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Improving the Soft Clay using Seashell and Eggshell for Road Construction

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***Abstract*- Farming residues like eggshells and Sea residues like seashells have turned into a well-known choice for enhancement of soft soils because of their expense viability and natural cordiality, making them a suitable choice for accomplishing sustainability in the construction. Soft clay soils have relatively low bearing capacity and high compressibility inducing settlement. For this reason, the construction of the subgrade in soft clay soils has met many problems. Expensive and traditional solutions are utilized in some projects, which usually encourage the idea of removing and replacing soft soils. Instead, land improvement is recently the best way to overcome this problem. This study aims to decrease the use of lime as the most common stabilizers utilized for soft soils; use recycled waste materials like seashell and eggshell powder is the new objective of this study. California bearing ratio tests were conducted to examine some changes in the engineering properties of treated soils by adding waste seashell and eggshell powder with different percentages of (2%, 4%, 6%, 8%, 10%, 12%, 14%, 16%, 18% and 20%) of dry weight of soil. The results show that the inclusion of seashell and eggshell powder increased the CBR of soft clay soil. The influence of adding seashell powder on soft clay soil is more effective than eggshell powder in road construction but finally, both of them can be used as a waste natural stabilizer to increase the CBR of soft clay soil.**

Keywords: **Soft Clay Soil, Seashell, Eggshell, California Bearing Ratio (CBR).**

I. INTRODUCTION

Soft clay soil is a low-strength soil that is greatly influenced by water, but it can be relatively solid when dry. When water is added to soft clay soil, it becomes plastic or flows like a liquid [2]. Due to the remarkable plasticity of clayey soils, soft clay can experience uncontrollable settlement and loss of bearing capacity. In Egypt, soft clay soil is widely distributed in the Central and Northern parts of Nile Delta, where they range from less than one meter to more than 15m in thickness. In many places of Nile Delta, particularly in the Northern part, soft clay soils cause irregular tilting of superstructures and severe damage to infrastructures. Soft clays have become problems of major importance to geotechnical engineers [13].

Different researchers stabilized the soft soils with different materials like cement kiln dust, fly ash and ceramic dust waste [3]. Other researchers investigated the enhancement of CBR of soft soils using lime-micro silica fume mixture [9] and reed ashes [10].
Many researchers have done many studies on stabilization of soft clay soils with expensive additives [18] but nowadays, there is justification for seeking cheaper additives like marble dust but it was used to stabilize the collapsing soil [1] and soft clay [12]. In this study, seashell and eggshell powder were used as cheap additives to improve the soft clay properties.

Among the Egyptian sea shorelines there are areas where considerable amount of shell and shell fragments with variable size and content are mixed with soil formation. If waste is left untreated for a long time, it can be a source of unpleasant smells due to either the decay of remnant flesh attached to sea shells or microbial decomposition of salts into gases such as NH3, H2S, and amine [8].

In Egypt, eggshell powder was produced annually with large quantities which add to the contamination and health risks of the environment [14].

Seashell and eggshell powder can be used as a partial replacement for industrial lime due to its chemical composition, which is similar to lime. Different researchers have studied different uses of seashell and eggshell like cement mortars [17], pervious concrete pavers [16] and cement blocks [7] for seashell and masonry blocks, clay bricks, soil stabilizer, cement replacement in concrete and mortar for eggshell [15].

II. GOALS AND OBJECTIVES

It has been found that some researchers have studied the influence of adding lime and expensive stabilizers on soft soils but others studied the effect of cheap and waste stabilizers like seashell and eggshell on the california bearing ratio of soft clay so, the study of the effect of utilization of seashell and eggshell powder on the CBR of soft clay soil could not be thoroughly investigated. Therefore, the objective of this research is to study the effect of adding seashell and eggshell powder on the CBR of soft clay soils to be used in pavement construction. In this research an experimental testing program is done to study the effect of adding seashell and eggshell powder on soft clay soils including X-Ray diffraction (XRD) and California bearing ratio (CBR).

III. MATERIALS AND METHODOLOGY

A. Used soil

Obtaining undisturbed soft clay samples from the site is too difficult so, the clay has been prepared in the laboratory using kaolin regarding to [11].

Kaolin based artificial soils have been particularly popular for laboratory work and has been widely used both in fundamental studies of soil behavior, soil stabilization and in physical model tests. The properties of pure kaolin are somewhat a typical of natural clay soils. The mineralogical and chemical properties of the kaolinite published by the manufacturer from (El Basatin for Industry/ Cairo /Egypt) were presented in tables 1 and 2. The geotechnical characteristics of soft clay soil performed in laboratory were presented in table 3. This powder was mixed with 22% water content to form a soft clay soil that can be used to simulate the natural soft clay. Different tests were performed on the prepared soft clay to study its properties.

Table 1: Chemical composition of the kaolinite used (Data sheet of the manufacturer).

Type of Mineral	Volumetric Content (%)
Clay Mineral	90.97
Sodium Feldspar	2.27
Potassium Feldspar	2.31
Free Quartz	4.45

Table 2: Chemical composition of the kaolinite used in this study (Data sheet of the manufacturer).

Element	Result (%)
Silicon dioxide (SiO2)	50-56 max
Aluminum oxide (AL2O3)	30-33 min
Iron oxide (Fe2O3)	1.0-1.3
Titanium dioxide (TiO2)	1.3-1.8
Calcium oxide (CaO)	0.10-0.25
Magnesium oxide (MgO)	0.05-0.10
Sodium oxide (Na2O)	0.07-0.15
Potassium oxide (K2O)	0.03-0.06
Chlorine (Cl)	< 0.05
Loss on ignition (105°C-1000°C)	11-12

Table 3: Geotechnical characteristics of soft clay soil.

Soil property	Unit	Value
Liquid limit, L.L	(-)	31.2%
Plastic Limit, P.L	(-)	15%
Plasticity index, P.I	(-)	16.2%
Specific gravity, Gs	(-)	2.64
Maximum dry density, $\gamma_{dry\ max}$	(kN/m^3)	18.54
Optimum moisture content, O.M.C	(-)	12.8%

B.Seashell powder

Seashells were obtained from Baltiem city, Egypt on the sea shore shown in figure 1.

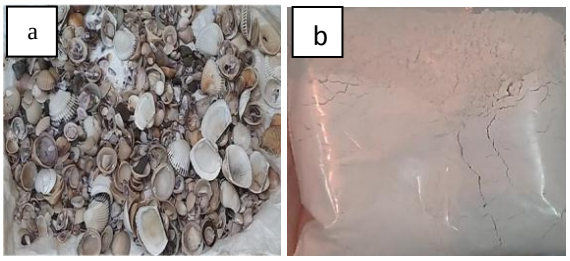

Fig. 1: Seashell (a) before and (b) after crushing

C. Eggshell powder

Eggshells were obtained from poultry of village city near Tanta city, Egypt. Seashells and Eggshells were grinded at faculty of science, Tanta University, Egypt using mill shown in figure 3.

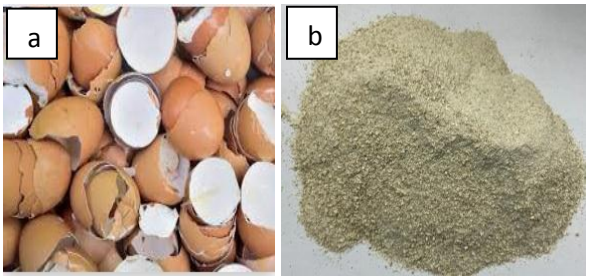

Fig. 2: Eggshell (a) before and (b) after crushing

Fig. 3: Grinder used for crushing seashell and eggshell.

IV. TESTING PROGRAM AND INVESTIGATED PARAMETERS

Ten different mixtures of the soil were mixed with (2, 4, 6, 8, 10, 12, 14, 16, 18 and 20%) of seashell and eggshell powder and a series of laboratory tests were carried out on the untreated and the treated soil as shown in table 4. In total, 47 tests were performed on the soft clay soil before and after adding seashell and eggshell powder with different percentages as follows:

1. X-Ray diffraction (XRD)
2. Modified proctor test.
3. California Bearing ratio (CBR).

Table 4: Experimental testing program

Test Series	Test Type	No. of Tests
S1	X-Ray Diffraction, XRD	7
S2	Compaction test	19
S2	California bearing ratio	21
Total		47

- Compaction tests according to (ASTM-D 1557) were conducted to study the effect of adding different additives on the density and the optimum water content characteristics of mixture. The compaction test was carried out on the soft clay alone, and on the soft clay mixed with different percentages of seashell and eggshell powder.
- For the california bearing ratio test, the samples were compacted at its maximum dry density and optimum moisture content then examined under the loading piston to get the stress at 2.5 mm and 5 mm penetration and then calculate the bearing ratios for each by dividing the corrected stresses by the standard stresses of 1000 psi (6.9 MPa) and 1500 psi (10.3 MPa) respectively, according to ASTM, D1883 – 07.

IV. RESULTS AND DISCUSSION

This study aimed to illustrate the impact of adding seashell and eggshell powder to soft clay soil to improve its characteristics. Different tests such as XRD pattern before and after treatment, compaction characteristics and California bearing ratio tests were conducted. The obtained results were analyzed and presented in this section

A. X-Ray Diffraction

XRD on the untreated and treated soft clay soil is shown in this part. The results of XRD on the untreated soft clay soil indicated that kaolinite is the main clay mineral of the soft clay soil prepared in laboratory with 69.3%. Other minerals were also detected in the samples such as quartz with 30.7% as illustrated in figure (4). XRD of seashell powder only was illustrated in figure (5) which point out that the main mineral is the aragonite with 96.2%. XRD of eggshell powder was also presented in figure (6) which also point out that it mainly consists of calcite. XRD of soft clay soil treated with 12% and 20% seashell powder addition were also illustrated in figures (7&8) respectively. XRD of soft clay treated with 6% and 20% eggshell powder were also shown in figures (9&10).

For the seashell powder, adding 12% seashell powder to soft clay, the kaolinite peak decreased from 1136 to 467 at 2theta equal 12.34o, while by further adding 20% seashell powder the kaolinite peak decreased to 248 at the same 2 theta which indicates that by adding more seashell powder, the kaolinite percentage decrease gradually developing new cementing compounds like Aluminum silicate hydroxide, Picromerite and Portlandite. These compounds fill the intermolecular voids between Kaolinite particles and increase the cohesion between its particles.

For eggshell powder addition, by adding 6% eggshell powder to soft clay soil, the kaolinite peak decreased from 1136 to 700, by further adding 20% eggshell powder, the kaolinite peak reached to 561 which also indicates forming new cementious compounds filling the voids between the clay minerals and increasing the cohesion of soft clay soil.

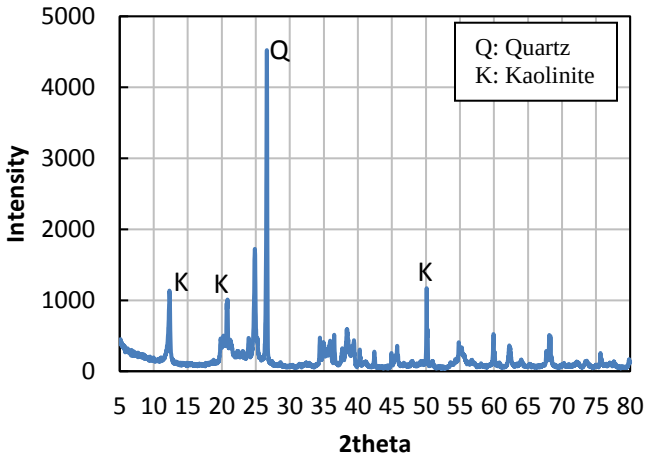

Fig. 4: X-Ray diffraction of soft clay soil.

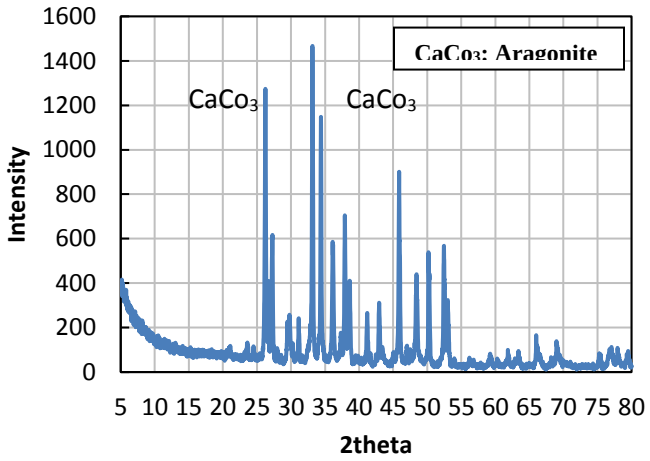

Fig. 5: X-Ray diffraction of seashell powder.

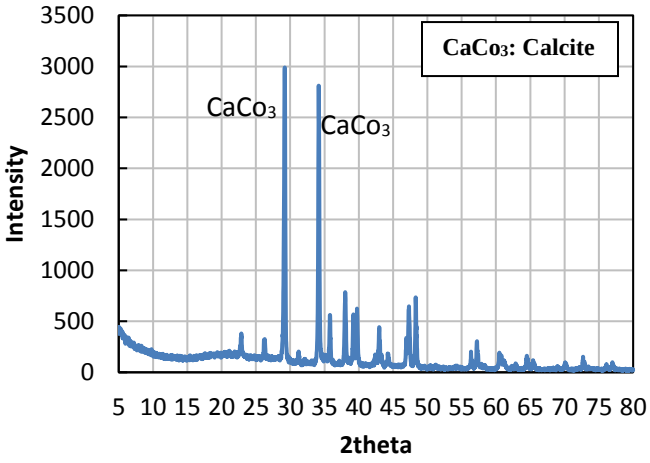

Fig. 6: X-Ray diffraction of eggshell powder.

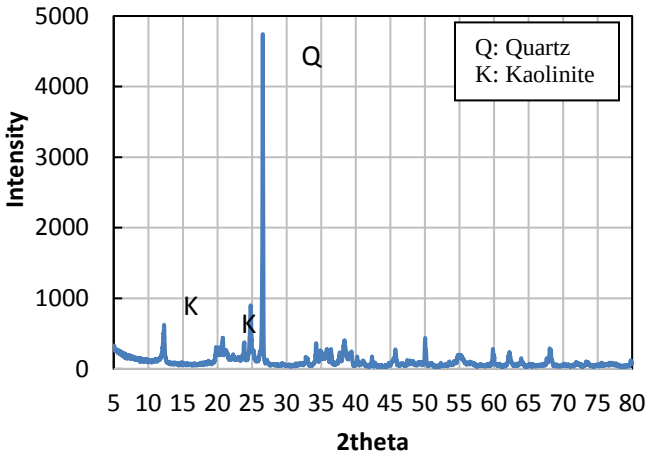

Fig. 7: X-Ray diffraction of soft clay soil with 12% seashell powder

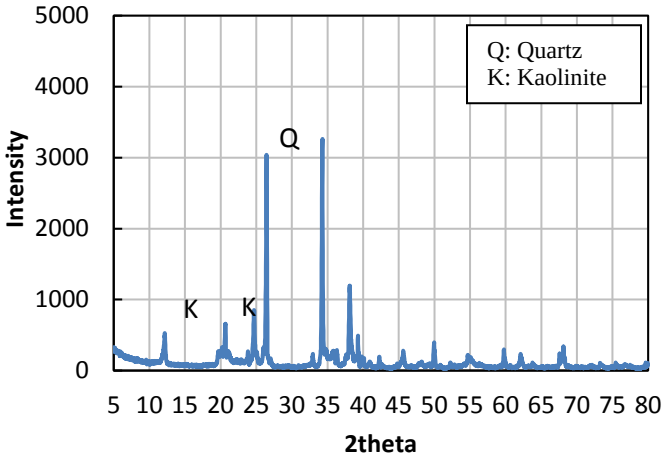

Fig. 8: X-Ray diffraction of soft clay soil with 20% seashell powde

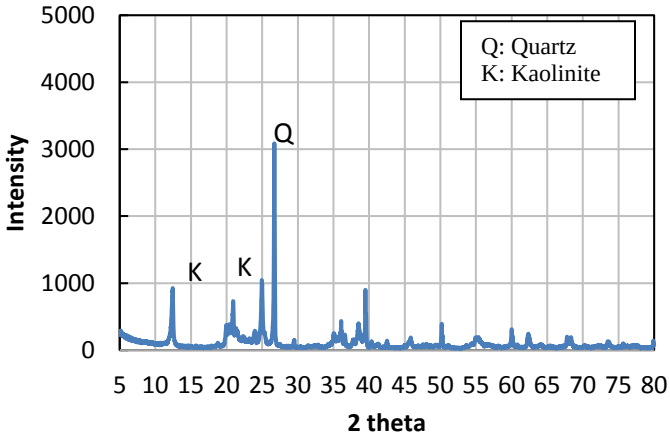

Fig. 9: X-Ray diffraction of soft clay soil with 6% eggshell powde

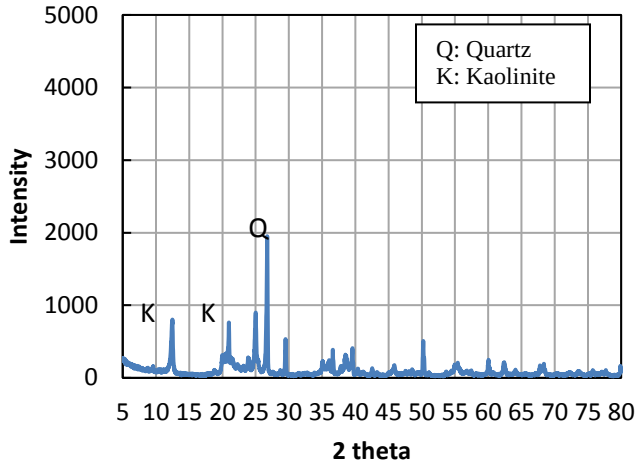

Fig. 10: X-Ray diffraction of soft clay soil with 20% eggshell

B. Modified proctor test

In this part, modified proctor test has been performed on the untreated and treated soft clay and the obtained results are shown in table (5). The maximum dry density increased as seashell and eggshell powder addition increased till reaching 16% seashell powder addition and 6% eggshell powder addition then decreased.

This increase in the maximum dry density is due to the replacement of the clay particles with seashell and eggshell powder particles which increases the friction between clay particles and presence of angle of internal friction by adding seashell and eggshell powder to soft clay soil.

The decrease in the maximum dry density values after the addition of 16% seashell powder and 6% eggshell powder was attributable to excess seashell and eggshell powder that occupies spaces within the soil to form weak bonds between the soil and the cementitious compounds formed by reaction.

Table 5: Compaction characteristics of untreated and treated soft clay with seashell and eggshell powder.

(%) of additives	Seashell powder		Eggshell powder	
	Maximum dry density, γ_{dry} max (kN/m3)	Optimum water content, OMC (%)	Maximum dry density, γ_{dry} max (kN/m3)	Optimum water content, OMC (%)
0	18.54	12.80	18.54	12.80
2	18.67	13.71	18.61	13.91
4	18.77	13.92	18.68	13.62
6	18.85	13.18	18.73	13.39
8	18.92	12.98	18.69	13.64
10	18.92	12.40	18.69	13.65
12	18.93	12.32	18.68	13.58
14	19.29	12.25	18.65	13.75
16	19.34	12.06	18.60	13.57
18	18.86	11.96	18.52	13.13

C. *California bearing ratio (CBR)*

The CBR of soft clay (untreated soil) and treated soil with different percentages of seashell and eggshell powder is shown in figures (11&12). The CBR ratio of soft clay soil is 0.97%. CBR ratio increased to 8.737% at 20% seashell powder addition and it increased to 6% at 20% eggshell powder addition. This increase is due to the soil particles are surrounded by seashell and eggshell powder. The seashell and eggshell powder are acting as a binder between the powder and soil particles which give reactions for the increase in the CBR. Thus, the soil particles can resist a higher force by penetration acting on it and therefore the CBR value increased and this is due to the presence of new materials from the reaction between calcium carbonate in additives and minerals of soft clay soil.

Figures 11 and 12 show the relationships between CBR ratio and different percentages of seashell and eggshell powder. By increasing seashell and eggshell powder, the CBR increases. The seashell powder addition has a great influence on the CBR ratio than the eggshell powder.

From these results, soft clay stabilized with seashell powder can be used in road construction and it is more effective than eggshell powder which also gave increase in CBR ratio but less than the CBR ratio of seashell powder addition. This is due to the results of XRD which indicates the decrease of the kaolinite peak at 12.34º from 1136 to 248 at seashell powder addition and 561 at 20% eggshell powder addition. This result points out the presence of new cementing compounds in case of seashell powder addition with a percentage more than the cementing compounds formed with eggshell powder addition. The presence of calcium carbonate in seashell powder is in form of aragonite which is the unstable form but in eggshell in form of calcite which is the stable form.

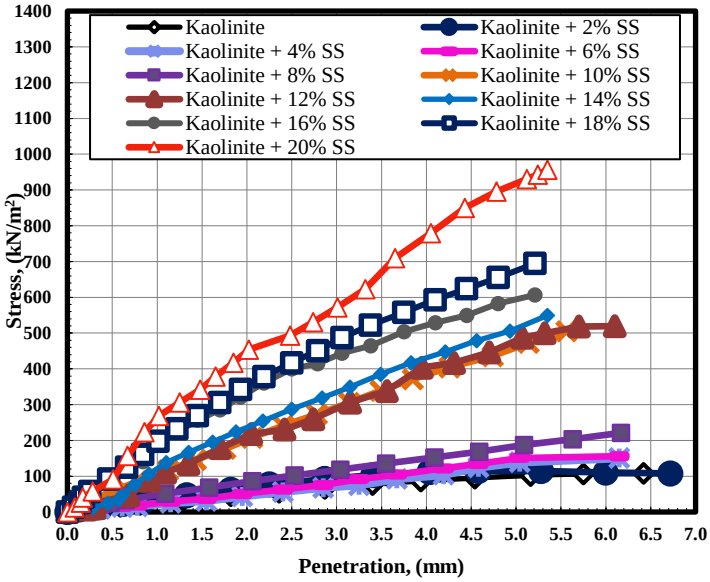

Fig. 11: CBR of untreated and treated soil with different percentages of seashell powder

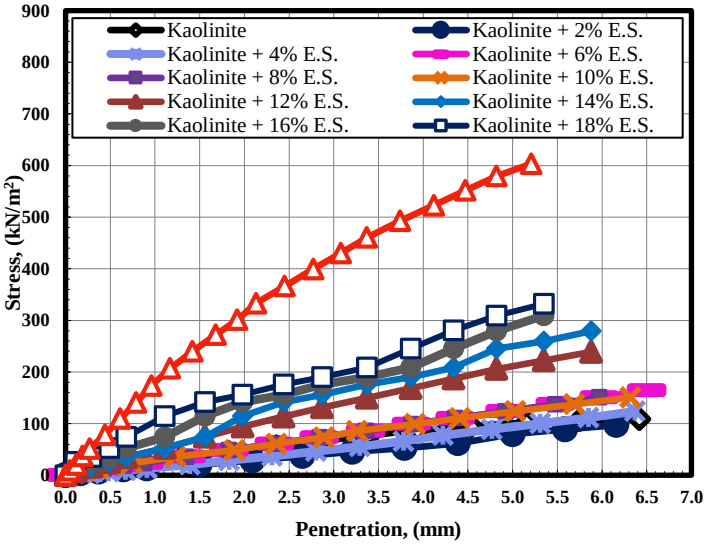

Fig. 12: CBR of untreated and treated soil with different percentages of eggshell powder.

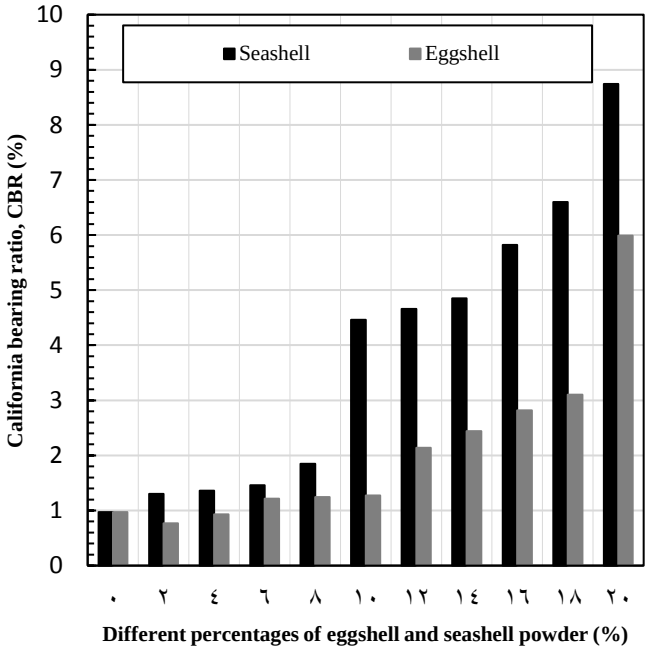

Fig. 13: Comparison between CBR of soft clay soil stabilized with seashell and eggshell powder

VI. CONCLUSIONS

From this study it can be concluded that soft clay soil improved with seashells and eggshells can be used in road construction, the main novel outcomes from this study are as follows:

1. The maximum dry density increased from 18.54 kN/m^3 to 19.34 kN/m^3 and to 18.73 kN/m^3 for 16% seashell and 6% eggshell powder addition respectively.

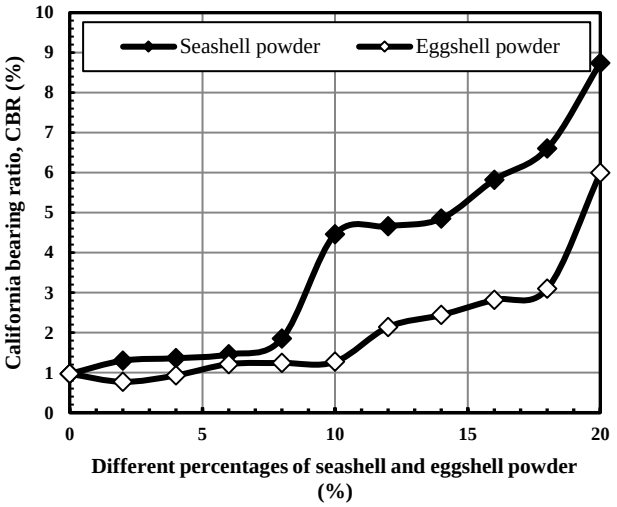

Fig. 14: CBR ratio with different percentages of seashell and eggshel powder

2. From XRD analysis, it is found that by increasing seashell and eggshell powder addition, the peak of kaolinite decrease gradually which indicates the formation of new cementing materials which increase the bond between soil particles and decrease the intermolecular voids.
3. Soft clay cannot be used in road construction as it has low CBR of 0.97% but improved soft clay with seashell and eggshell powders have higher values of CBR. It is found to be increased from 0.97% to 8.73% and 6% for seashell and eggshell powder addition respectively.
4. The increase in CBR ratio is due to the pozzolanic reaction happens between soft clay soil minerals and calcium carbonate found in seashell and eggshell powder forming new cementing compounds acting as a binder between the additive and soil particles which give reactions for the increase in the CBR.
5. Seashell powder addition is more effective than eggshell powder addition in pavement construction

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