective than sand treatment only with lime. However, the optimum result obtained by combination of lime and fly ash.

In all specimens were observed a development tendency in maximum dry density after sand stabilization with the increase of additives amounts. In addition, there is a remarkable improve in the maximum dry density of samples, which had fly ash, while lime tarted samples had a moderate increase in maximum dry density in compared with other stabilizer combination. The highest increment of maximum dry density related to the combination of %1 lime-%10 fly ash and %2 lime-%10 fly ash samples.

In general, utilization of additive were increased the optimum moisture content of sand and associated with stabilizer increment. Based on obtained result, the increase of samples moisture content after lime stabilization was more than sand treatment with fly ash and lime-fly ash. Although in sand treatment with lime the optimum moisture content was decreased with the increase in lime content, the decrement of moisture content in sand stabilization with fly ash were notable than lime specimens.

Applying the combination of one and two-percentage lime with five-percentage fly ash leads to the greatest moisture content compared with other samples. In contrast, combination of lime additives with ten percent of fly ash lead to maximum improvement in maximum dry density and lower optimum moisture content among other samples.

In overall the result suggests that increment in moisture content of sand after lime stabilization was more than sand treatment with fly ash. Moreover, fly ash stabilization led to more increment in the maximum dry density of sand in compared with lime treated samples.

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