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MITIGATE PERFORMANCE OF SHALLOW SOFT COHESIVE DEPOSIT SOIL USING BY-PRODUCT STEEL SLAG AGGREGATE

Naema Ali Ebraheim Ali*

Associate Professor, Civil Engineering Dpt., Higher Institute of Engineering & Technology, King-Marriot, Alex., Egypt.

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***Corresponding Author**
Dr. Naema Ali Ebraheim Ali
Associate Professor, Civil Engineering Dpt., Higher Institute of Engineering & Technology, King-Marriot, Alex., Egypt.

ABSTRACT

Using by-product materials, west and recycle material should be widely used for economic and environmental reasons. Steel Slag Aggregate (SSA) can be used to control the highly problematic soft cohesive deposit soil to be adequate to support engineering structures. Laboratory study is carried out to investigate the geotechnical characteristics of soft cohesive deposit soil by Atterberg limits tests, the optimum moisture contents (OMC) the maximum dry densities (MDD) and California bearing ratio (CBR) and strength properties, the unconfined compressive strength test (UCS), vane tests (VT), before and after mitigate. Experimental results of using different gradation of crushed (SSA) to improve the soft cohesive deposit, it was mixed with various percentages, (15%, 25% and 35%) of dry weight of deposit soil are carryout. Soft cohesive deposit and various mixtures are examined for its geotechnical properties and its strength parameters. The results of soft cohesive deposit at different partially replacement percentages were compared to conclude the overall best gradation and optimum percentage of that particular material, (SSA) added to soft cohesive deposit soil based on modified the geotechnical characteristics of these deposit soil. Also, field plate load tests program was developed and conducted on improved soft cohesive deposit soils. The results introduce the development of practical, economical and environmentally safe geochemical methods for soft cohesive deposit soil stabilization and mitigated its low bearing capacity and eliminated its excess settlement risk about 50%.

KEYWORDS: Improvement, Soft cohesive deposit, Gradation of Steel Slag Aggregate.

INTRODUCTION

Challenging faced all geotechnical engineers when using soft cohesive deposit soil, either as a foundation medium or construction material because of its excessive settlement over a small time period and its low bearing capacity. Soft cohesive deposit soil is a one of the highly problematic soil with low shear strength which cover the majority parts of Alexandria Egypt. By rapid urbanization, highway construction and infrastructure development in region of soft cohesive deposit in Alexandria this soil is inefficient to support any engineering structures, infrastructure, transportation roads, and pavement before eliminate or reduce the effect of its compressibility and large volume change under load. Thus, there is an urgent need to study the technique of 'remove and partially replace with light material for soft soil' reference,[1] for improving a weak deposit soil in term of geotechnical requirements, settlement and bearing capacity.

There are many projects suffered from several problems related to construction on or by soft cohesive deposit soils, such as cracks, tilting and failure the foundation soil. These problems could happen due excess of load exceeds the ultimate limit capacity and excess settlement. A reference,[2] Al-Bared et al., (2017) reported a brief of the various ground improvement methods and many researches,[5,9,11,13] studied using Chemical, Cement and lime in Maine clay improvement. Another researches,[1,6,8] were reported that the most commonly adopted method stabilizers for soft soils as a Cementous material. Under the dilemma of non-renewable natural resources shortage and environmental pollution issues, it is a significant economic and environmental benefit to replace the lime or cement in the construction with a large amount of Steel Slag. One of recent applications of steel slag powder and steel slag aggregate were used for high performance concrete and high compressive strength concrete, reference.[4] Other researches,[7,12,13] reported that a steel slag–fly ash–was used as solidified material for road base material.

A reference,[3] Li et al., (2017), reported that, more than 12–20% of solid waste output in the world is Steel Slag which is a kind of solid waste produced in steelmaking industry. Slag used all over the world in road and railway construction and for engineering and has many advantages over natural rock. In Egypt about (2.1~3.6) million tons of Steel Slag produced by year in full capacity of industry, quoted by reference.[10] Mouss et al, (2019). Soil replacement technique is the easiest and oldest method to improve the soft soils underneath the shallow foundations by reducing the settlement by replacing weak soil (e.g. medium or soft clay and organic soils) with more competent materials such as sand, gravel or other suitable granular materials.[1]

In this study the soft cohesive soil deposit samples, used was retrieved from a Charcoal store site Km.21 Umm Zaghio road Alexandria, Egypt. Described soil investigations including soil laboratory tests and in-situ plate test on natural and improved soft cohesive soil deposit. Also, parametric study is done with various removal and partially replacement soil with various percentage of crushed (SSA) with various gradation used and analyzed to obtain the replacement best grain size and percentage of (SSA).

Experimental Tests and Material

The used soft cohesive deposit soil from a Charcoal store site Km.21 Umm Zaghio road Alexandria, Egypt was obtained from an excavation process at depth 1.50 m. The liquid and plastic limits were obtained and the soft soil classified according to the unified classification system, (USCS), as inorganic clay of high plasticity Silty Clay. Steel Slag Aggregate (SSA), obtained from AL EZZ-Dekhelia steel factory after air cooled about period six months to avoid any expansive in volume due to free oxides hydration and crushed.

A parametric study is done with various partially remove and replace with modified excavated soil mixed with various percentage of crushed (SSA) related to dried excavated soft soil and analyzed to obtain the optimal % of crushed (SSA) replacement and its best grain size. In this paper Also, describes soil investigations including soil laboratory and in-situ plate test which was carried out at a Charcoal store site Km.21 Umm Zaghio, Figure (1) shows the site, (SSA) and soil profile.

Figure (1): a.View of by-product - Steel Slag (ASS) in Study Site - (Various graded and percentage of crushed (SSA) was used).

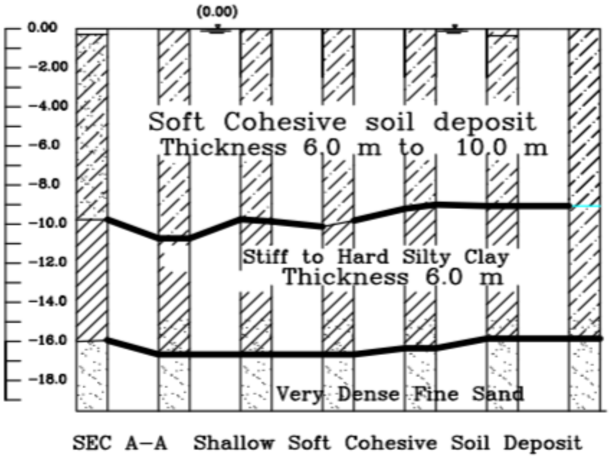

Figure (1): The site, (SSA) and soil profile.

To prepare treated samples, the dry soft cohesive soil deposit was mixed in a dry condition with various gradation, (S1, S2, S3, S4 and S5) and various percentages of crushed (SSA), (15%, 25% and 35%) in fifteen various mixtures models. Table (1) and fig. (2) shown the gradation of (ASS) samples used and all testing procedures were performed as specified in the ASTM standard.

Table 1: (ASS) various gradation, (S1, S2, S3, S4 and S5) details.

Properties	Grade of (SSA) using in improved soft cohesive soil deposit with various percentages				
Sample name	S-1	S-2	S-3	S-4	S-5
Dry unit weight (kN/m^3)	22.5	23.2	25.2	26.8	27.2
% gravel Sizes	96.68	94.81	82.07	11.01	6.02
% Sand Sizes	0.66	0.51	13.41	87.39	87.61
% fines Sizes	2.65	4.68	4.52	1.6	6.37
Effective Diameter De mm.	13.04	9.65	2.67	0.67	0.21
Uniformity Coefficient Cu	2.11	2.09	3.99	4.23	7.30
Gradation Coefficient Cc	1.3	0.86	1.28	1.19	1.33

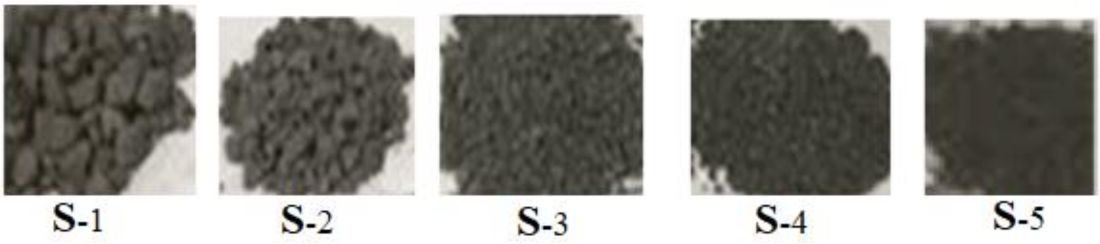

Figure (2): a.Photo of steel slag aggregate (SSA).

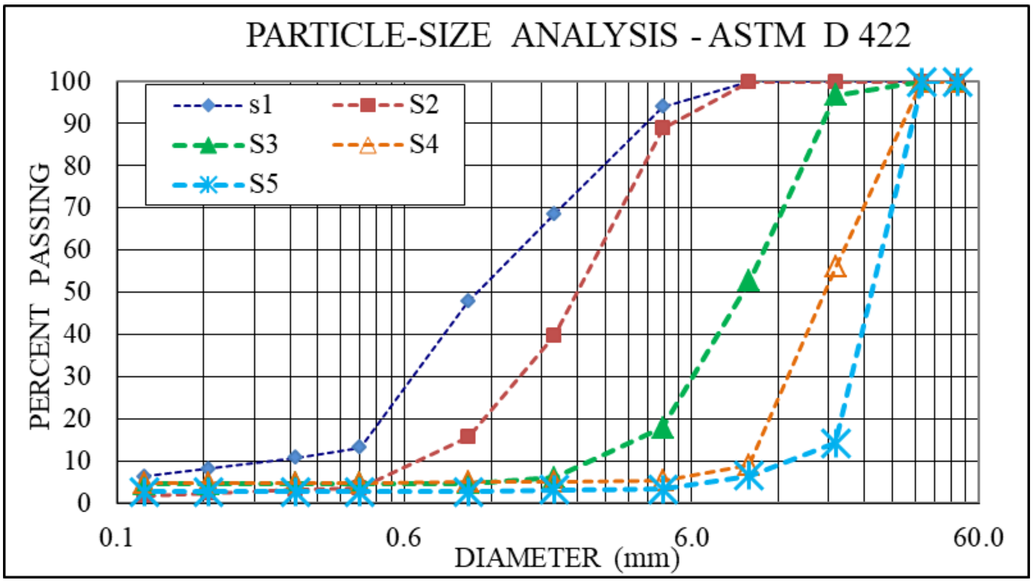

Figure (2): b. Grain size distribution of steel slag (ASS) used.

Laboratory and Fieldtests Program

Prior to improve the site, borings were performed, fig. (1). The field vane tests (FVT), were conducted at the site for the confirmation of soil stratification and the evaluation of various engineering soil parameters. Thin wall tube samplers were used in the sampling of soft cohesive deposit soil layer, helby tube samplers were used, to get a relatively undisturbed sample. The liner sample is then sealed for later classification and laboratory testing. All the samples obtained were tested in the laboratory for their physical properties such as natural water content, bulk density, specific gravity, liquid and plastic limits, for soil classification. Another selected sample has been tested for engineering properties, several laboratory vane tests (VT) and unconfined comprisable tests (UCS) have been conducted on cylindrical specimen for obtained shear strength. Also, compressibility properties have been conducted on cylindrical specimen. Table (2) shows the physical and mechanical properties of the top soft cohesive deposit soil with thickness, (6.0~10.0) meter underground surface.

Table (2): Soft cohesive soil deposit and (ASS) properties.

Properties		Soil	(SSA)
Initial water content (%)		40.50	-
Bulk Density (kN/m^3)		18.60	
Specific Gravity Gs %		2.64	2.85, 3.02
	% Sand	38.50	S1, S2, S3, S4 & S5
	% Silt	28.60	
	% Clay	32.90	
Liquid Limit,		54.4	-
Plasticity Index		28.0	
Soil Classification.(USCS)		CH	
Free Swell Index %		NIL	-
Shear Strength Cu (kPa)		40	-
Max. dry Density (MDD) (kN/m^3)		15.45	S1, S2, S3, S4 & S5
Optimum Moisture Contents (OMC) %		14.50	
(CBR) % Soaked, 2.5 mm Penetrated		0.95	
(CBR) % Un-soaked		1.75	

Experimental procedures in the lab at total of 15 various mixtures models were performed. The soft cohesive soil deposit was dried, crushed and mixed with required quantity of water to get the Initial water content, (40.5%). The average of unconfined compressive strength test (UCS) and vane tests (VT) using to measure of the prepared soft cohesive soil deposit, (Clay) shear strength, c_u which found to be 40 kPa after several trial. Various gradation, (S1, S2, S3, S4 and S5) and various percentages of crushed (SSA), (15%, 25% and 35%) were added to the treated soil. All testes were carried out to determine engineering properties of mitigated and natural cohesive deposit soils at the conditions of optimum water content (OMC) and maximum dry density (MDD).

DISCUSSION TEST RESULTS

Laboratory tests were conducted on natural and improved soil, vane test (VT) and California bearing ratio (CBR) of all the mixes at (OMC) and (MDD). Table (3) indicates the all density of the mixtures investigated in this study. One can observed that for the sandy size (SSA) the mixtures density increases with the increase percentage of (ASS), but when the gravelly size of (SSA) increased up to 90% grain size, the mixtures density decrease.

Table 3: Various Mixtures of sixteen Models.

Properties		**Soil**	**Mix (1)**	**Mix (2)**	**Mix (3)**	**Mix (4)**	**Mix (5)**
Dry unit weight (kN/m^3) Of mixtures models	Gradation	13.24	S1	S2	S3	S4	S5
	15%		16.58	16.81	17.30	17.52	17.86
	25%		18.20	18.50	19.10	19.85	20.15
	35%		21.00	21.20	21.65	22.25	22.80

Stander compaction test is conducted on natural and improved soil figures (3-a) & (3-b) illustrate the results of (OMC) and (MDD) for the various mixtures at (SSA) percentages (15%, 25% and 35%) of the dry soft cohesive soil deposit respectively. These figures have been indicated that all the mixes (OMC) ranges between (10.0 ~12.2) % and were not affected by change the fine (SSA) of the Mixtures used in this study. The Figures also shows that the maximum dry density increased with low optimum moisture and the percentage of (SSA).

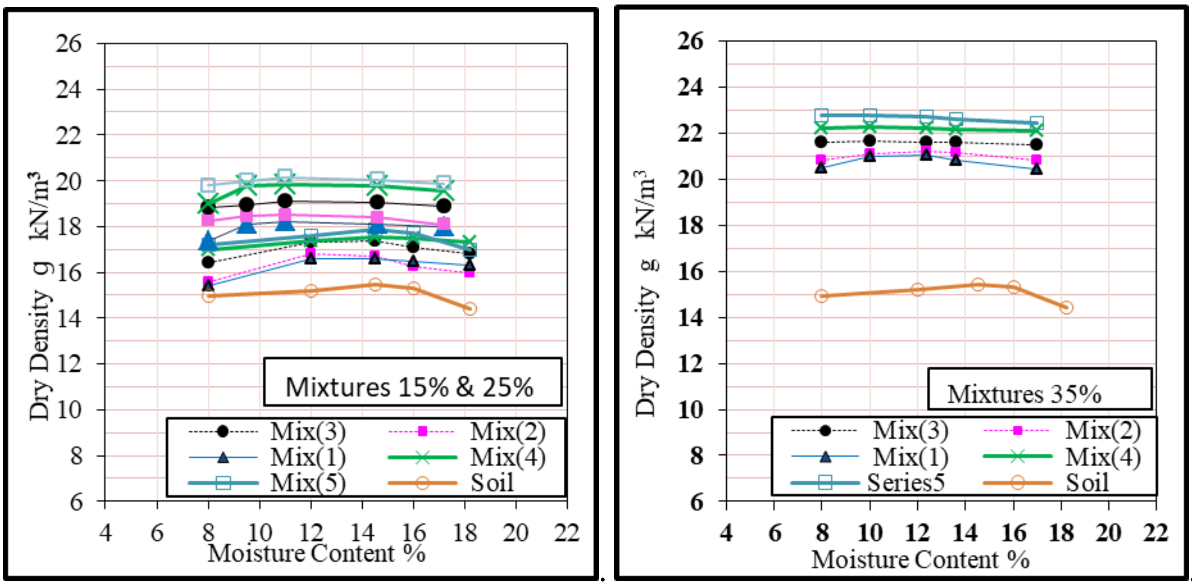

Fig. (3): Relation Between of optimum water content (OMC) and maximum dry density (MDD) at various percentage of (SSA).

The mixed soil strength was examined by measured conducting CBR tests, unconfined compressive strength test (UCS) and vane tests (VT). The figure (4) indicates some of the laboratory test results which indicates that the increased the percentage of (SSA) increase the soil strength. Also, the results indicate that the coarse grain size is an excellent material to improved such these soft soil because of its granular nature which provide additional shear strength to the mixture. Aloes, the finger indicates with the increase of compaction degree and slag content, the CBR value of the soil mixture stabilized is increasing at a percentage 35% of Steel Slag Aggregate (SSA).

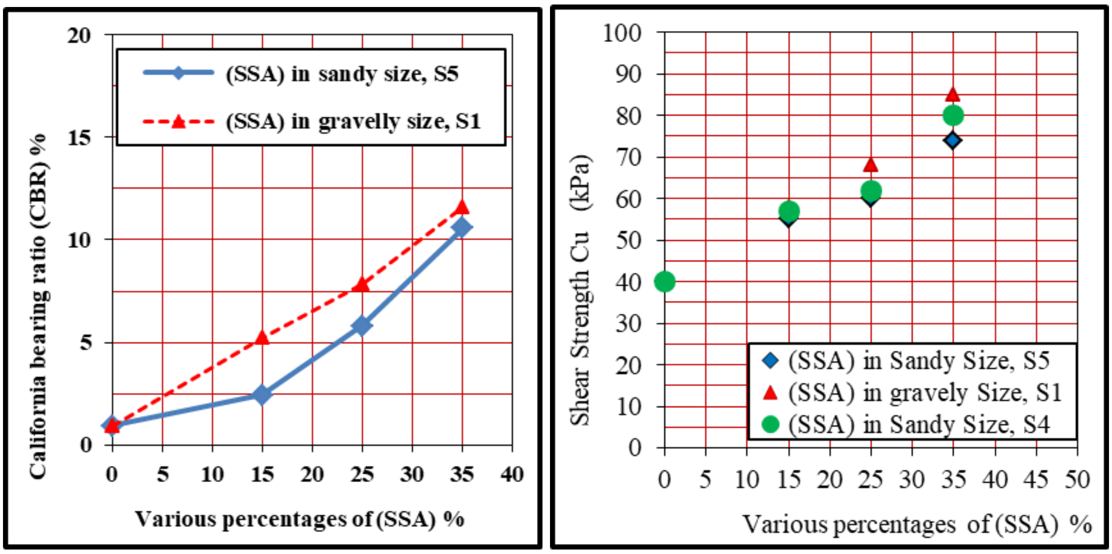

Fig. (4): Relation Between mixed soil load capacity and shear strength at various percentage of (SSA).

Survey Impact on Field Plate Load Tests settlement

Field Plate Load Tests (PLTs) were conducted using a circular plate with diameter 0.80 m. The plate was placed on a depth 0.50 m from the ground surface before and after soil mitigated with partially remove and replace with modified excavated soil mixed with different gradation of Steel Slag Aggregate (SSA) as shown in figure (1), (SSA),S1in gravelly size and (SSA), S5 in Sandy size with thickness 1.00 m in both cases, to examine the soil strength and its bearing capacity. The results of plate load tests using the load versus settlement curve are shown in Fig. (4).

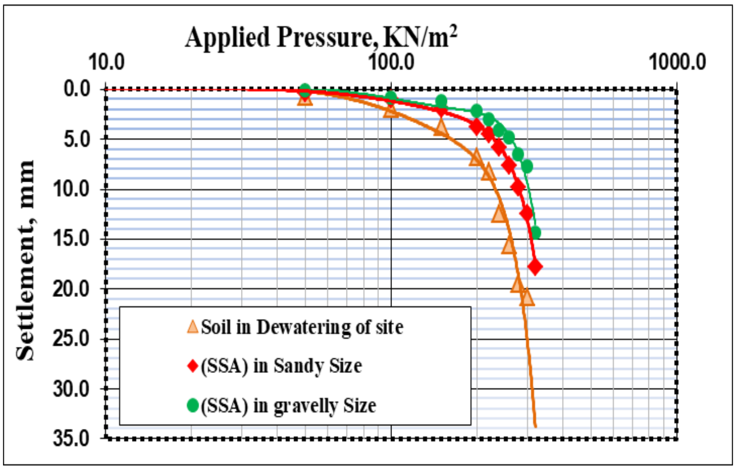

Fig. (5): Relation Between of settlement and applied load at various percentage of (SSA) in site.

Figure (5) indicates that the improved ground had adequate bearing capacity, the plate load test results only reflected the condition of the upper layer of 1.20–2.00 m deep in the compacted layer. Thus, to study the critical area for settlement would be the deeper zone where the (SSA) was mixed with soft cohesive deposit soil, which was not significantly stressed by the plate load tests.

Therefore, the settlement of improved foundation soil in site measured after six months after using the storage areas which loaded with 120 kN/m^2 the maximum settlement after this period were more than the maximum settlement. The total settlement of the measured at the same time were 50 and 60 mm for areas improved by (SSA) graded gravelly size, S1 and sandy size, S5 respectively. The total allowable settlement as specified by the design of the storage areas was 100 mm.

CONCLUTIONS

The present study introduced some of typical results of laboratory tests and in-situ tests prior and after improved and analyzed. It is founded that soil laboratory test is suitable for the study of the engineering improved properties. Load carrying capacity of the improved soil with the gravelly size of (SSA) increase with increase the percentage up to 35% because of the increase friction and gave a stiffer response compared with using sandy size at the same percentage. The manual and visual classification of (SSA) in gravelly size showed that the slag surface texture angular and rough. The failure strain in plate load test result of 25% steel slag soil in sandy size is larger than that of steel slag soil in gravelly size, which has better deformation characteristics because of improve soil permeability. It should be noted that the soil steel slag mixtures, physical and mechanical properties can be changes with change of steel slag the steelmaking process.

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