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IMPROVEMENT OF TENSILE PROPERTIES OF SAND-CEMENT BASES BY USE OF LIME

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ABSTRACT:

Cement stabilized soils have been used as base or subbase layer for a great variety of roads and pavements to reduce the verticle pressure transmitted to the subgrade.

Cement stabilized soils, however, tend to develop tensile stresses, and thus cracks, at the bottom of the base layer due to either wheel loads or restrained thermal shrinkage movements.

The objective of this on going research is to evaluate the improvement of the tensile strength resulting from adding lime to the sand-cement mix.

The lime cement was fixed at seven percent of the total dry weight of the sample, Design mixtures DM0, DM1, DM2, DM3 and DM4 containing lime to cement ratios of 0/100, 10/90, 20/80, 30/70 and 40/60 respectively, have been tested and characterized by both unconfined compressive strength and indirect tensile strength.

Results indicated that tensile strength increased by more than 200, 29, and 10 percent for DM1, DM2, DM3, respectively, and decreased by 10 percent for DM4.

1. INTRODUCTION

Stabilization has been used in various types of engineering problem. In road construction, the purpose of stabilization is to produce a material which is strong and durable cnough to act as a base or sub-base course. One of the most common additives used in soil stabilization is cement, lime, and bitumen.

Failure of sand-cement stabilized road bases and subbases can occur in three main ways, by cracking, by deformation, and by disintegration of the stabilized material into a loose granular mass.

The problem of cracking in Sand-cement base or subbase course is due to shrinkage effects as a result of loosing water in the sand-cement mixes by hydration and evaporation. The main characteristic led to shrinkage cracking is the low tensile strength of sand-cement mixes. Deformation is inevitably proceded by cracking but the cracks may not always be visible at the road surface. The failure of the stabilized soil by disintegration into a loose mass is not very common and is most likely to be due to deficiency in the ancuats of stablizer, deficiency in the qualify of the stablizer and deficiency in compaction or curing. Whereas failures due to deformation or disintegration could be eleminated by proper design and strict quality control, failures due to shrinkage cracking are not controled yet.

A long-term research work is going on in Civil Engineering Department at Al-Fateh University in Tripoli, aiming to improve the tensile strength of sand-cement mixes by using lime. In the preliminary stage of this research work.

1.1 Sand-Cement Stabilization

Sandy soils generally are stabilized readily with cement. There are many cases on record (1,2,3) in which cement has been added to cohesionless sands with success. The amount of cement required for hardening depends, by and large on the void ratio of the compacted material. Cement requirements for sandy soils ranges between 5 and 12 percent by weight. Moreover, full details of the tests whichd have been devised to give a reliable guide to its long-term performance in the field are to be found in British Standard.

In North Africa, and particularly in Libya, where sandy soils are available in abundance, sand-cement stabilization may be one of the most suitable and economic construction method of highways and airfield pavements.

Sandy soils are high quality soils, having little or no plasticity as well as easy for mixing and compaction. Thus it provide high quality cement stabilization and provide low cost road construction. On one hand, the quality of sand-cement expressed in unconfined compressive strengths, or modulus of elasticity are of rather high valves, thus enabling sand-cement to be used in road base stabilization for heavy traffic road pavements. On the other hand, sand-cement has in its nature cracking phenomena, high strinkage stresses occur during early life of sand-cement base course resulting in transverse cracks across the pavements width and tend to reflect on the surface.

1.2 Lime Stabilization

Lime stabilization is a proven method of improving the road building properties of clay soils. A considerable improvement in strength and stability can be achieved in the presence of excess moisture.

As a general rule, sands do not react with lime because they do not contain clay minerals. Sandy-clay mixtures and fine grained soils have been stabilized with success, depending upon the pozzolonic nature of the clay minerals in the mixture.

There has been, however, a limited research in which cement and lime used together for stabilization.

1.3 Objectives

The previously stated problem indicated the need for further research and studies. This research work aims to minimize or eleminate shrinkage cracking associated with sand-cement bases. Moreover, the overall objective of this study is to improve the tensile strength of sand-cement bases by admixing lime into sand-cement mix.

2. MATERIALS AND TESTING PROCEDURES

2.1 Materials

The materials which were considred in this study are consisted of fine sand, portland cement and lime.

The soil which was used in this research project represents the prevailing local soil in Tripoli region. The soil is non plastic uniform fine sand classified as SM According to the Unified system. It has a liquid limit of 21 and specific gravity of 2.61. Its optimum moisture content equals to 13.5 percent, its maximum dry density is 1.685 9m/cm^3, and it liquid limit is 21 percent. It is classified according to AASHTO as A-2.4.

Portland cement used in this study is type I, a product of AL-Khoms Cement Factory located 120 km east of Tripoli.

The lime used in this study and the most commonly used in soil stabilization is normaly hydrated lime.

2..2 Design Mixes of Sand-cement - lime:

Several design mixes (DM) were prepared using different proportions of cement and lime. The total percentage of cement and lime admixture is fixed at 7% by weight of the dry sand. The only variable here is the lime-cement ratio (L/C) which was chosen as 0/100, 10/90, 20/80, 30/70 and 40/660 ppercents and designated as DMO, DMI, DM2, DM3 and DM4 respectively.

It is important to note that the above listı´d proportions are based on 7% by weight of the dry fine sand.

Testing Procedures

The following tests were performed on the selected design mixes:

* Moisture-density relationship,
* Unconfined compressive strength, and
* Indirect tensile strength test

a. Moisture-Density Relationship

The objective of this test is to determine the moisture density curve for each DM. In this test, the fine sand is treated with a 7% admixture of cement and lime by weight of the air dried sand passing No.4 sieve and in a five different DMS, as indicated above.

For every DM, 3-kg of soil samples were mixed with water in increment of 2%, starting from 8% to 20% and left in sealed bags for a minimum of 24 hours before adding cement and lime. The required amounts of cement and lime were added to the rest sand and mixed by a mechanicald mixer for 2 minutes. The compaction procedure was performed according to the modified AASHTO compaction test(U25) The mixture is compacted in 5 successive layers in a . Each lever received 25 blows with bammer falling from 18 inch height. At the end a moisture density curve was developed for each DM. The optimum moisture content and the maximum dry density were then determined and are presented in Table (1). The highest maximum dry density value reported in table (1) was 1.77 for DM4 and the lowest maximum dry density value was 1.74 for DM1. The maximum optimum moisture content obtained was 13.2 percent for DM0 and the minimum optimum moisture conten was 12.5 percent for DM1. From the maximum and minimum values of dry densities and optimum moisture contents it is clear that; the variations in dry densities and moisture contents are not significant, and the variations in maximum dry densities and optimum moisture contents are inconsistent with the variations in L/C ratio. Therefore, it could be concluded that; (1) L/C Ratios have no effect on maximum dry density and optimum moisture content; (2) one value of maximum dry density and optimum moisture content could be used for all design mixes.

An optimum moisture content of 13 percent and maximum dry density of 1.77 grm/cm^3 were selected to be used for preparation of testing specimens for all design mixes.

b. Preparation of Specimns

A standard mould of 2 in (50.08mm) inside diameter and 7 in. (17.78mm) height was used for making univorm specimens of 2 in. (50.08mm) in diameter and 4 in. (10.16mm) high. All specimens have the same density and size.

The predetermined wet sand-cement-lime mixture was filled in the mould while the bottom plunger in position. Then, the top plunger was placed in position and pressured to close up the mould. Immediately after the extrusion of the specimen from the mould, the specimen was waxed by the paraffin wax and left for curing. A total of 90 specimens were prepared for testing, 30 specimens for each of the curing periods 7, 14 and 28 days. All tests were triplicated.

c. Unconfined compression test

The test was carried out according to the standard procedure (6). In addition to the unconfined compressive strength, the results of this test include the stress-strains relationship.

d. Indirect Tension Test (Split Test)

The test was performed according to ASTM C496. The test involves loading a cylindrical specimen with a compressive load along two opposite generators. The splitting failure occured along the diametrical. The tensile strengths was calculated as follows:

$$t \cdot \frac{2P}{\pi L d}$$

t = splitting tensile strengths
p = maximum applied load
L = length
d = diameter

TEST RESULTS AND ANALYSIS.

Test Results

The laboratory test results are preserred in tables and figures

≡ follows:

- Table 1 presents the maximum dry density and optimum moisture content for various design mixes
- Table 2 presents the tensile strengths of the design mixes for different curing periods.
- Table 3 presents the unconfined compcressive strength of various design mixes at different curing periods.
- Table 4 shows Tensile strength ratios of various design mixes.
- Figure 1 presents the grain size cistribution of used soil.
- Figure 2 illustrates the relationship between tensile strength and L/C ratio for different curing periods.
- Figure 3 shows the relationship between compressive strengths and L/C ratio for various curing periods.
- Figure 4 presents the tensile strengths ratios for various lime-cement ratios.

3.2 Analysis of Results:

a. As presented in table 2, and illustrated in figure 1, maximum tensile strengths for 14 and 28 days curing are increased sharply to design mix DM 1 having L/C Ratio 10/90, and then decreased sharply to DM2 and further increase in lime-cement ratio resulted in a steady decrease tensile strength.

The actual values of tensile strength as obtained in this study are in the order of .38Pa (3.8kg/cm^2) indicating satisfactory results. Furthermore, more spectacular results cand be expected when applying higher ratios of cement (e.g. 10-12% with fine sands).

b. Compressive strength results as presented in table 3 and illustrated in figure 2 indicate similar growth in compressive strength values reaching DM 1 absolute maximum after 14 and 28 days of curing. It is also worth to mention here that the compressive strength values decreased sharply to DM 2, then it shows steady decrease in its values with the increase of L/C Ratio.

c. One of the most effective ways effective ways to test the effect of lime on the tensile strength of sand-cement mixes is to compare the tensile strength values of sand-cement-lime mixes to that of sand-cement mixes as shown in figure 3 and presented in Takble 4. It is clearly that DM 1 having L/C Ratio of 10/90 resulted in tensile strength equals more than two times of that sand-cement mix. DM 0. However, the other design mixes DM 2 and DM 3 have shown a little-pit higher tensile strength values than DM 0. DM 4 is the only design mix resulted in less tensile strength values than DM 0.

d. Using the Elastic Theory, the relationship between crackd spacing (L) and crack width (δ) can be expressed as:

$$(\nearrow L) \leftarrow [\sigma_t^{SCL} >> \sigma_t^{SC}] \rightarrow (\swarrow L)$$

and

$$(\swarrow \delta) \leftarrow [E_t^{SCL} << E^{SC}] \rightarrow (\nearrow \delta)$$

Using the viscoelastic approach, for stresses (σ) and deformation (E) the relationship between SCL, SC, during the curing period, can be presented as follows:

$$[\swarrow \sigma) \leftarrow [M^{SCL} > M^{SC}] \rightarrow (\nearrow \sigma)$$

Where SC yields higher stresses than those of SCL, because the viscous companent M in SCL stabilized materials releases shrinkage stresses and substitute crack formation by permanent deformation.

These two facts (d, e) and the above stated findings (a, b, c.) show that sand-cement-lime mixes to be preferable to sand-cement mixes.

4. CONCLUSIONS AND RECOMMENDATIONS

This research represented the prilimenary stages of laboratory testing of sand-cement-lime mixes. The results indicated that DM 1 provided the highest compressive and tensile strength values relative to the other four design mixes used.

This one can conclude that fine sand in the Tripoli area can be modified to be used as base or subbase layer once the stabilization admixture is added on the bases of DM 1 which contained L/C ratio of 10/90.

Results obtained in this research effort incourages the continution of this research program to determine the optimum admixture proportions.

In order to reach the most rational and reliable results the following recommendation are made:

a. The Lime-Cement ratios should be based on higher levels of cement content (10-12%) in case of the used fine sand which is singles-sized.

b. Curing period should be extended to investigation long term behaviour.

c. Efforts should be made to verify the findings of this research through a full scale road tests.

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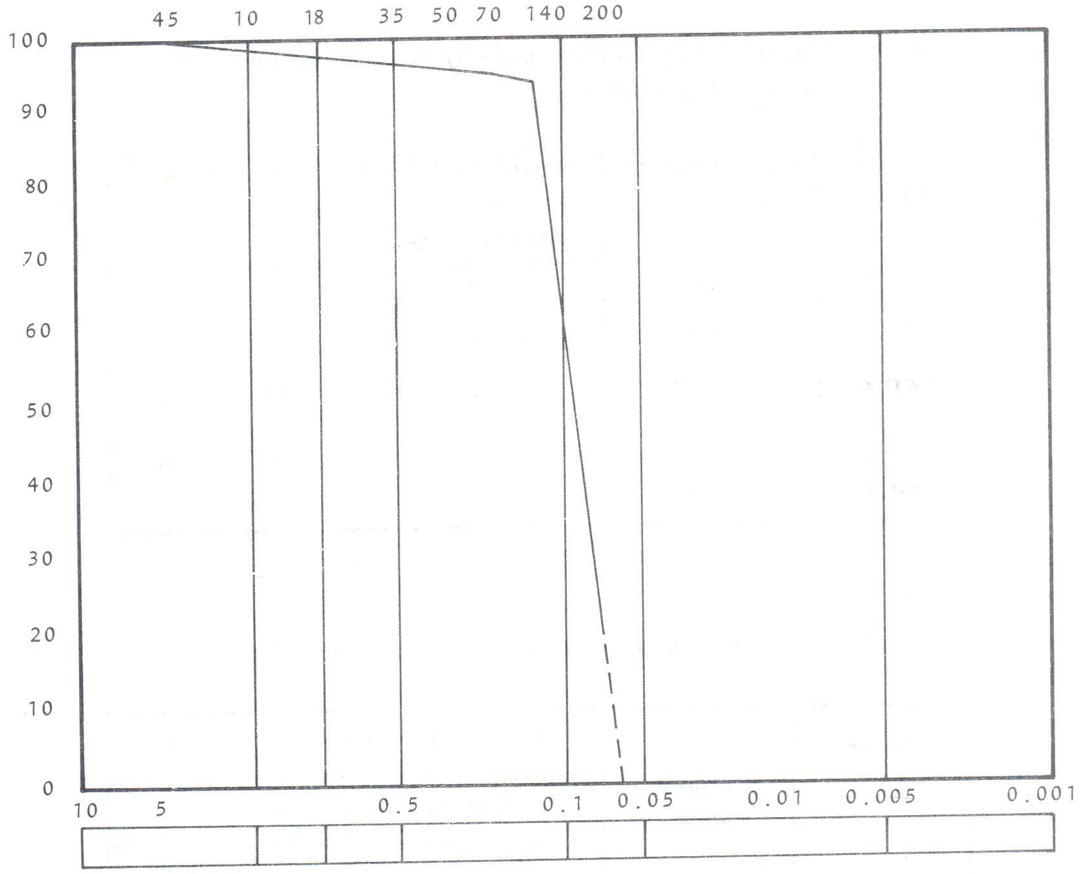
Table 1 : Maximum Dry Density and Optimum Moisture Content for Various Design Mixes.

Design Max	Lame-Cement Ratio	Miximum Dry Density gm/cm^2	Optimum Misture content %
DM 0	0/100	1.766	13.22
DM 1	10/90	1.74	12.50
DM 2	20/80	1.75	12.80
DM 3	30/70	1.75	12.80
DM 4	40/60	1.77	13.20

Table 2 : Tensile Strength for Various Design Mixes

Design Mix	Lime - Cement Ration	Tensile Strength, * Kg/cm^2 (pa)		
		Curing period (days)		
		7	14	28
DM 0	0/100	0.75 (0.75)	1.24 (.124)	1.85(.185)
DM 1	10/90	0.845 (.08)	2.60 (.260)	3.8 (.38)
DM 2	20/80	1.0 (0.1)	1.6 (.16)	2.4 (.24)
DM 3	30/70	1.27 (0.127)	1.4 (.14)	2.0 (.20)
DM 4	40/60	0.90 (0.09)	1.13 (.113)	1.7 (.17)

* Average of three tests



Design Mix	Tensile Strength (Kg/cm^2) curing Period (days) 14	28
DM O	1.24	1.85
DM 1	2.6	3.8
DM 2	1.6	2.4
DM 3	1.4	2.0
DM 4	1.13	1.2

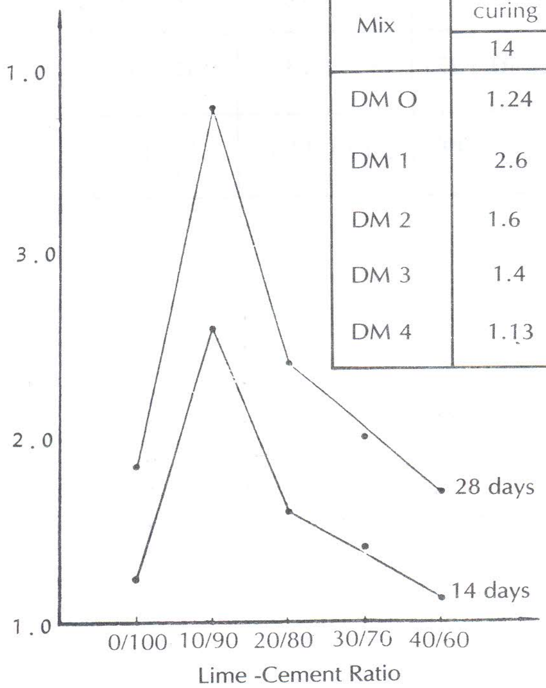


Fig 2 - Tensile Strength VS Lime-Cement Ratio