Available online at www.pelagiaresearchlibrary.com

Pelagia Research Library

European Journal of Experimental Biology, 2012, 2 (6):2378-2384

ISSN: 2248 –9215
CODEN (USA): EJEBAU

Laboratory Investigation of the Effect of Eggshell powder on Plasticity Index in Clay and Expansive Soils

[1]Arash Barazesh, [2]Hamidreza Saba, [3]Mehdi Gharib, [4]Moustafa Yousefi Rad

[1]Department of Civil Engineering, Arak Branch, Islamic Azad University, Arak, Iran
[2]Amirkabir University of Technology, Tehran, Iran
[3]Department of Architecture, Aliabad katoul Branch, Islamic Azad University, Aliabad Katoul, Iran
[4]Department of Geology, Payam Nour University, Tehran, Iran

---

ABSTRACT

Nowadays, considerable attention has been paid to the utilization of alternative materials, which bear higher engineering quality than traditional materials and are financially affordable. Soil is one of the most important materials used in a variety of construction projects including earth canals and earth dams. The fact that soil may provide all the resistance characteristics necessary for a project illustrates the importance of various methods used to improve soil quality. Clay soil is widely used in most of the construction projects. Clay soils, particularly soft clay soils, have good plastic properties so that increased moisture results in their decreased shear strength, compressive strength and volume changes. These damages typically take an irreparable toll on structures, which further clarifies the importance of soil improvement. Considering millions of tons of waste produced annually across the country, which not only poses the problem of disposal but also adds to environmental contamination and health risks, utilization of such refuse and industrial wastes and their subsidiary products as alternatives to construction materials may effectively contribute to environmental preservation and minimization of their adverse effects on the environment. In the present study, eggshell powder was used as a waste to combine with soil so that the plasticity properties of clay soil were investigated in different mixture proportions. Then the plasticity properties of soils including liquid and plasticity limits as well as plasticity index, already measured, were compared with those of the experimental specimens mixed with eggshell powder in different proportions.

Keywords: Expansive Soil, Clay, Soil Stabilization, Waste, Eggshell Powder, Plasticity Limit, Liquid Limit, Plasticity Index

---

INTRODUCTION

In situ improvement of soil properties using additives is commonly referred to as soil stabilization, which is often used with fine soils. Indeed, soil stabilization is a process whereby natural or synthetic materials are added to soil improving soil properties. It is typically used to modify and improve low-quality materials, which brings about changes in soil properties including decreased rate of subsidence, decreased adhesion coefficient in soils with high cohesion (clay), increased adhesion coefficient in soils with low cohesion (sand), reduced percentage of water absorption and prevention of soil expansion, reduced cost of earth structures (transport), speeded road construction operations, resistance to frost and defrost, improved ductility, reduced rigidity of earth structures, lack of weed growth in the surface of earth structures such as roads and reduced thickness of bearing layers [3]. Over the last years, environmental issues have prompted human to use industrial wastes as alternatives to some construction materials. Both earthwork researchers and engineers have paid considerable attention to using wastes in soil stabilization and improving physical and mechanical properties of soils. This may help both remove environmental problems and contribute to the economy. Industrial wastes such as fly ash, iron slag, wood ash, plastic wastes and iron filings show considerable potential to stabilize soils, which are occasionally used to improve geotechnical properties of poor soils. Expansive soils shrink when they lose their moisture but swell when they absorb water. Moisture absorption may occur as a result of raining, torrents, leaking pipes of water or sewage, and impeded surface water evaporation due to the built structures adjacent to water reservoirs. Clay soils are highly vulnerable to swelling [18, 15]

Reasons for soil compaction and expansion
Soil compaction and expansion depends on different factors as follows [17]:
- Type and amount of clay minerals in soil
- The level of soil moisture
- Dry density of soil

One of the most common methods of fine soil improvement is stabilize it using additives that improve soil properties through physical and chemical changes. It is, however, worth noting that fine soils behavior should be well studied before deciding on the method of improvement.

Purposes of soil stabilization
Soil modification or stabilization is usually carried out to achieve the following goals [3, 4, 9, 10]:
- Increasing soil strength, geotechnical properties and bearing capacity
- Changing soil permeability, reducing water absorption percentage, and preventing soil swelling and compaction
- Preventing structure subsidence
- Reducing adhesion in highly adhesive soils
- Increasing adhesion in soils with low adhesion (sands)
- Increasing safety factor against slope, levees and earth dam sliding
- Increasing soil endurance, modification of soft and low-resistance soils, and preventing soil erosion
- Reducing soil plasticity index

A review of literature on soil stabilization using additives
Soil-stabilizing factors have long been in use so that cement was first used as a stabilizing factor in road construction in the US in early twentieth century [6]. Still, it was not until 1960 that scientific investigations began on additives to clay to improve its strength profile. At the time, adding lime or cement to clay was found to significantly improve clay strength properties including shear and compressive strengths. Since then, geotechnical scientists have conducted extensive research on the effect of additives on soils, particularly clays. Studying strength properties of improved clays, Diamond (1975) concluded that such clays may be used in runway substructure, earth dams and hydraulic structures where they are vulnerable to erosion. Chen (1975) conducted studies on the lime proportions necessary to stabilize clays and reported that 2-8 percent lime was necessary to stabilize clays. Construction Industry Research and Information Association (CIRIA) studied the effect of delayed compaction of soils mixed with additives and reported that any delay in compaction process following the addition of additives prevented soil density to reach its maximum value. Hammond (1992) conducted studies on improving and increasing the strength of clay soils stabilized with lime and concluded that clay-lime mixture was so strong that it can be used to stabilize canal side slopes and to build structure foundations when the foundation bears a moderate load. Kumar et al. (2007) investigated the effect of fly ash, lime and polyester fibers on compaction and strength properties of expansive soils. They reported that cured seven-day, fourteen-day and 28-day specimens of clay-lime-fly ash mixture showed higher unconfined compressive strength than specimens without fly ash mixture. They also found that polyester fibers significantly increased the strength of soil-lime-fly ash mixture.

Almost every industrial activity ends up with the exhaustion of natural resources, which results in the accumulation of products or wastes. In the modern world, wastes and refuses have come to be a serious problem so that a line of research is devoted to investigate how wastes may be used without taking a toll on the society. The accumulation of wastes often brings about adverse outcomes. For example, a report published in Britain estimates eggshell wastes to range from 10,000 to 11,000 tons per year, which specifically poses a problem as to how to use these wastes [16]. Using wastes as alternatives offers two major advantages: preservation of natural resources and elimination of voluminous wastes. Some potential wastes to use in road construction and soil stabilization include coal shale, pulverized fuel ash, furnace clinker, eggshell powder, iron slag, incinerator ash and agricultural wastes, among others. Some of these wastes are widely in use in the world for a variety of purposes. As an example, studies have been conducted on the use of eggshell powder to stabilize non-adherent soils in Japan [8].

Stabilizing agents such as lime and pitch are expensive and need to be replaced economically. Research has shown that eggshell is a rich source of lime, calcium and protein so that it may be used as an alternative to such soil stabilizers as lime because it contains lime-like ingredients [1]. Used as source of lime in agriculture, eggshell proved to contain a considerable amount of lime [1, 13]. In the present study, eggshell powder was used as an alternative to stabilize expansive soils. To this end, various laboratory experiments were carried out on soil specimens mixed with different percentages of additives (1-25% weight percent) and the effect of eggshell powder was examined on Atterberg properties of the specimens.

MATERIALS AND METHODS

The present experiments were conducted consistent with ASTM standards. The study aimed to investigate the effect of eggshell powder additives on selected soils. To this end, Atterberg limits experiments (ASTM: D4318) were performed. In this regard, to study the effect of eggshell powder on soil plasticity properties, liquid limit and plasticity experiments were conducted on soil specimens with primary plasticity indices equal to 26, 31, 35, 39 and 45 using different proportions of additives (1-25 weight percent). Then the results were compared.

RESULTS

Effect of eggshell powder on soil plasticity properties

The following figures illustrate the results of liquid and plasticity limits tests on soil specimens with different plasticity indices stabilized with different proportions of eggshell powder.

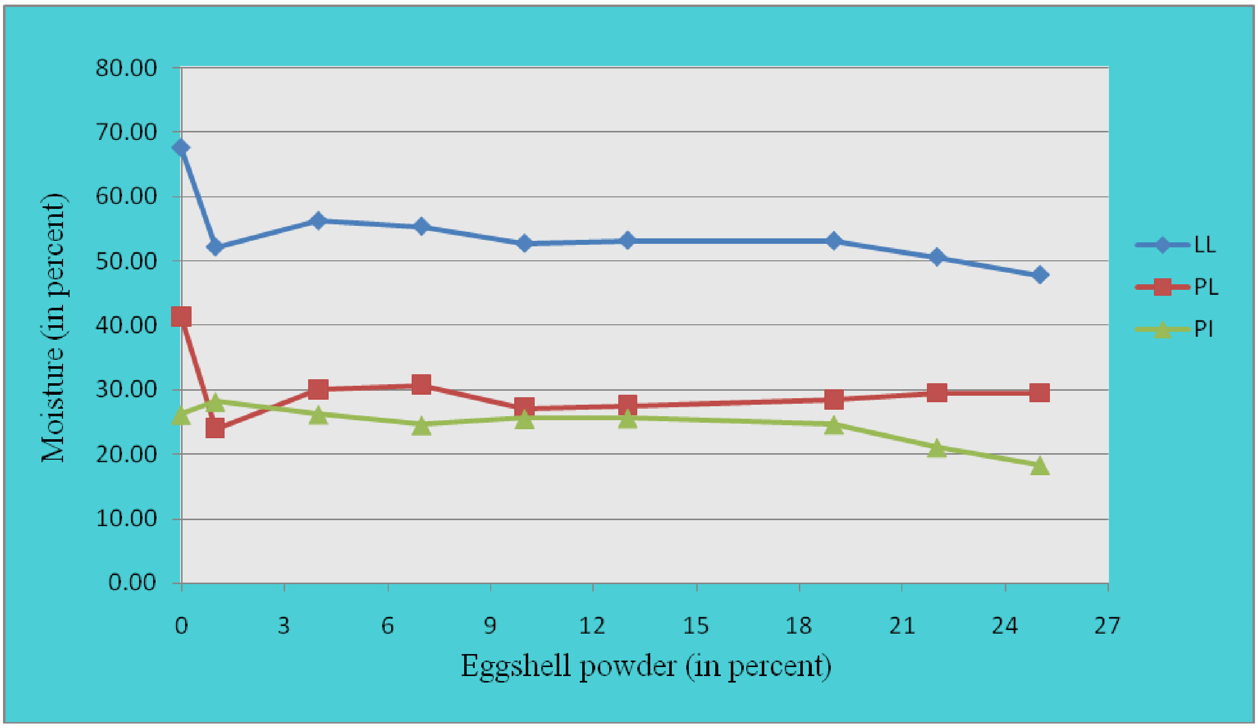

Figure 1. Effect of various weight percents of eggshell powder on plasticity properties in soil specimens with primary plasticity index 26

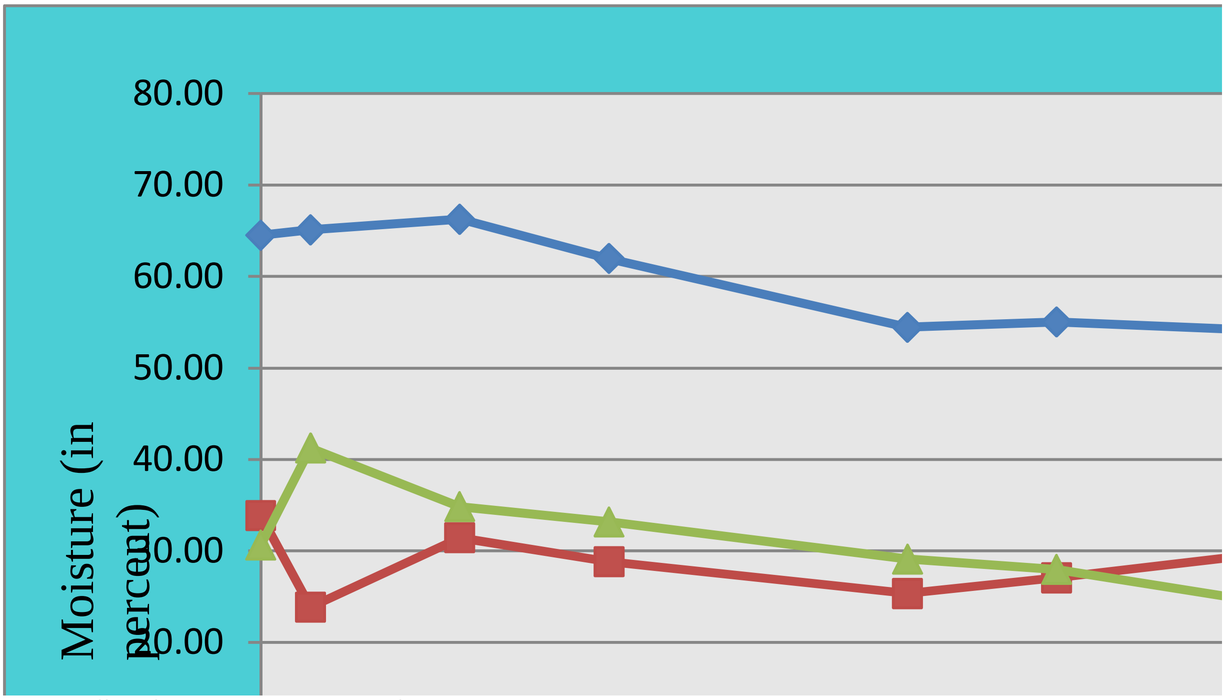

Figure 2. Effect of various weight percents of eggshell powder on plasticity properties in soil specimens with primary plasticity index 31

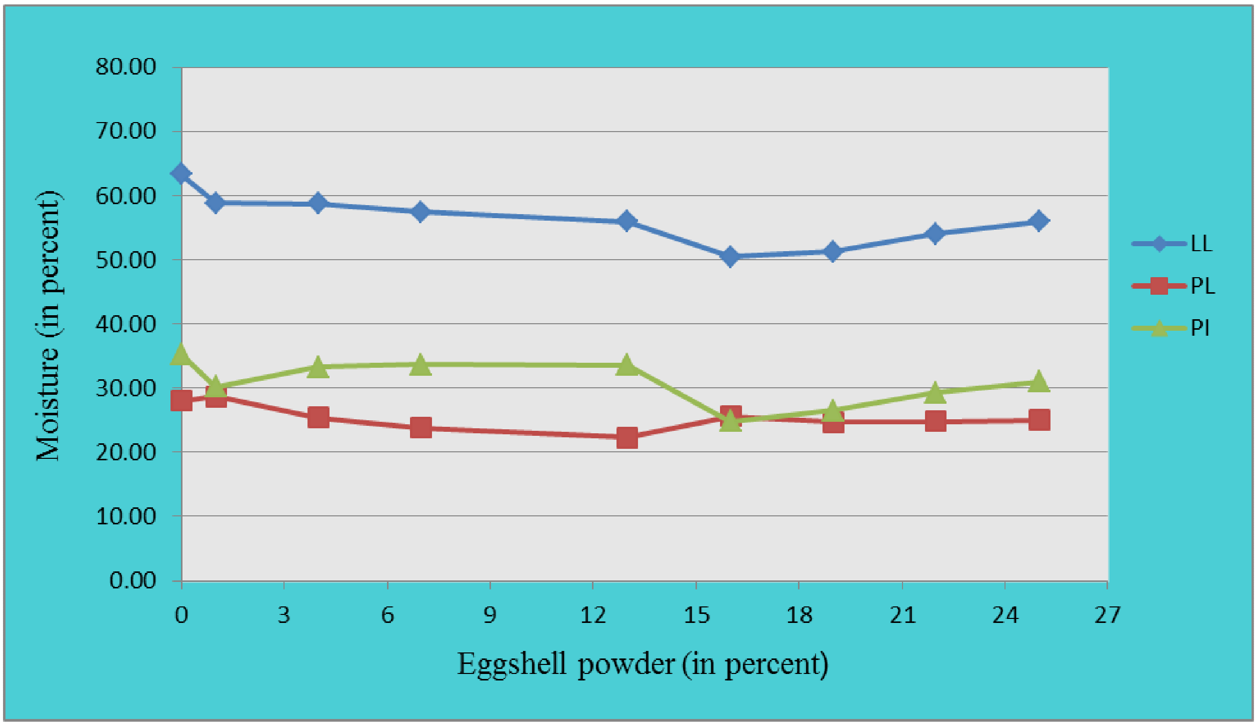

Figure 3. Effect of various weight percents of eggshell powder on plasticity properties in soil specimens with primary plasticity index 35

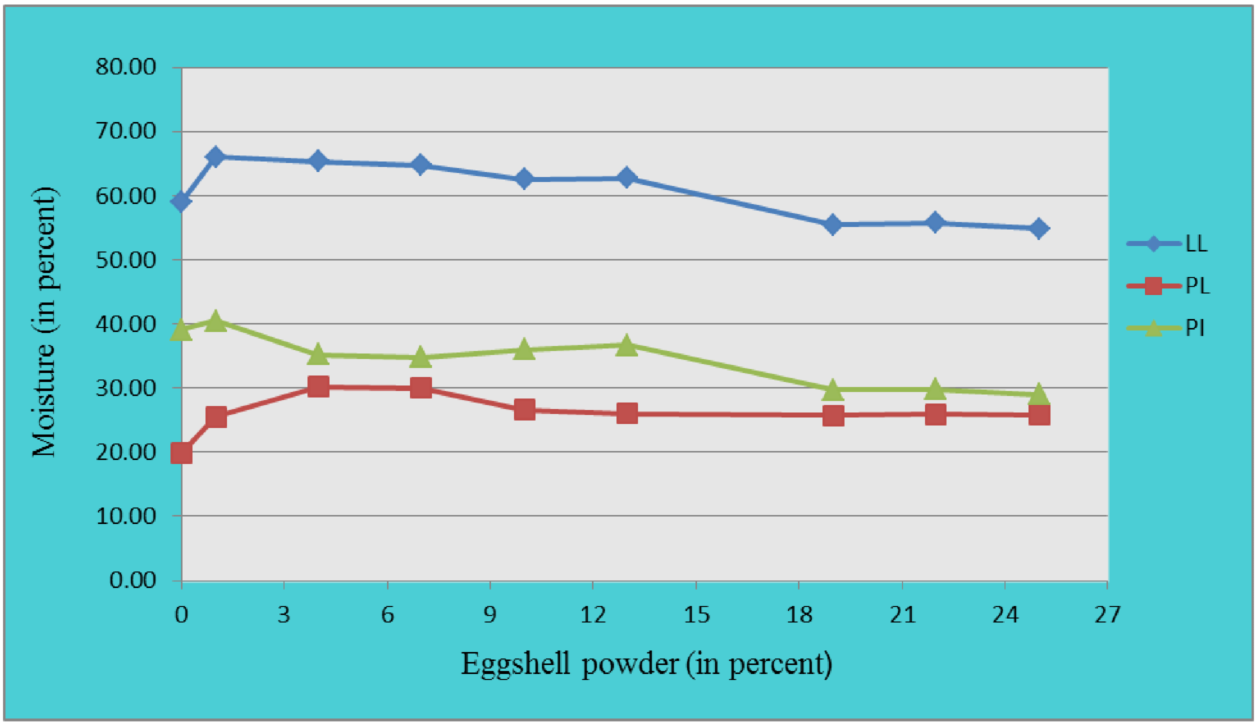

Figure 4. Effect of various weight percents of eggshell powder on plasticity properties in soil specimens with primary plasticity index 39

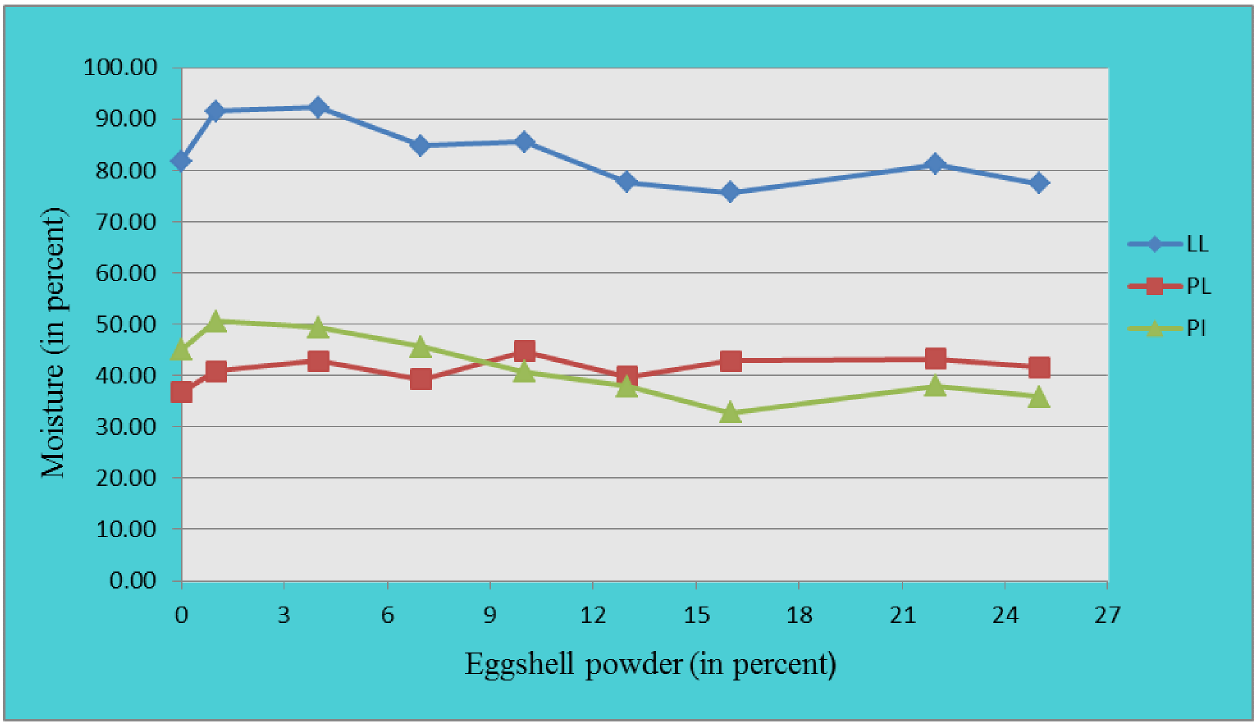

Figure 5. Effect of various weight percents of eggshell powder on plasticity properties in soil specimens with primary plasticity index 45

DISCUSSION AND CONCLUSION

Performing Atterberg limits tests, the selected soil specimens – with primary plasticity indices 26, 31, 35, 39, 45 – were mixed with different proportions of eggshell powder (1-25 weight percent). In each stage of experiments, Atterberg limits tests were performed on soil-eggshell powder mixtures and the results were shown in Figures. The following results were achieved from experiments on specimen mixtures:

Soil specimen with primary plasticity index 26

- Variations in the liquid limit of primary soil specimen decreased as the proportion of eggshell powder increased in the mixture; however, the addition of different percentages of the additive did not significantly affect this decrease.
- Results of plasticity limit tests on this specimen with different proportions of eggshell powder showed that, as with the plasticity limit, the liquid limit of specimen did not significantly change as the percentage of additives increased. Overall, the additive had a decreasing effect on the specimen though this decrease was less dramatic in the final proportions of the mixture.
- Adding different proportions of eggshell powder to this soil specimen reduced the plasticity index. The decrease was more conspicuous in the final proportions of the mixture resulting in a sharper decrease in the plasticity index.

Soil specimen with primary plasticity index 31

- In different stages and proportions of soil-eggshell powder mixture, a decrease was observed in the liquid limit of specimens. The decrease was intensified in intermediate stages but then moderated and relatively maintained to the end of the experiment.
- Plasticity index was found to decrease in all proportions of soil-eggshell powder mixture. The decrease, however, did not follow a logical pattern so that it varied fuzzily in different stages.
- With regard to plasticity index variations, first, a slight increase was found in the plasticity index comparing with primary unmixed soil specimen. However, as the percentage of eggshell powder increased in soil specimen, a decreasing trend was found in the plasticity index, which continued to the end of the experiment. Therefore, adding different proportions of eggshell powder to soil specimen reduced the plasticity index in the specimens.

Soil specimen with primary plasticity index 35

- As shown in the figure, any proportion of soil-eggshell powder mixture resulted in reduced liquid limit in the specimens. The decrease showed a fluctuating pattern in intermediate mixture percentages though the overall pattern of liquid limit was reductive.
- Different proportions of soil-eggshell powder mixture revealed a decrease in the liquid limit of specimens comparing with primary liquid limit of unmixed soil. The decreased followed a linear slope in final mixture proportions and the variation moderated.
- Different proportions of soil-eggshell powder mixtures resulted in reduced plasticity index of specimens comparing with the primary unmixed soil specimens.

Soil specimen with primary plasticity index 39

- Initial proportions of soil-eggshell powder mixture resulted in a slight increase in liquid limit in the mixture; however, the overall results showed a decrease in the liquid limit of mixture specimens comparing with the primary unmixed soil specimens.
- The specimen plasticity limit was in the increase up to 10 percent eggshell addition; however, the increasing trend was almost stopped from 10 percent and over so that the figure followed a gentle slope to the final stage where no significant variation was found in the values of plasticity limit.
- Different proportions of soil-eggshell powder mixture resulted in decreased plasticity index in the mixture comparing with the primary unmixed soil specimens. The decrease, however, was more moderate at the initial and final mixture proportions but more considerable in the intermediate proportions.

Soil specimen with primary plasticity index 45

- Considering the variations of liquid limits, initial proportions of soil-eggshell powder mixture slightly increased liquid limit, but the increased proportion of eggshell powder resulted in decreased liquid limit comparing with the primary unmixed soil specimens. Thus, eggshell powder reduced liquid limit in the soil specimens.
- Plasticity limit increased in the soil-eggshell powder mixture. The increase was more considerable in the initial proportions of eggshell addition but moderate in the final proportions, following a linear slope, comparing with the unmixed soil specimens.
- Different proportions of soil-eggshell powder mixture reduced the plasticity index in the specimens so that the largest decrease was noticed in the specimen with 16 percent eggshell powder addition. Besides, the experiments showed a high rate of decrease so that the variations in plasticity index were conspicuous.

In the end, considering the present experimental findings, the following conclusions may be drawn from experimenting on eggshell powder added to clay soils with primary plasticity indices 26, 31, 35, 39, 45:

a) Adding eggshell powder to expansive soil specimens reduced plasticity index in the mixtures. This decrease entailed a relatively sharp slope in all specimens indicating the significant effect of eggshell powder on the clay soils plasticity index. Increased proportion of eggshell powder in the specimens resulted in sharper decrease in the respective index.

b) Different proportions of eggshell powder added to soil specimens resulted in decreases in the liquid limit in the specimens so that with increased proportion of eggshell powder, the decrease was sharper in the respective index.
c) In soil specimens with primary plasticity indices 39 and 45, soil-eggshell powder mixture resulted in increased plasticity indices. However, the same index decreased in other specimens. Besides, lower proportions of soil-eggshell powder mixture resulted in greater variations in plasticity index while higher percentages of the mixture did not reveal a significant change in the indices.

REFERENCES

[1] Amu OO, Fajobi AB, Oke BO, *Res J Agri Biol Sci*, **2005,** 1(1): 80-84.
[2] Asadi M, Zeinali F, Proceedings of National Iranian Reinforcement Conference, **2008**.
[3] Bagholi Zadeh E, MA thesis, Tehran University (Tehran, Iran, **2008**).
[4] Behnia K, Tabatabaie A, *Soil mechanics*, Publications of Tehran University, **2005**.
[5] Chen FH, *Elsevier Science*, Amsterdam, the Netherlands, **1975**.
[6] Clare KE, Cruchly AE, *Geotechnique*, **1957,** 7: 97-110.
[7] Construction Industry Research and Information Association, *Laterite in road pavements, TRRL*. London: Special Publication, **1989,** 47.
[8] Croft CP, McGeory D, Carlson DH, *Physical geology*, 8th Ed. New York: McGraw Hill Companies Inc, **1999,** 48-56.
[9] Das BM, *Principles of geotechnical engineering*, Tehran: Pars Aeen Publications, **2008**.
[10] Das BM, *Principles of geotechnical engineering*, Tehran: Pars Aeen Publications, **1994**.
[11] Diamond S, Soil stabilization for erosion control, **1975,** 75-20**.**
[12] Hammond AA, *Manufacture and use of lime and pozzolana cements in Africa*, In Neville Hill, London: Intermediate Technology Publications, **1992,** 35-46.
[13] John H, Paul K, Integrated Crop Management Conference, Iowa State University, **2006**.
[14] Kumar A, Walia BS, Bajaj A, *J Mater Civil Engin*, **2007,** 19 (3): 242-248.
[15] Nelson JD, Miller DJ, *Expansive Soils, Problems and Practice in Foundation*, John Wiley and Sons Inc, **1992,** 259.
[16] Tocan AGJ, *Agricultural Wastes*, **1999,** 4: 335-343.
[17] Wayne AC, *J Construc Engin Manag*, **1984,** 110 (3): 359-374.
[18] Yazici V, GBFS-Lime Combinations and GBFS Cement, **2004.**