Asian Journal of Applied Sciences (ISSN: 2321 – 0893)
Volume 03 – Issue 05, October 2015

Assessment of Stabilized Dredged Sediments using Portland Cement for Geotechnical Engineering Applications along Hurghada Coast, Red Sea, Egypt

A. El- Shinawi[1*] and V. Kramarenko[2]

[1]Department of Geology, Faculty of science,
Zagazig University, Zagazig, Egypt).

[2]Department of Hydrogeology and Engineering Geology, Institute of Natural Resources
Tomsk Polytechnic University, Tomsk, Russian

[*]*Corresponding author's email: geoabdelaziz [AT] yahoo.com*

ABSTRACT----*This paper presents details of a study that deals with determination of physical, mechanical and geotechnical properties of dredged sediments used in reclamation projects along Hurghada coast, Red Sea, Egypt. Petrographically, the collected dredged sediments are differentiated into two quartz arenite and quartz wacke.Authigenic clay minerals are uncommon in such sediments. Kaolinite is the main mineral with subordinate illite and rare chlorite. In addition, a series of laboratory tests are conducted on thirty two soil samples to assess such sediments when it is stabilized by a cement additive. Here, essential laboratory tests on the overall soil properties including grain size distribution, liquid limit, plastic limit, compaction at the modified level, CBR and unconfined compressionindicates that the dredged sedimentsare considered desirable for Portland cement stabilization. Compressibility results indicate that it is possible to improve the soil strength at different binder content for each cement concentration and curing time. Taking into account increasing of cement percentage and the length of time curing, the soil strength of the collected dredged samples were improved. Accordingly, the stabilization with Portland cement can improve the geotechnical dredged sediments along Hurghada coast. Further, utilization of stabilized dredged sediments can be used for various utilities such as brick industry, roof-tile, and concrete brick and as subgrade of road pavement.*

Keywords---- Dredged sediments, soil cement, stabilization, Portland cement, unconfined compressive strength, CBR.

---

1. INTRODUCTION

The coastal and marine resources of the Red Sea are contributed to oil exploration and touristic development of Egypt. Along the Red sea coast, the progressive development depends mainly upon the tourist industry accompanied with intensive urbanization. In addition, this development requires many facilities in the form of coastal constructions, recreational locations, artificial lagoons, jetties and marinas (Mohamed, 2000).Hurghada city, Red sea governorate capital, is one of the main and famous tourist centers in Egypt located on the Red Sea coast (Fig. 1).Because Hurghada can be considered as a city under construction, different types of development projects with a high rate of construction can be noticed. Consequently, dredging and landfilling in Hurghada coastal area are common activities (Mansour et al. 1997 and Mansour et al. 2001); the dredged sediments volume on 2007 was about 30 million m^3 and growing all the time (Mahmoud A. Dar, 2005).Dredging has been carried out to construct lagoons, boat channels, causeways and port facilities such as jetties in some parts of Hurghada city (Mansour, et al., 2007). Accordingly, recent sediments study in the beach and intertidal zone along the Hurghada coast are very important in assessing potential environmental hazards.

In general, dredging operations and the dredged disposal materials are considered an important source of the filling materials in the tidal flat areas (Barbosa and Almeida, 2001). Further, the physical and mechanical properties of the dredged sediments are not suitable to be used directly as subgrade or any construction materials. Therefore, Characterization and assessment is the first step in determining the suitability of material for final placement options such as beneficial use, unconfined open water placement, confined disposal facility (CDF) placement, confined aquatic disposal (CAD), or landfilling. Recently, geotechnical studies have shown that the use of cementations additives, e.g., Portland cement, cement kiln dust, quick lime and lime kiln dust, can stabilize and solidify soils and marine sediments containing unacceptable level of constituents. For example, (Solanki, et al.2013) reported that the soil stabilization with cement which is compared with the use of lime and fly ash as stabilization material. In another study, these materials modify soil properties through cation exchange, flocculation and agglomeration. Additionally, cement provides hydration products, which increase the strength and support values of the subgrade materials as well as enhance the permanence of the treatment (Samira Brakni, 2009).

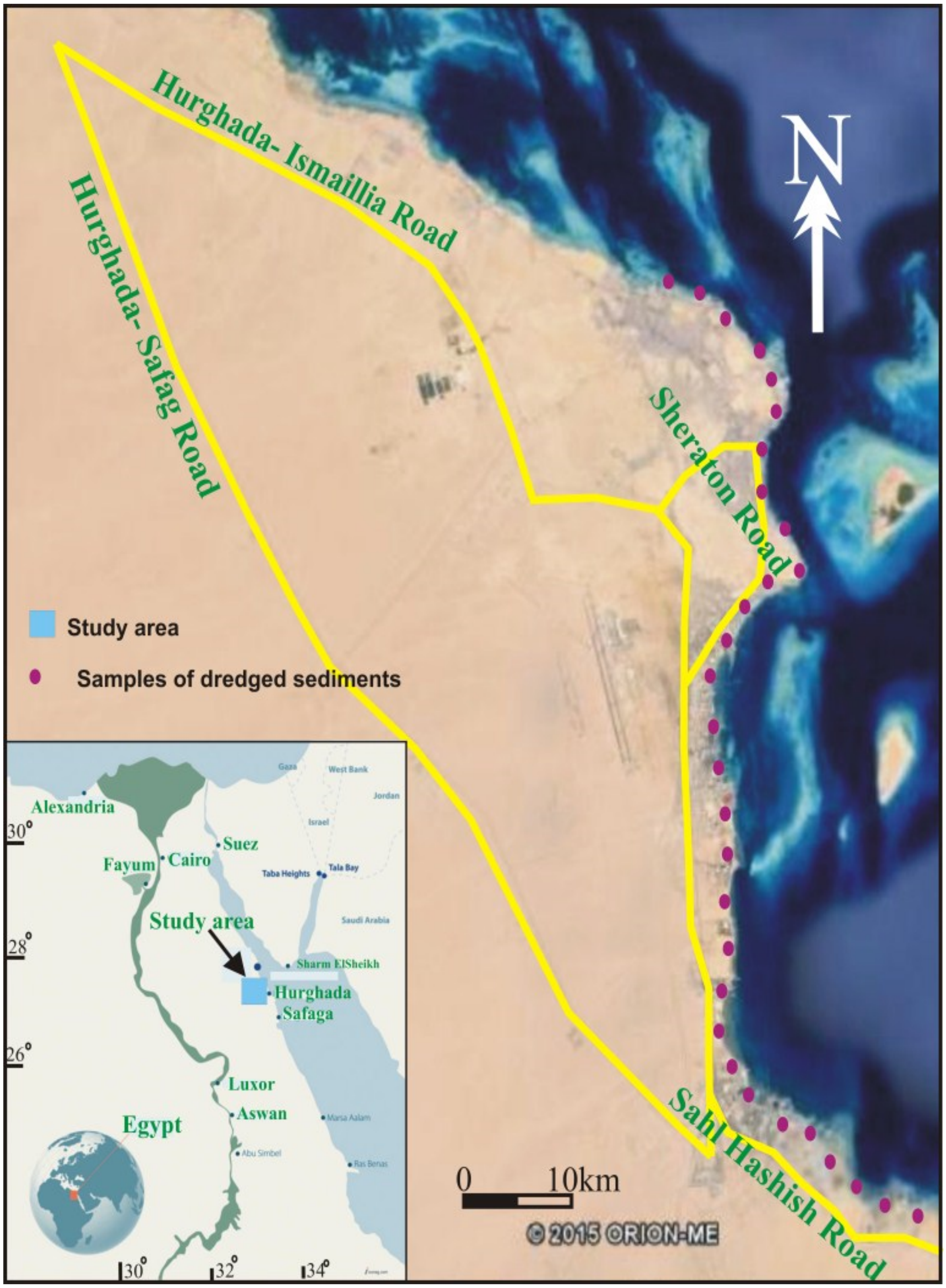


Figure 1: Location and sampling of dredged sediments along Hurghada city, Red sea coast, Egypt

In most studies mentioned above, dredged sediments stabilization with Portland cement improved the subgrade properties at a lower cost than either removing and replacing material or increasing the base thickness to reduce subgrade stress. A particular emphasize of this study is to assess the geotechnical properties and mineralogical composition of the dredged sediments along Hurghada coast, Red Sea, Egypt. In the following, (i) we first briefly present the experimental procedures and the resulting data, (ii) outline the essential aspects of the Portland Cement mechanism proposed by (Recommended Practice for Stabilization of Subgrade Soils and Base Materials, NCHRP., 2009), whose practical validity we seek to test in this study and (iii) finally, the results were presented and discussed in comparison with pure/original dredged sediments.

2. SOIL STABILIZATION TECHNIQUES

The American Concrete Institute (ACI) defines soil cement as a mixture of soil and a measured amount of cement and water mixed to a high density. Soil cement has been classically defined as a stabilized soil in which the coarse aggregate, sand size and larger (coarser than 75 μ m) is surrounded and bonded by a matrix of cement paste and fine soil particles. Portland cement is comprised of calcium-silicates and calcium-aluminates that hydrate to form cementitious products. Cement hydration is relatively fast and causes immediate strength gain in stabilized layers (Little, D. N., E. H. Males, J. R. Prusinski, and Stewart, B., 2000). Therefore, a mellowing period is not typically allowed between mixing of the components (soil, cement, and water) and compaction. In fact it is general practice to compact soil cement before or shortly after initial set, usually within about 2 hours. Unless compaction is achieved within this period traditional compaction energy may not be capable of developing target density. However, Portland cement has been successfully used in certain situations with extended mellowing periods, well beyond 2 to 4 hours. Generally, the soil is remixed after the mellowing periods to achieve a homogeneous mixture before compaction. Although the ultimate strength of a soil cement product with an extended mellowing period may be lower than one in which compaction is achieved before initial set, the strength achieved over time in the soil with the extended mellowing period may be acceptable and the extended mellowing may enhance the ultimate product by producing improved uniformity. Nevertheless, the conventional practice is to compact soil cement within 2 hours of initial mixing. During the hydration process, free lime, $Ca(OH)_2$ is produced. In fact up to about 25 percent of the cement paste (cement and water mix) on a weight basis is lime. This free lime in the high pH environment has the ability to react pozzolanically with soil, just as lime does and this reaction continues as long as the pH is high enough, generally above about 10.5.

3. GEOLOGY OF THE STUDY AREA

The study area lies in Hurghada city in the Red Sea Governorate which, is bordered on the north by the Suez Governorate, to the east by the Red Sea, and to the west by the governorates of Aswan. The Hurghada coast consists mainly of fringing coral reefs living over the coralline limestone terraces of the tidal flat (references). The terraces are represented by Quaternary coralline limestone, raised landward. Along Hurghada coast, the tidal flat are composed of submersible biogenic clastic sediments mixed somewhat with terrigenous beaches. Along the shore, there is an almost continuous band of emergent reef terraces between 0.5 to 10km wide (El-Sayed,1984). The tidal flat are varying in width from few tens of meters to a few hundreds of meters and can be differentiated into four main parts; beach, intertidal, back-reef and fore-reef zones (**Mansour, 2000**). The shore area is skirted by a raised reefal terrace about 1.0 m in height from the Quaternary coralline limestone. The intertidal zone has rocky fossil reef substratum covered with thin layer of soft biogenic deposits.

The wide spread impact of the sediments has been observed in Hurghada, where such sediments have spread to extensive fringing reefs down the coastline and to the adjacent islands and offshore reefs, forming a thick veneer of fine sediments on the surface of the corals (**UNEP**, **1997**).(**Frihy et al.,2004**) reported that the coastline of Hurghada is naturally sheltered against waves dominantly blown from the north and northwest. Coarse sand partially covers the beach and the inner shallow part of the tidal flat, about half of its width. They added, the outer part of the tidal flat and its contiguous tidal slope including tidal crest are mainly composed of reefal rocks. Sand also covers the bottom of the natural lagoons “pools” which exist on the outer part of the tidal flat.

4. MATERIALS AND METHODS

The coastline of the study area was completely altered by dredging and landfilling operations. Thirty two bulk samples were collected from different sites along Hurghada coast. A properly designed sampling plan was prepared to minimize sampling error and to optimize sampling efficiency. This requires a plan to randomize sampling locations (ASCE.,2000). However, boring and sampling programs must be planned and executed within budget constraints with appropriate consideration of other variables that can affect the site investigation. Direct observation of subsurface conditions and retrieval of field samples can be achieved by examination of soil formations using accessible excavations, such as shafts, tunnels, test pits, or trenches, or by drilling and sampling to obtain cores orcuttings. Since stabilization operations involve mixing and compaction operations that destroy the original soil fabric, disturbance of samples during extraction does not normally compromise the quality of neither the sample nor its acceptability for testing. Hence undisturbed soil samples are not normally required for testing to evaluate the efficacy of soil stabilization. The testing involves evaluation of the soil properties including gradation, Atterberg limits and mineralogy.

General guidelines for stabilization, the plasticity index should be less than 30 for sandy materials. For fine-grained soils, soils with more than 50 percent by weight passing 75 μ m sieve, the general consistency guidelines are that the plasticity index should be less than 20 and the liquid limit (LL) should be less than 40 in order to ensure proper mixing (**United Facilities Criteria,**2004). A more specific general guideline based on the fines content is given in the equation below which defines the upper limit of P.I. for selecting soil for cement stabilization (**Terrel, et al.,**1979).

$$P.I \leq 20 + \frac{50 - (\%\ smaller\ than\ \ 0.075\,mm)}{4}$$

The Federal Highway Administration recommends the use of cement in materials with less than 35 percent passing no. 200 sieve and a plasticity index (PI) less than 20 (Oglesby et al., 1963).Stabilization projects are site specific and require integration of standard test methods, analysis procedures and design steps to develop acceptable solutions. Many variables should be considered in soil treatment, especially if the treatment is performed with the intent of providing a long-term effect on soil properties. Soil-stabilizer interactions vary with soil type and so does the extent of improvement in soil properties. Hence developing a common procedure applicable for all types of stabilizers is not practical. Instead, a generalized, flowchart-based approach, which provides the steps that should be followed in stabilizer selection, is presented in (Fig. 2).

In addition, compaction tests were undertaken to determine the density moisture content relationship. Soaked and un-soaked California Bearing Ratio (CBR) tests and unconfined compressive strength were performed on the dredged sediments samples at optimum moisture content and maximum dry density. Finally the data and results were analyzed in order to propose suitable evaluation for the stabilized dredged sediments in different geotechnical engineering applications.

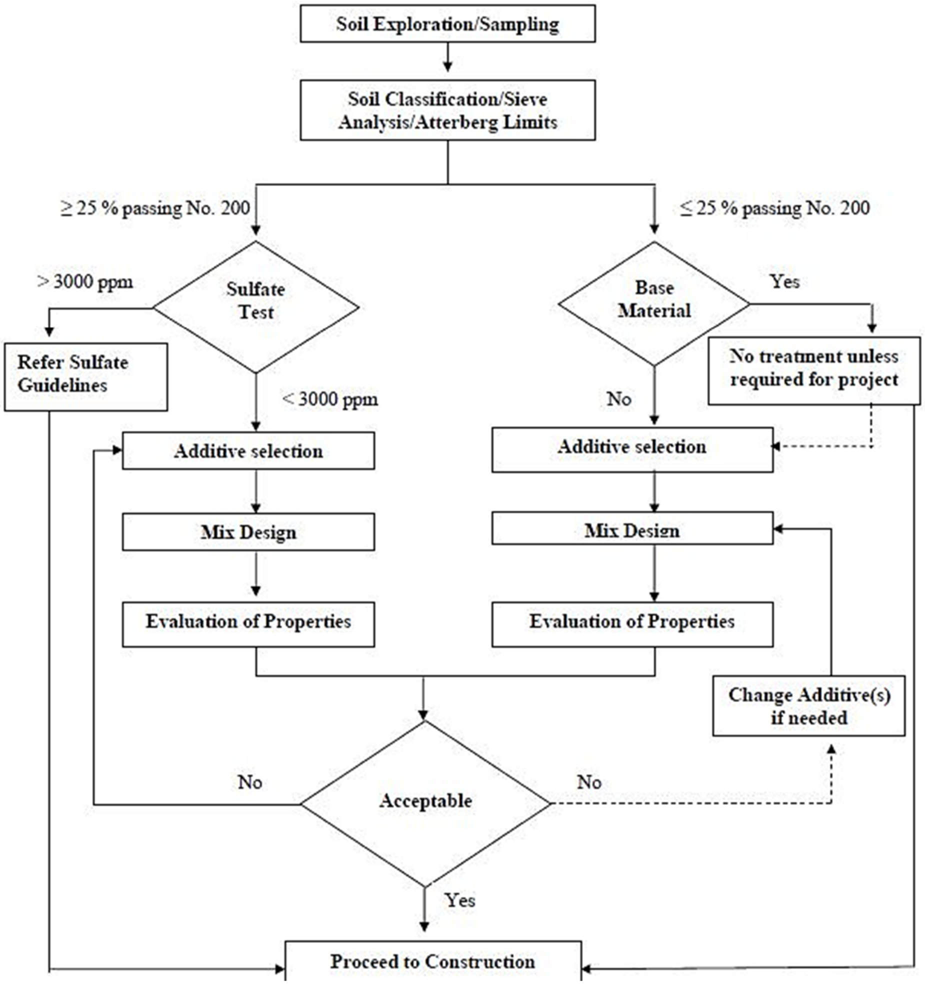


Figure 2: Guideline for stabilization of soils & base materials (Texas Department of Transportation, 2008)

5. RESULTS AND DISCUSSION

5.1 Classification tests

The natural water content is as low as 23.53 % and as high as 38.60%, while the specific varies between 2.41 and 2.53 (ASTM D 854-14, 2014). The dry density varies between 1.25 g/cm^3 and 1.75 g/cm^3. The liquid limit (W_L) of the dredged sediments is 47.19-49.22 %, the plastic limit varies between 30.15-30.66 % and the plasticity index ranges between 17.04 and 18.44% (ASTM. D 4318-05, 2005). Test results of the samples in the direct shear represent soil cohesion C varies between 0.06 and 0.08 kg/cm^2, while theinternal friction angle ϕ varies between 17°and 20°. These sediments were justified to be low strength.

The results of the grain size distribution analysis (ASTM D- 422, 2007) are summarized in table 1 and figure 3. The average amount of silt& clay, sand 17.05, 76.22 and gravel size particles are 17.05, 76.22 and 6.25 %. The dredged sediments along the study area were dominated by fine sand and mud and classified as clayey sand sediments (ASTM. D-2487-11, 2011). These clayey sand sediments with a plasticity index ranges between 10 and 20 % and below 25 % passing the no. 200 sieve are considered desirable for Portland cement stabilization (NCHRP., 2009).

Table 1: Typical results of classification tests in the study area

Index properties	Unit	Result
Specific gravity(Gs)	-	2.41- 2.53
Water content (w)	%	23.53-38.60
Wet density ($^{\gamma}$wet)	g/cm^3	1.48-2.06
Dry density ($^{\gamma}$wet)	g/cm^3	1.25-1.75
Liquid limit(WL)	%	47.19-49.22
Plastic limit(PL)	%	30.15-30.66
Plasticity index	%	17.04-18.44
Porosity	%	65.60-68.21
Saturation degree	%	94.86-99.06
friction angle	degree	17° -20°
Cohesion	Kg/cm^2	0.06-0.08
Sieve analysis		
a) Sand	%	80.32- 82.25
b) Silt &clay	%	12.22-17.05

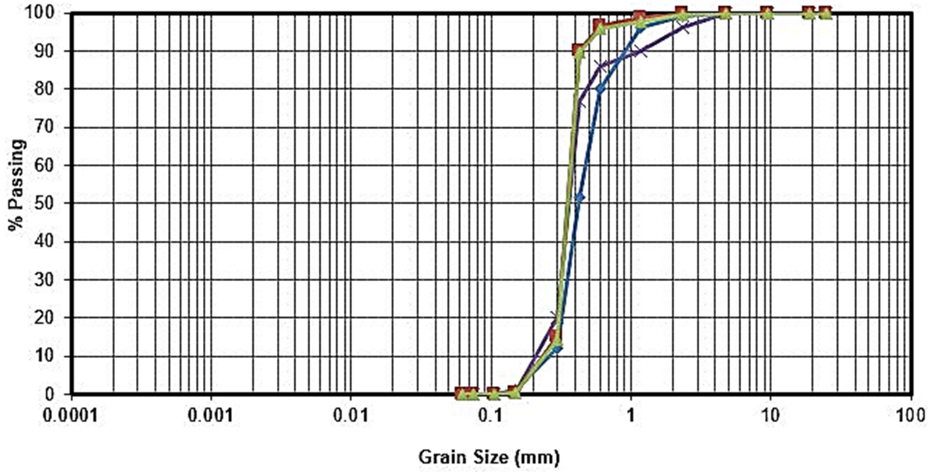


Figure 3: Grain size distribution curves of the dredged sediments

5.2 Mineralogical composition of the dredged sediments

Selected five samples representing the dredged sediments of clayey sand were examined microscopically. It were differentiate petrographically into two main varieties,quartzarenite and quartz wacke according to (Pettijohn, 1975). Both of them are subdivided into two subvarieties, according to cement and matrix materials, argillaceous and calcareous respectively.

Quartz Arenite consists of 75% quartz; clay minerals 17%; feldspars have a maximum abundance of (orthoclase and microcline). Generally the K- feldspar grains are altered to kaolinite and this indicated for the continental and near shore environment (Chamleyet al., 1990). The matrix amounts reach to about 12%. Matrix is mostly composed of argillaceous materials (Fig. 4a). The cement is mainly composed of silica and clay minerals as pore filling (Fig. 4b).

Quartz Wacke relatively is the more common type of sands that are associated with argillaceous materials as matrix. Quartz grains amount reach to 65%, these wackes mainly are of the quartz wacke type. The matrix amounts reach to 27%, it is mostly composed of clay minerals (Fig. 4c). Particularly, clay minerals occur as pore-filling materials and forms dark brown patches fill the pores Fig. (4d).

5.2.1 Clay minerals

Authigenic clay minerals are uncommon in the dredged sediments. Kaolinite is the main mineral with subordinate illite and rare chlorite. Kaolinite is recorded as both a pore-lining and pore-filling phase. The kaolinite pore-lining has vermicular forms (Figure 5a). It consist of stacks arranged right to postdate quartz overgrowth cement, it represents that the kaolinite particles were engulfed in quartz overgrowths (Figure 5b). Illite is found as subordinate content in studied sediments.

It is hairy-like, generally as pore linings, coating authigenic and detrital quartz (Figure 5c). Chlorite present in the form of pore fills rosettes growing normal to detrital grains (Figure 5d). Degree of sediment expansiveness is categorized into low to medium with clay mineral illite, chlorite and kaolinite.

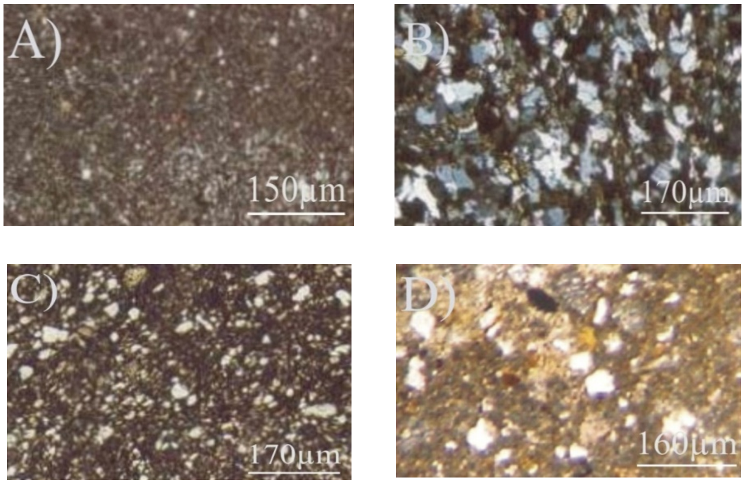


Figure 4: Photomicrographs showing,(A) Fine quartz grains in quartz arenite. (B) Quartz grains embedded in brownish clasts of fine-grained material which are composed of clay minerals. (C) Quartz grains with fine grained materials filling the pores as clay matrix in quartz wacke and (D) Clay matrix of quartz wacke occur as pore-filling

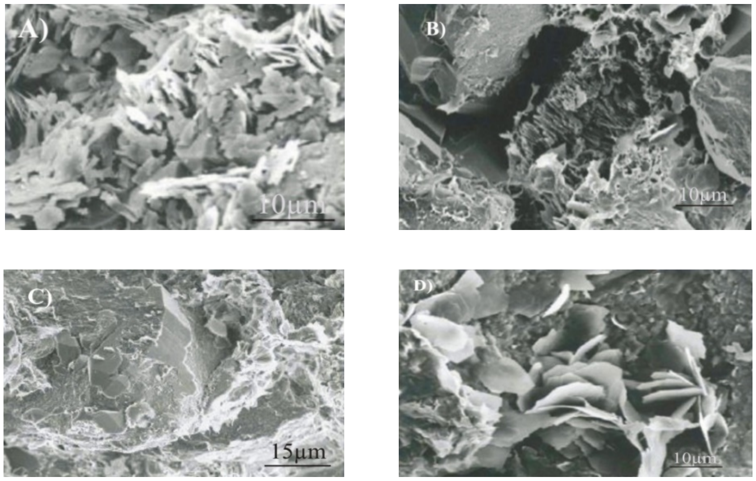


Figure 5:(a) SEM illite; a hair- like delicate from coating quartz grains (b) SEM of pseudohexagonal kaolinite (c) SEM authigenic booklet kaolinite engulfing quartz overgrowth indicates co-precipitation as pore-filling (d) SEM of chlorite in rosettes developed as pore lining on detrital grains

5.3 Geochemical composition of the dredged sediments

Five samples were selected for chemical analysis in order to know the chemical composition of these dredged sediments. The results indicated that these sediments contained several kinds of oxides such as SiO_2, AL_2O_3, H_2O, Fe total, CaO, Na_2O, K_2O, and MgO. Silicon-dioxide (SiO_2) occupies the dominant portion with the percentage of 75.42% to 77.31%, followed by Aluminum Oxide (Al_2O_3) with approximately 6.76% to 6.81%, then H_2O (6.20% to 7.21%), and Fe total (4.12% - 4.21%). The CaO percentage ranging from 1.12 % to 1.21 % is due to carbonate cement in some dredged sediments. MgO percentage varies from 0.56 % to 0.97 % and they are attributed to the presence of ferromagnesian minerals as suggested by the presence of chlorite (Table 2). Low values are commensurate with scarcity of feldspar and Mica in thin sections. The other substances are available with relatively small amount.

Table 2. Geochemical composition of the dredged sediments

Major elements	Range of Value (%)
SIO_2	75.42- 77.31
Al_2O_3	6.76- 6.81
Fe total	4.12- 4.21
Na_2O	1.06-10.07
CaO	1.12- 1.21
K_2O	0.87- 0.98
MgO	0.56- 0.97
H_2O	6.20- 7.21

5.3.1The Moisture Density Relationship

The compaction test (Modified Proctor) was performed for the dredged sedimentsaccording to (ASTM. D 558-82, 2006), generally the water acts as a lubricant between soil particles during the soil compaction process. Because of this, in the initial stages of compaction, the dry unit weight of compaction increases. The compaction test results shown that the maximum dry density for clayey sand dredged sediments 1.82 ton/$m^3$and the optimum moisture content 16.12 % in pure or original case, dredged sediments with 5% cement shown maximum dry density 1.75 and the optimum moisture content 18.13 % and with 10 % cement shown maximum dry density 1.71 and the optimum moisture content 18.64 % (Table 3 and Fig. 6). Flocculation of clay particles by cement cause an increase in optimum moisture content and decrease the maximum dry density for cement-soil mixes whereas the higher density of cement relative to soil can result in a higher density for mixes.

Table 3: Proctor density of the dredgedsediments.

Parameters	Sample	Sample+ 5% cement	Sample +10% cement
Maximum Drydensity(gm/$_{cm}{}^{3}$)	1.82	1.75	1.71
Optimum Moisturecontent(%)	16.12	18.13	18.64

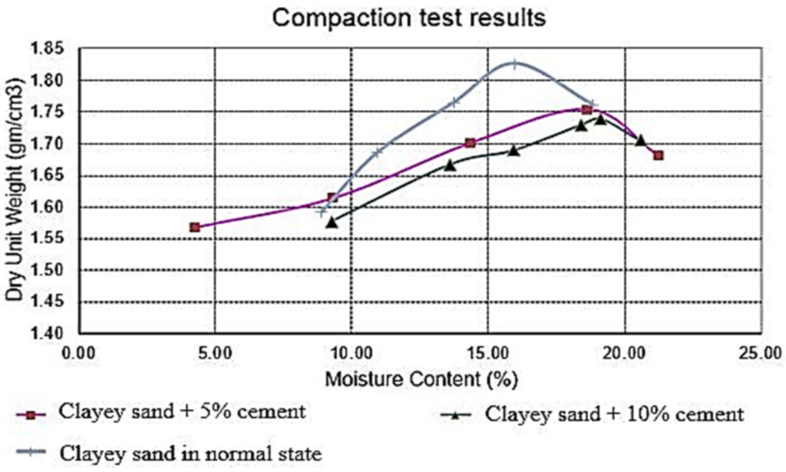


Figure 6: Modified Proctor Compaction Curves of the dredged sediments

5.4 The stabilization of dredged sediments by Portland cement

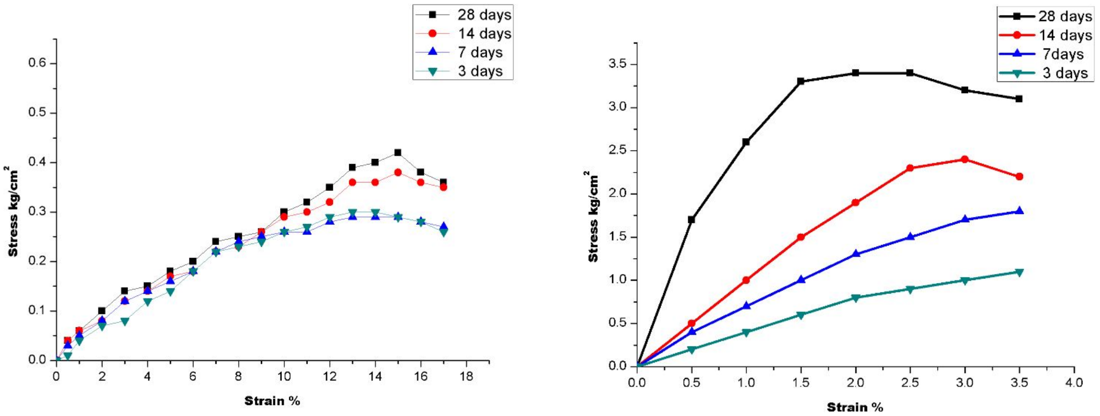
The characteristics tests of the dredged sediments stabilized by Portland cement based on ASTM standard. The potential of compressive strength (ASTM. D 2216, 2013&ASTM. C 109, 2013) and CBR (ASTM. D1883-14, 2014) using Portland cement with the variety of cement content and curing time. The results were obtained by use of percentages of mixing cement, 0%, 5%, 10% and 20% of the weight of dredged sediments samples(Grubb, 2010).

5.4.1 Unconfined compressive strength

A uniaxial test with a compressive test instrument and a constant rate of strain (about 0.5 mm/min) was used for each specimen. The curing time for unconfined compressive strength is 3 days, 7 days, 14 days and 28 days, for instances the curve shape of the mixing of 0%, 5%, 10%, and 20% cement (Table 4 and Fig. 7).

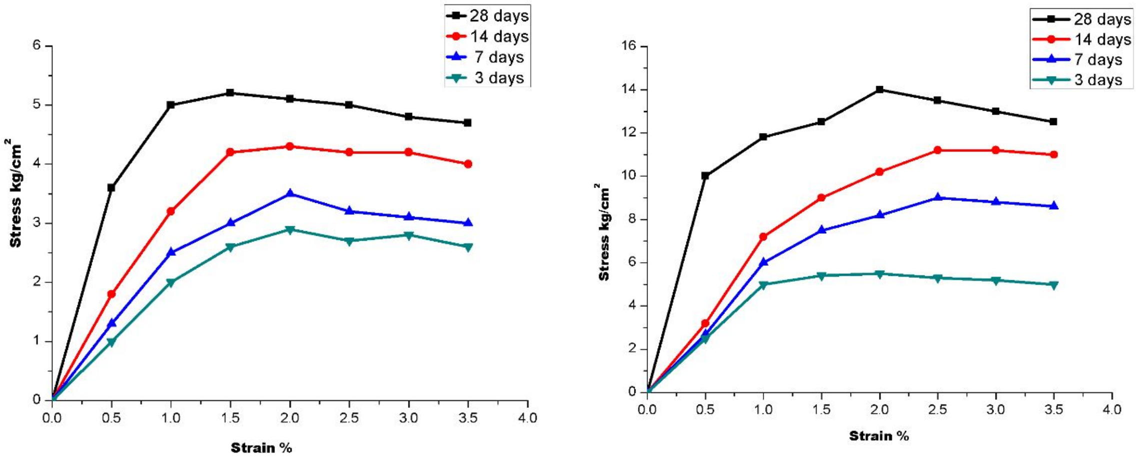
Table 4: Summary of Compression testing results with variations of cement content

Curing time	**Cement addition%**			
Day	**0**	**5**	**10**	**20**
3	0.25	0.92	2.81	4.81
7	0.30	1.52	3.28	8.75
14	0.37	2.32	4.21	10.67
28	0.41	3.28	5.14	13.91



(a) Cement Stabilization 0%

(b) Cement Stabilization 5%



(c) Cement Stabilization 10%

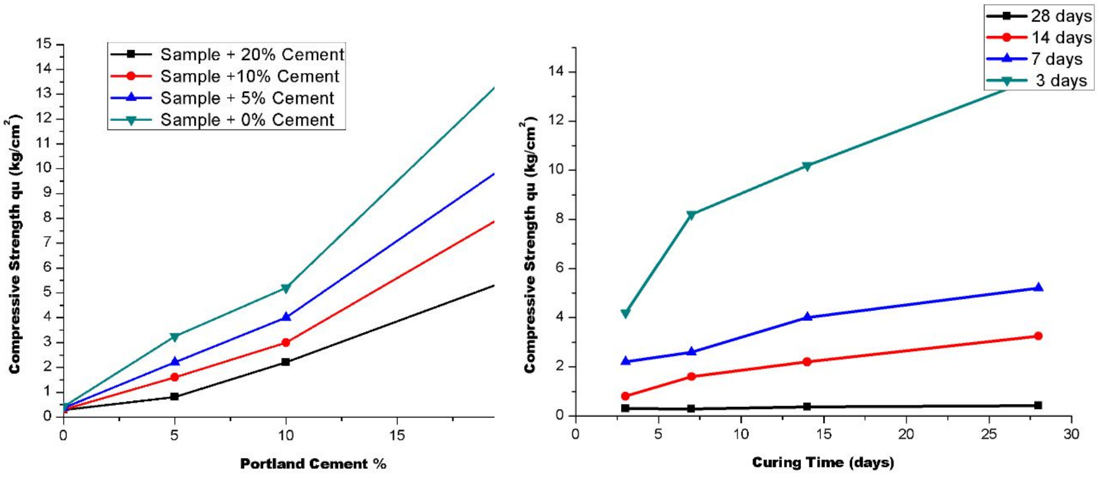
(d) Cement Stabilization 20%

Figure 7: Stress- strain curves of stabilized dredged sediments by Portland cement

Stress-strain curve of dredged sediments stabilized with cement provides the strength increase in the range of 0.25 kg/cm^2 (0% cement), 0.92 kg/cm^2 (5% cement), 2.81 kg/cm^2 (10% cement) and 4.81 kg/cm^2 (20% cement) for 3 days of curing time while for 28 days of curing time, the strength is 0.41 kg/cm^2 (0% cement), 3.28 kg/cm^2 (5% cement), 5.14 kg/cm^2 (10% cement) and 13.91 kg/cm^2 (20% cement), tends to increase linearly with the increasing of cement's percentage.

5.4.2 The analysis on the relationship between compressive strength (Q_u) with cement content and curing time are shown below.

Based on the results above, it can be inferred that the dredged sediments which isstabilized by cement has tendency of increase on its value of compressive strength. The higher the percentage of cement and the length of curing time (Fig. 8a&b), the greater the value of compressive strength.



(a) (b)

Figure 8: The relationship between the compressive strength with Portland cement content (a) and with curing time (b).

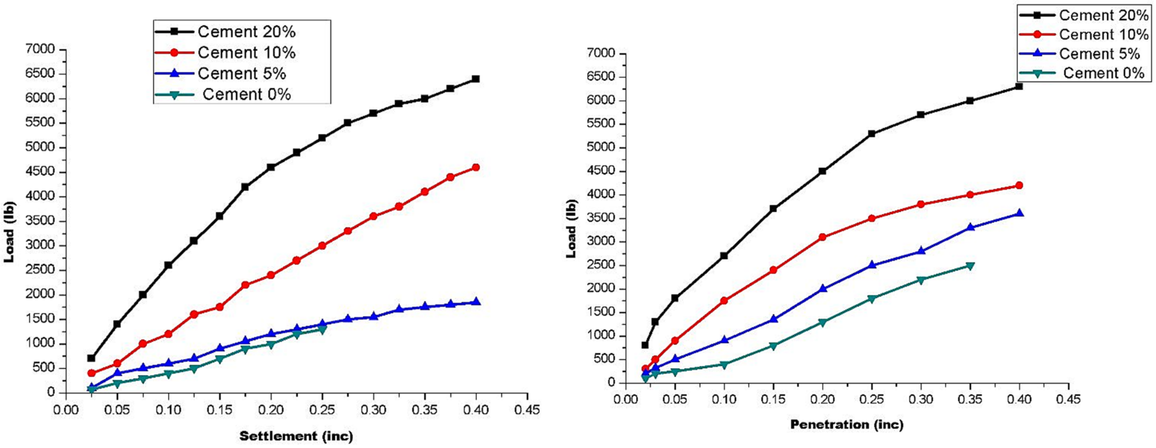
5.5CBR test (California Bearing Ratio)

The California Bearing Ratio (CBR) has been accepted as a useful for evaluating the suitability of soils for geotechnical engineering applications. CBR test which was conducted according to (ASTM. D1883-14, 2014). The CBR test, it is divided into two types soaked and un-soaked. The CBR values are presented in (Table 5).The results of CBR test showed that based on previous data, the dredged sediments Clayey sand (SC) that mainly composed of sands with clays and has medium plasticity. The adding of cement with different variations (0%, 5%, 10% and 20%) to soil emerged special reaction to form lumps made the sediment grains become large (Figure 9). With the increase of cement percentage, it can be seen that the CBR value has also increased.

Table 5. Laboratory testing results of soaked and un-soaked CBR with variations of cement content

	Reduction	**Unit**	**Cement addition%**			
	(Inc.)	%	0	5	10	20
Soaked	0.1	%	25.25	40.25	45.37	48.23
	0.2	%	35.13	50.24	55.37	63.22
Un-soaked	0.1	%	29.52	46.18	52.34	56.33
	0.2	%	40.15	55.22	63.55	68.26

Based on the analysis of CBR test's result, both CBR soaked and un-soaked showed that the type of dredged sediments from pure/original dredged sediments and stabilized dredged sediments experienced some changes and the rise of CBR's value. However, the value of CBR soaked is lower than that of un-soaked. This influenced by the penetration of water through voids of mixture of soil and soil-cement. In general, the testing value of CBR will increase as the percentage addition of cement mixture and water content implied.



a) Soaked b)Un-Soaked

Figure 9: CaliforniaBearingRatio test(CBR) ofcement stabilized dredged sediments

6. TYPICAL UTILIZATION OF STABILIZED DREDGED SEDIMENTS

The investigation on mineralogy and physical characteristics of dredged sediments, test results justified main characteristics of dredged sediments of the coastal line as clayey sand. In considering several alternatives for utilizing sediment potency for various need economically, such as brick industry, roof-tile, concrete brick, paving block, earthenware, plant media (paddy field), subgrade, etc., sediment characteristics could be advantaged by soil stabilization methods. It seems, the potency stabilized admixture is supported highly by the existence of the other raw materials (such as sand, clay, lime, chaff, rice field, etc.).

7. SUMMARY AND CONCLUSION

The goal of this study was to evaluate stabilized dredged sediments using Portland cement for geotechnical engineering along Hurghada coast, Red Sea, Egypt. In this work, the physical and mechanical properties of dredged sediments were carried out. In addition, the geotechnical properties and mineralogy validity of Portland cement on dredged sediments stabilization was examined along Hurghada coast. The results of this study indicate that: (1) from the analysis of laboratory experiments, the dredged sediments were classified as clayey sand with law strength reflecting that the use of dredged sediments for subgrade or construction are not suitable; (2) the process of chemical modification or stabilization with calcium-based chemicals requires a basic understanding of the mechanisms of reaction. Each calcium-based stabilizer contains some amount of free lime (CaO or $Ca(OH)_2$) that reacts pozzolanically with the fine particles (clay and some silt). Normally, lime is 90 percent or more CaO or $Ca(OH)_2$ and therefore provides the most available free lime over the longest period of time in the treatment process of any of the traditional stabilizers as Portland cement, (3) the classification tests should be reported and the role of Portland cement on dredged sediments stabilization can be considered and (4) the relation between the cement percentage and the length of time curing should be reported. Furthermore, the stabilized dredged sediments are of extremely high importance in industry, roof-tile, concrete brick, paving block, earthenware, plant media (paddy field) and subgrade. The ability of Portland cement on stabilization of dredged sediments along Hurghada coast is therefore of high desire. This study provides a very specific understanding of the role of Portland cement on improving the geotechnical properties of dredged sediments along Hurghada coast. This should be expanded for much better understanding of the stabilization of dredged sediments soil is possible to conduct in large scale, with effective cost and environmentally compatible.

The normal moisture conditioning protocol for Portland cement stabilization includes moist curing and a 4-hour soak before strength testing. The authors recommend strength testing after moisture conditioning as the appropriate metric of determining strength for stabilization processes.

8. ACKNOWLEDGEMENTS

The first author (A, El Shinawi) would like to express appreciation to Dr. Muhammed Nabih for assistance with samples collection during field work. A, El Shinawi would like to express appreciation to Dr. M Attwa for discussions and valuable great support. The first author also thanks Ahmed Nosier helped with some figures and writing. The authors would like to thank an anonymous reviewer for many helpful comments and suggestions.

9. REFERENCES

- Abbas M. Mansour, Ahmed W. Mohamed, Gemal Kamal ElDien and Sayed M. sayed, (2007).Impact of development projects on the sediments and the environment along the coast of hurghada, red sea, egyptian journal of aquatic research, VOL. 33 NO. 1, pp 59-84.

- American Concrete Institute (1990)"State-of-the-Art Report on Soil Cement." ACI 230.1R-90, ACI Materials Journal, Vol. 87, No. 4, pp. 23.

- American Concrete Institute (2000)" 116R-90: Cement and Concrete Terminology." ACI Committee 116.

- ASCE (2000) "Technical Engineering and Design Guides as Adapted from US Army Core of Engineers, No. 30 - Soil Sampling." American Society of Civil Engineers, Virginia.

- ASTM (2005). Standard Test Methods for liquid limit, plastic limit and plasticity index of soils, D 4318-05, West Conshohocken, Pa.

- ASTM (2006).Test Methods for Moisture Density Relations of Soil-Cement Mixtures D 558-82.

- ASTM (2014). Standard Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils, West Conshohocken, Pa. D1883-14.
- ASTM (2014). Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer, D 854-14, West Conshohcken, Pa.

- ASTM 2007. Standard test methods for particle size analysis of soil, (D- 422).

- ASTM. (2011). Unified Soil Classification (D- 2487-11).

- ASTM. (2013).Standard test method for unconfined compressive strength of intact Cohesive Soil, (D- 2216).

- ASTM (2013).Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens) C109 / C109M – 13.

- Barbosa, M.C. and Almeida, M.S. (2001).Dredging and disposal of fine sediments in the state of Rio de Janeiro, Brazil. Journal of Hazardous Materials, 85: 15- 38.

- Chamley, H., Deconinck, J. F. &Millot, G. (1990). ComptesRendus de l'Acade´mie des Sciences, Paris 311 (II), 1529–1536.

- El-Sayed, M.K. (1984).Reefal sediments of Al-Ghardaka, Northern Red Sea, Egypt. Marine Geology, 56: 259-271.

- Frihy, O.E.; El Ganaini, M.A.; El Sayed, W.R. and Iskander M.M. (2004). The role of fringing coral reef in beach protection of Hurghada, Gulf of Suez, Red Sea of Egypt. Ecological Engineering, 22: 17-25.
- Grubb, D. G., Chrysochoou, M., Smith, C. J., and Malasavage, N.E. (2010) Stabilized Dredged Material I: A parametric study. J. Geotech. Geoenviron. Eng., 136(8), 1011–1024.

- Little, D. N., E. H. Males, J. R. Prusinski, and Stewart,B.(2000) "Cementitiousstabilization." 79th Millennium Rep. Series, Transportation Research Board, Washington, D. C

- Mansour, A.M. (2000).Quaternary reef terraces of Red Sea coast, Egypt, and their tectonic relationship to tectonics/eustatics. Sedimentology of Egypt, 8: 19-33.

- Mansour, A.M.; Nawar, A.H. and Mohamed M.A. (1997). Recent intertidal sediments and the negative impact of human activities, Red Sea Coast, Egypt. J. of Geology, 41/2A: 239-272.

- Mansour, A.M.; Nawar, A.H. and Mohammad, A.W. (2000-I). Shallow marine sediments, Red Sea, Egypt: restricted distribution of coral debris. Sed. J of Egypt, vol. 8: 63-73.

- Mohamed, A.M. (2000). Comparative geological study of the ancient and recent coral reefs along the northern part of the Red Sea coast, Egypt. Ph. D. thesis, Faculty of Science, Zagazig Univ., Egypt. Pp. 169.

- Mahmoud A. Dar. (2005) "coastal habitats degradation due to Chronic and recent landfilling along the red sea" first Ain Shams university international conference on environmental engineering April 9-11 2005.

- NCHRP (2009). "Recommended Practice for Stabilization of Subgrade Soils and Base Materials". Texas Transportation Institute, A&M University College Station, Texas, Web only document 144.

- Oglesby, C. H., and L. I. Hewes, (1963) "Highway Engineering." John Wiley and Sons, Inc. New York.

- Pettijohn, F.J. (1975). Sedimentary Rocks. Harper and Row, New York.

- Solanki, P., Khoury, N., Zaman, M.M., (2013). "Engineering properties and moisture susceptibility of silty clay stabilized with lime, Class c FlyAsh, and Cement Kiln Dus"t.

- Samira Brakni, Nor EdineAbriak& Arnaud Hequette, (2009).Formulation of artificial aggregates from dredged harbour sediments for coastline stabilization. Taylor& Francis online DOI: 10.1080/09593330902990154, vol. 30, issue 8.

- Terrel, R. L., J. A. Epps, E. J. Barenberg, J.K. Mitchell, and M. R. Thompson, (1979). "Soil Stabilization in pavement Structures - A User Manual." FHWA Research Report No. FHWA-IP-80-2, WA.Texas Department of Transportation, (2008)"Guidelines for Modification and Stabilization of Soils and Base for Use in Pavement Structures." ftp://ftp.dot.state
- tx.us/pub/txdotinfo/ md/tech/stabilization.pdf.

- UNEP (1997). Assessment of land-based sources and activities affecting the marine environment in the Red Sea and Gulf of Aden. Untied Nation Environmental Program (UNEP), Regional seas reports and studies, No. 166, 62p.

- United Facilities Criteria (3-250-11), (2004) "Soil Stabilization for Pavements, TM 5-822-14/AFJMAN32/1019". http://www.wbdg.org/ccb/DOD/UFC/ufc_3_250_11. Pdf (Jul. 16, 2006).