ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 2, August 2013

Improvement of Swelling Soil under Traffic Areas Using Dust Shield Polymer

Talaat A. Ahmed, Ahmed O. Kamel
[1] Assistant prof., Civil Engineering Department, Sohag University
[2] Demonstrator, Civil Engineering Department, Sohag University

Abstract— In this paper, the swelling soil of subgrade foundation for supporting pavements at New Sohag city was treated with polymer additives (Dust Shield) 1%, 2%, 3% and 4% by dry weight of soil. The main results show that the increase of additives lead to apparent reductions in optimum moisture content, and swelling potential as well as increase in maximum dry density, California bearing ratio, unconfined compressive strength. This study established optimum dosage levels for each of the treated additives. Based on the results obtained, it can be concluded that the expansive soil can be successfully improved by Dust Shield.

***Index Terms*—Swelling soil, Dust Shield polymer (DSP), California bearing ratio (CBR), unconfined compressive strength (UCS).**

I. INTRODUCTION

Expansive soils denote clayey soils that not only possess the tendency to swell or increase in volume but also to shrink or decrease in volume when the prevailing moisture condition is allowed to change. Such change of moisture content of these soils can emanate from rains, floods, or leakage of sewer lines. The response of expansive soils in the form of swelling and shrinkage due to changes in water content is frequently expressed superficially as heaving and settlement of lightly loaded geotechnical structures such as pavements, railways, roadways, channel and foundations or reservoir linings. Expansive materials that exhibit swelling problems include bentonitic mudstones, marls and silty mudstones, argillaceous lime- stones and altered conglomerates. Consequently, expansive soils cause distress and damage to structures founded on them "Amer [1]". The climate in Egypt is arid, with high evaporation rates, so that there is always a moisture deficiency in soils and rocks. Supply of water from any source is liable to cause ground heave in any soils or rocks possessing swelling potential. Dangers of expansive soils seem to be overlooked during the design and construction of some projects. Problems associated with expansive soils in Egypt are predominantly related to the presence of montmorillonite clay minerals in soils. As a result, some of structures in New Sohag City were subjected to distress and damage and in worst cases some building were demolished "Mamdouh [2]. Extensive studies have been carried out on the stabilization of expansive soils using various additives such as lime, cement, fly ash, industrial waste products and Polypropylene Fiber [3–15]. However, the literature indicates minimal studies on the stabilization of expansive soils were taken place in Egypt. Therefore, this study was carried out to add new additives available commercially. Lime is widely used in civil engineering applications. "Ilknur[3], AlMukhtar[4], Ramesh[5], Jagadish[6], Muzahim[7], Maria[8]" found that when lime is added to clay soils in the presence of water, a number of reactions occur leading to the improvement of soil properties. Flocculation is primarily responsible for the modification of engineering properties of clay soils when treated with lime. Adding of lime significantly reduces the swelling potential, liquid limit, plasticity index and maximum dry density of the soil, and increases its optimum water content. Cement stabilization is similar to that of lime and produces similar results. Cement stabilization develops from the cementitious links between the calcium silicate and aluminate hydration products and the soil particles. Add cement to clay soil reduces the liquid limit, plasticity index and swelling potential, also it causes increasing the shrinkage limit and shear strength "Croft[9], Amer[10]". Fly ash produced in the combustion of coals exhibits self-cementing characteristics and can be used in a wide range of stabilization applications. Fly ash treatment can effectively reduce the swell potential of highly plastic clays and prevent the swell beneath the smaller foundation pressures. Laboratory test results on these soils indicate that fly ash is effective in improving the texture and plasticity of the fly ash treated soils by reducing the amount of clay size particles, plasticity index and the swell potential "Amer[9], Vinay[10], Mallikarjuna[12], Mir[13]". Fiber inclusions cause significant modification and improvement in the engineering behavior of soils. A number of research studies on fiber-reinforced soils have recently been carried out through triaxial tests, unconfined compression tests, CBR tests, direct shear tests, and tensile and flexural strength tests. One of the primary advantages of randomly distributed fibers is the absence of potential planes of weakness that can develop parallel to oriented reinforcement. (Mirzababaei[14]; Abd El Megeed[15]).

II. EXPRIMENTAL PROGRAM

A. Materials

1. Natural Soil

Swelling soil was obtained from the roads of New Sohag City from sub-base layer at a depth of 2 meters. Natural soil was greenish grey, very hard, laminated silty clay with traces

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of fine sand and calcareous matters. The physical and mechanical properties of natural soil are shown in Table I.

2. Additives

Dust Shield is a concentrate liquid copolymer that when diluted in water and applied bonds soil particles together to resist dust and erosion. Dust Shield is colorless when dry and is non-toxic to plant and animal life. Properties of Additive are given in Table II. (http://www.soil-loc.com/products/dustshield)

B. Laboratory Tests

The soil was treated with the additive at percentages 1.0%, 2.0%, 3.0% and 4.0% of unit weight of dry soil, then the geotechnical properties is determined.

Table I. Properties of Natural Soil.

Characteristics	Values
Depth (m)	2
Natural water content (%)	3.4
Field dry unit weight (t/m3)	2.05
Specific gravity “G_S”	2.69
pH	8.9
Passing No. 200 sieve (%)	90
Clay content (≤ 2 μm) (%)	42
Clay activity	0.945
Unified Soil Classification “U.S.C.”	VHC
Montmorillonite	73.7
Illite	5.3
Kaolinite	21
Liquid limit “L.L.” (%)	70.7
Plastic limit “P.L.” (%)	31
Shrinkage limits “S.L.” (%)	9
Plasticity index “P.I.” (%)	39.7
Optimum moisture content “O.M.C.” (%)	16
Maximum dry unit weight (KN/m^3)	1.52
Swelling Potential “S” (%)	40
Swelling Pressure “S_p” (kg/cm^2)	3.95
Unconfined Compression strength “UCS” (kg/cm2) “unsoaked”	6.03
Unconfined Compression strength “UCS” (kg/cm2) “soaked”	4.21
California bearing ratio “CBR” (%) “unsoaked”	10.5
California bearing ratio “CBR” (%) “soaked”	6.2

Table II. Characteristics of Additive

Properties	Dust Shield
Physical State	Milky liquid
Boiling Point	>200 degrees F
Solubility in Water	Dilatable
Density	8.7 lbs/gal

III. RESULTS AND ANALYSIS

Influence of additives on the geotechnical characteristics of expansive soil was investigated by conducting Atterberg Limits, modified Proctor compaction tests, swelling tests, unconfined compression tests and California bearing ratio at different percentage (as shown Table III).

Table III. Test Results.

Characteristics	0.0% N.S*	1 %	2 %	3 %	4 %
L.L.%	70.7	63.2	58.4	51.7	50.3
P.L.%	31	34.8	36.5	38.4	40.7
P.I.%	39.7	28.4	21.9	13.3	9.6
U.S.C.	VHC	MH	MH	MH	MH
γ_{dmax} (t/m^3)	1.52	1.58	1.62	1.63	1.64
O.M.C %	16.0	15.0	13.5	12.8	12.7
S%	40.0	25.1	18.6	12.9	11.8
S_P (kg/cm^2)	3.95	2.92	2.08	1.67	1.50
UCS (unsoaked)	6.03	6.68	7.17	7.24	6.82
UCS (soaked)	4.21	4.3	4.45	4.21	4.2
CBR%(unsoaked)	10.5	13.1	14.8	14.4	11.3
CBR%(soaked)	6.2	7.1	8.6	8.9	6.8

**N.S means Natural soil*

A. Atterberg limits

The variation of Atterberg limits values with different percentages of chemical additive added to the expansive soil is presented in the Fig. 1. It is observed that the decrease in the liquid limit is significant up to 3% of chemical added to the expansive clay, beyond 3% there is a nominal decrease. Nominal increase in plastic limit of stabilized expansive clay is observed with increase the percentage of the chemical. Fig.1 shows the variation of plasticity index with the addition of chemicals to expansive clay. The increase in the plastic limit and the decrease in the liquid limit cause a net reduction in the plasticity index.

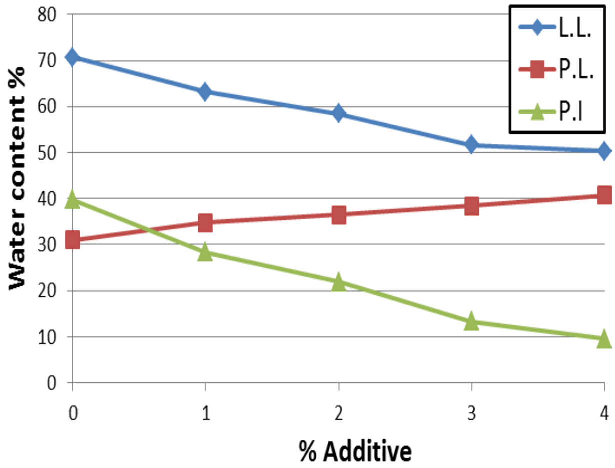

Fig.1 Effect of additive on Atterberg limits.

B. Compaction Characteristics

Addition of Dust Shield caused an increase in $\gamma_{d\ max}$ and a decrease in O.M.C. Also it’s found that the increase in density and the decrease in optimum moisture content have continued up to 3% and then approximately no change occurs (as shown in Fig. 2).

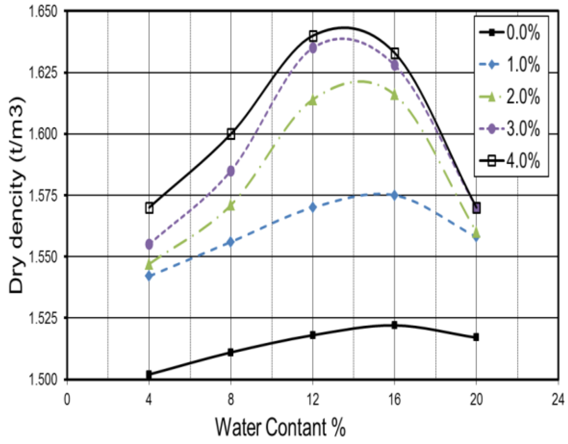

Fig.2 Effect of Additive on the compaction Proctor test.

C. *Swelling Characteristics*

The swelling potential and swelling pressure values of expansive soil are decreasing with increasing the ratio of Dust Shield. Then, the best additive content for reducing swelling characteristics of soil seems to be 3.0%, as no significant gain in swelling index was obtained by using higher ratios of additives content (as shown in Figures 3 and 4).

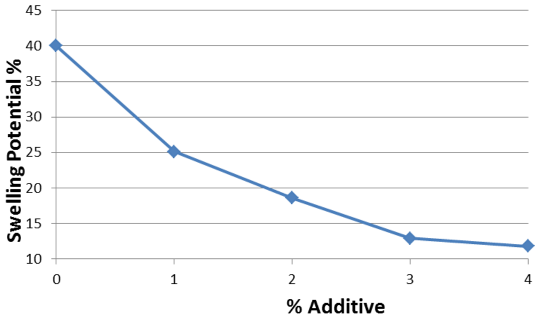

Fig.3 Effect of additive on swelling potential.

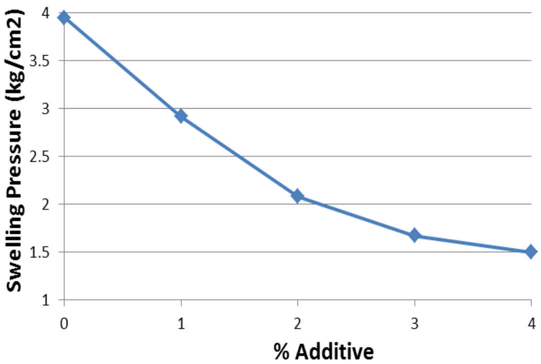

Fig.4 Effect of additive on swelling pressure.

D. *Shear Strength*

For unsoaked samples, the unconfined compressive strength of expansive soil is increasing with increasing the ratio of additive. Moreover, the rate of increase is great up to 2.0% additive, and then the increase approximately is constant up to 3.0% additive, thereafter it is decreasing. However, for soaked samples, there is approximately no change in the unconfined compressive strength with adding Dust Shield (as shown in Fig.5).

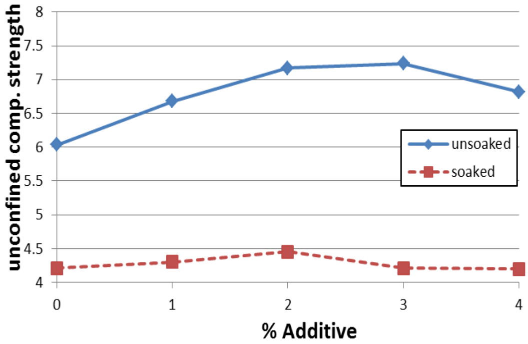

Fig.5 Effect of additive on unconfined comp. strength

E. *California Bearing Ratio (CBR)*

For unsoaked and soaked samples, California bearing ratio of expansive soil is increasing with increasing the ratio of additive. Moreover, the rate of increase is great up to 2.0% additive, and then the increase approximately is constant up to 3.0% additive, thereafter it is decreasing (as shown in Fig.6).

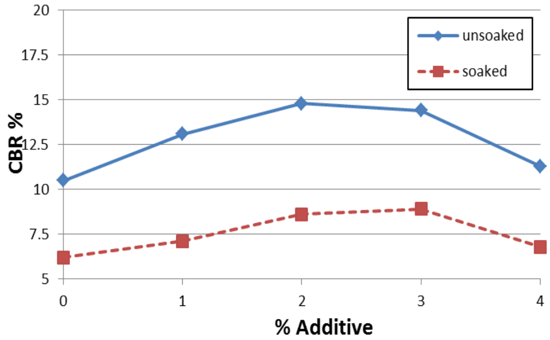

Fig.6 Effect of additive on CBR%

IV. CONCLUSION

- The liquid limit and plasticity index of expansive soil decrease, and the plastic limit of expansive soil increases with increase rate of Dust Shield.
- An increase in $\gamma_{d\ max}$ and a decrease in O.M.C. happened on expansive soil with adding of Dust Shield.
- Swelling values (swelling potential and pressure) of the expansive soil decrease when the soil is treated with additive.
- The rate of unconfined compressive strength and California bearing ratio of soil increases with increasing percentage additive up to 2.0%.
- From the results of the present study, Dust Shield can be used to be a good stabilizer of expansive soil under Traffic Areas.

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ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 2, August 2013

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