Mechanical characterization of plastic soil treated with eggshell lime additive.

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ABSTRACT

Egg shells are one of the materials rich in calcium carbonate (caco3), and they are wastes that are thrown in large quantities(Consoli et al., 2019). Therefore, reusing these wastes in engineering works is one of the objectives of this study. The eggshell powder lime (ESL) was selected and 6% from the dry soil weight was selected as the optimum ratio. It was used to improve the mechanical properties of medium to high plasticity of the soil with a moisture content of 20%. The results showed a significant improvement in the strength of unconfined compressive strength, as well as the improvement of the direct shear and the improvement of the flexural strength of the samples. The results showed also an improvement in the compressive strength of the curing time of soil for periods of 7,14,28,50,100 days.

Keywords: Eggshells, Eggshell's lime powder, Plastic soils, Soil treated with Lime.

1. Introduction

One of the problems of exploiting natural resources to obtain primary raw materials in the construction materials industry is damage to the environment. Thus, it is necessary to search for alternative materials that dispense with traditional materials such as agricultural, urban, industrial waste and others. It is also a source of geotechnical concern, especially materials that contain calcium such as Portland cement and lime, which are used to stabilize the soil. Because the production of calcium oxides requires the extraction of large quantities of minerals that affect the local soil, water, flora, and fauna. In additionally, these alternative materials are less expensive, so they are economically and reduce carbon dioxide emissions, so they are environmentally friendly. The main environmental problems in the lime production industry in the future will focus on the processes of limestone extraction and mineral production and this is what researchers focus on. Hence, it is necessary to search for alternative sources of calcium or calcium oxides.

By 2022, global lime production will exceed 5.5 billion tons, according to the forecast by Global Industry Analyst Inc. (2019) of which the greatest beneficiary is construction and civil engineering industry , according to the ELA Final Report (2018) the total EU production of lime products was 23.9 million tons.

Egg shells can be considered one of the raw materials in the production of lime because it is rich in calcium(Amaral et al., 2013). When properly burned, it turns into quicklime, which can then be converted into slaked lime by water (Stadelman 2000)(Oliveira et al., 2013)(Bensaifi et al., 2019). The world production of egg in 2016 amounted to 81 million tons, depending on FAO (2018). The world's production of eggshells in 2016 will be approximately 8.1 million tons, considering that the shells constitute 10% of the weight of the egg (Borron 2004).

There are many uses for eggshells, including for the production of paper, animal feed, correction of soil PH, and the removal of heavy metals from contaminated soil and water(Ok et al., 2011).

From eggshells can be make hydrated lime (calcium hydroxide) [Ca(OH)2] and which used to manufacture of mortar for restoration purposes (Beck et al., 2010), as well as a green catalyst(Chavan et al., 2015)(Laca et al., 2017). It can be replaced by up to 30% of the weight in the production of Portland cement for making of soil-cement bricks because it contains calcium carbonate [Ca(OH)2] (Amaral et al., 2013). It was found that there is a similarity between the physical and chemical characterization of quicklime extracted from eggshells and commercial lime (Ferraz et al., 2018).

Through this research, we try to improve the mechanical properties of the soil by stabilizing it with calcined eggshells [Ca(OH)2] (hydrated lime).

2. Materials and methods

The materials used in this study were medium to high plastic soil and Eggshell. The soil used in this study was collected from Al-Kindi second Quarter, specifically from the Diwan Residential Compound, Mosul State, Iraq. Relatively samples of the soil were collected from the trial pit between the depths of 1.5 and 1.8 m. The eggshell powder was prepared from the eggshells collected from the fast food restaurants. The eggshells were burn at a temperature of 1000 °C for five hours for Calcination to obtain quicklime and then adding water to obtain slaked lime (Hydrated Lime Ca(OH)2) and milled into powder form which was sieved through sieve #200 with 75mm aperture(Beck et al., 2010). The uniform powdery form of the sieved milled eggshell allows for faster and effective chemical reaction because of its large surface area.

2.1 Sample preparation and experimental program

The soil was dried at a temperature of (60 °C) for two days before using it and placed inside plastic bags to maintain its moisture. Then, proportions of eggshell powder were taken, which are (2, 4, 6 and 8 %) of the weight of the dry soil with moisture content of (12, 14, 16, 18 and 20 %) of the weight of the dry soil. It was determined 6% of the eggshell and 20% of the moisture content as the optimum ratio, which gave the highest compressive strength. The mold with dimensions (50*100) mm was used to test the unconfined compressive strength according to ASTM (D2166-68). The mold was used with dimensions (100 * 100 * 400 mm) to test the flexural strength. The direct shear samples were taken after the flexural test samples were examined from the intact parts. After completing the preparation of the samples, they are covered with two layers of aluminum foil and two layers of wax and cured at a temperature of (49°C) for two days according to the Illinois method, To study the effect of the curing time on the samples for a period of (7, 14, 28, 50 and 100) days on the unconfined compressive strength, the samples were covered with two layers of aluminum and two layers of wax at a temperature of (25°C) along these periods, then the layers of aluminum and wax are removed, and then testing.

3. Results and Discussions

3.1 Unconfined compressive strength

3.1.1 for natural soil (NS):

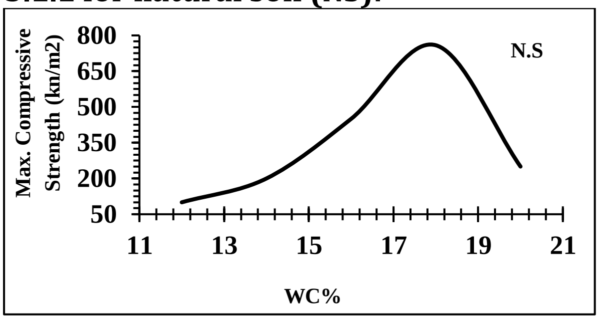

Figure 3-1 Curve of Unconfined Compressive Strength and Moisture Content for Natural Soil

From the fig. 3-1, it is shown that the value of the unconfined compressive strength increases with the increase in the moisture content, where the percentage of water was (12%) with the lowest unconfined compressive strength ($150kn/m^2$) and the increase in the unconfined compressive strength continued, reaching a peak ($759kn/m^2$) at (18%) from moisture content. Then we noticed a decrease in the unconfined compressive strength when the moisture content increase.

3-1-2 for eggshells lime powder

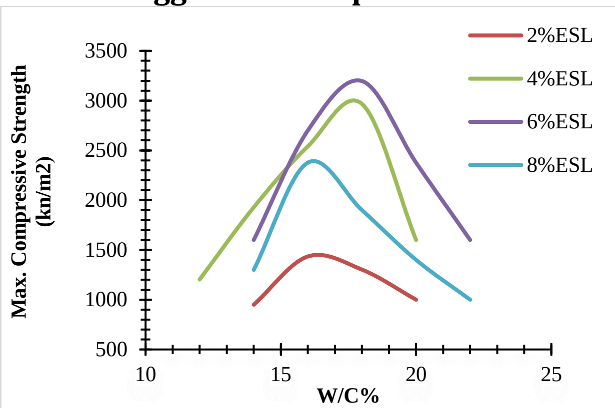

Figure 3-2 Curve of Unconfined Compressive Strength and Moisture Content for Eggshells powder

From the fig. 3-2, it is shown that There are four percentages of eggshells lime powder taken as a weight percentage of dry soil weight (2, 4, 6 and 8) % with moisture content (12, 14, 16, 18 and 20) %. We note that (2%) of eggshell lime powder gave the best unconfined compressive strength (1434 kn/m^2) at (16%) from moisture content, then the unconfined compressive strength decreased continuously at (18% and 20%) from moisture content. And we note that (4%) of eggshells lime powder led to a continuous increase in the unconfined compressive strength, and the best unconfined compressive strength was ($2966kn/m^2$) at (18%), then the unconfined compressive resistance decreased at (20%) from moisture content. Also, (6%) of eggshells lime powder had a continuous increase in unconfined compressive strength, and the best unconfined compressive strength was ($3197kn/m^2$) at 18%, then the unconfined compressive strength decreased at 20%. And 8% of the eggshell lime powder had the best unconfined compressive strength (2377 kn/m^2) at the moisture content of (16%), and then the unconfined compressive strength decreased at the moisture content of (18% and 20%).

From the above it is shown that the best percentage that gave the best unconfined compressive strength is (6%) at moisture content of (18%).

3-1-3 for natural soil with eggshell lime powder

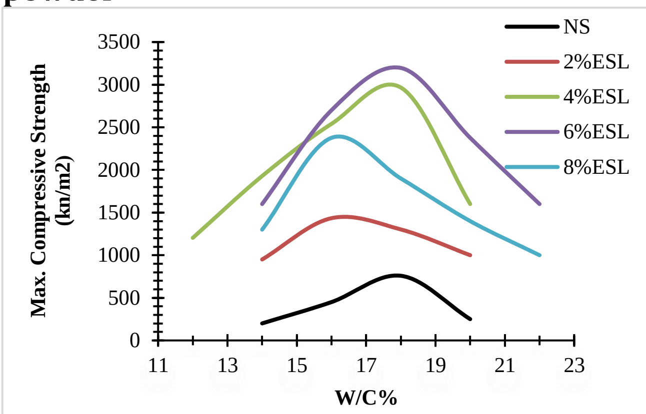

Figure 3-3 Curve of Unconfined Compressive Strength and Moisture Content for Eggshells powder with Natural Soil

From the fig. 3-3, We note that all the added percentages of egg shells lime powder led to an improvement in the unconfined compression strength, especially the 6%, which improved the unconfined compressive strength in a high way, which means the effectiveness of eggshell lime because it contains high amounts of calcium oxide (CaO).

3-2 Flexural Strength

3-2-1 Flexural Strength for Natural Soil

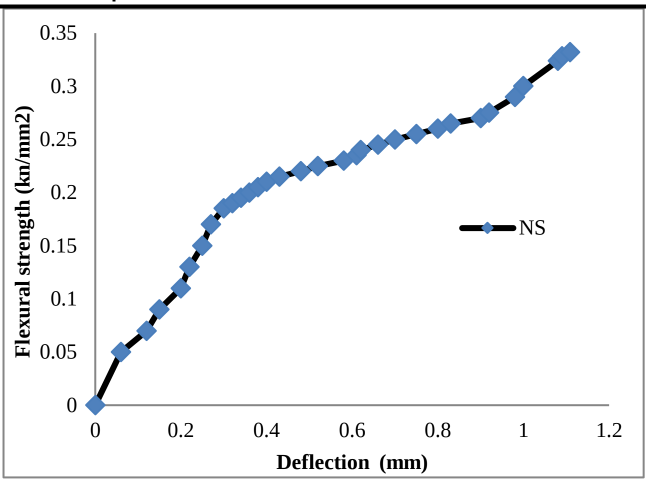

Figure 3-4 Curve of Flexural Strength and Deflection for Natural Soil

From the fig. 3-4, we note that gradual rise of the curve until it reaches the point of failure at Flexural strength of ($0.332 kn/mm^2$) and deflection of (1.109mm).

Note: The sample was prepared at the optimum moisture content (18%), which gave the highest unconfined compressive strength, and the sample was stroked on five layers, each layer (106) stroke.

3-2-2 Flexural Strength for Eggshells lime powder

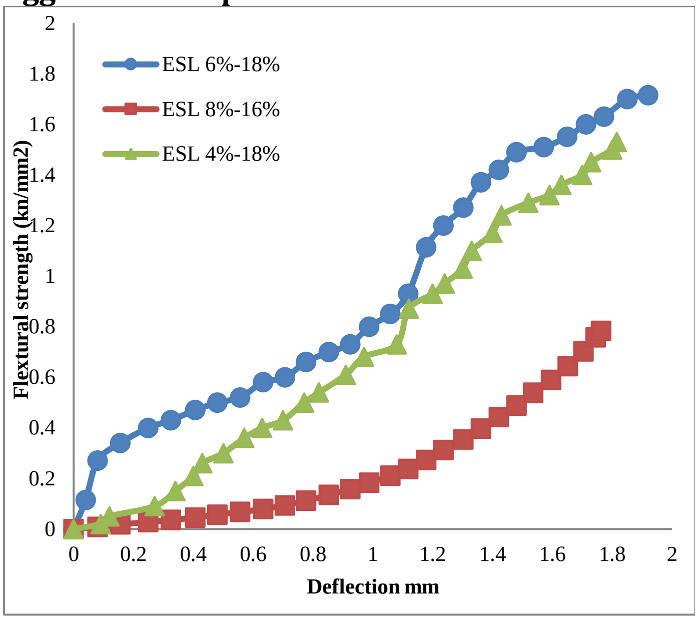

Figure 3-5 Curve of Flexural Strength and Deflection for Eggshells powder

Three percentages of eggshells (4, 6, and 8%) were selected at the optimum moisture content (18, 18, and 16%) from the fig. 3-5. We note that the greatest Flexural strength is ($1.715 kn/mm^2$)at a deflection of (1.92mm) for (6%), While the Flexural strength was ($1.53 kn/mm^2$) at a deflection of (1.815mm) for (4%) and the Flexural strength was ($0.7836 kn/mm^2$) at a deflection of (1.763mm) for (8%).

3-2-2 Flexural Strength for Eggshells lime powder with Natural Soil

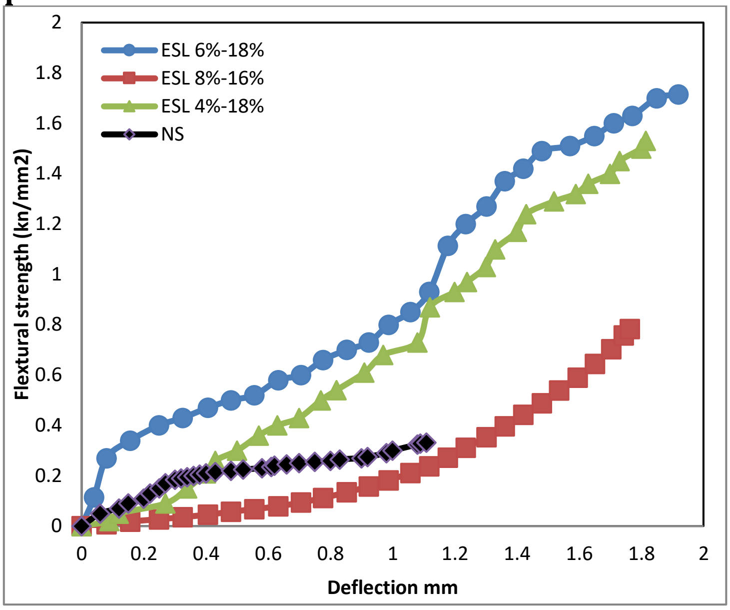

Figure 3-6 Curve of Flexural Strength and Deflection for Eggshells powder with Natural Soil

From the fig. 3-6, we note that all the added percentages of eggshells lime powder led to an improvement in the Flexural Strength and Deflection with an increase in the time to failure, especially the (6%). Which means the effectiveness of eggshell lime, this is because the eggshell lime powder material acted as a bonding material for the molecules and filler the voids, and this is due to the Pozzolanic interactions.

3.3 Direct Shear

Materials	Cohesion (C) (kn/m^2)	Internal Friction Angle (ϕ)
Natural Soil	25	26.7
4% ESL	34.4	44.1
6% ESL	36.1	46.71
8% ESL	32	43.44

Table 3-1values of cohesion strength and internal friction angle for natural soil and eggshells lime powder

From table 3-1, we not that the cohesion strength for natural soil is ($25kn/m^2$) and internal friction angle is (26.7°), While the cohesion strength ($36.1kn/mm^2$) at an internal friction angle (46.71°) for (6%) and the Flexural strength ($34.4kn/mm^2$) at an internal friction angle (44.1°) for (4%) and the cohesion strength ($32kn/mm^2$) at an internal friction angle (43.44°) for (8%). Through the values we obtained, we notice an increase in the cohesion strength and the internal friction angle of the soil treated with eggshells lime powder.

3.4 Effect of curing period on unconfined compressive strength

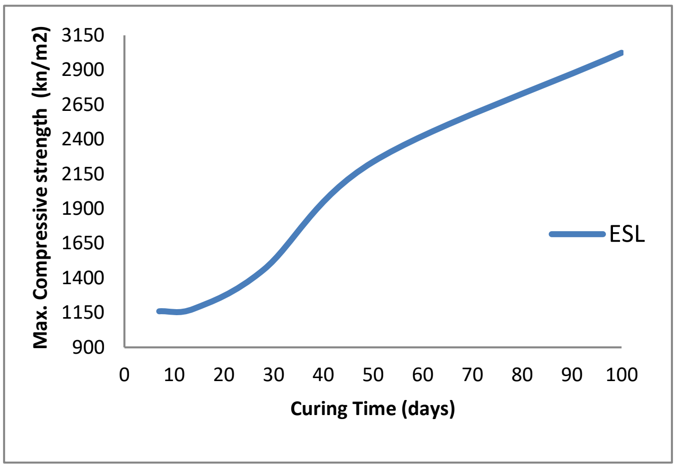

Figure 3-7 Effect of curing period on unconfined compressive strength

From the figure 3-7, We note an increase in the values of unconfined compressive strength, as it was ($1160.161kn/m^2$) at 7 days, ($1179.007kn/m^2$) at 14 days, ($1459.747kn/m^2$) at 28 days, ($2237.348kn/m^2$) at 50 days and ($3024.251kn/m^2$) at 100 days, we note the continuation of the increase in the strength with time and this is due to the continuation of the Pozzolanic interaction between the additive and clay particles.

4. Conclusion

All the tests that were conducted on the clay soil treated with eggshell lime powder in this research showed improvement and this is because the eggshells lime powder contain large amounts of calcium carbonate, which is responsible for the pozzolanic interactions, as it works on the bonding of particles between the soil and the stabilizer, as well as filling the voids.

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