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Study of selected soil stabilization material and the cost impact

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Abstract :*The study is centered on the available techniques and procedures of soil stabilization and to keep geotechnical engineers abreast of the cheaper technologies with respect to soil stabilization and a need to do what is best in this field through a review of the most important techniques and additives for the soil. The economic factor represented by the costs aspects is a very important factor in major projects like highway projects. The article reviews the most important soil stabilization methods and the cheapest to select them as cheap and effective materials to increase load resistance at the same time.The study included three types of additives by reviewing the theoretical aspects, the forth is field study concerned of the highway project by adding the cement residues conducting the laboratory test of the samples taken from the site. The soil was classified according to (AASHTO). The study proved that the addition of cement residues to clayey soil (base layer) improves its stabilization to limited limits. From the economical side of the material used will reduce the cost of soil stabilization by 45 % compared to classical materials.*

Keywords: *soil, soil stabilization,highways,situ, clayey soil, cost*

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I. Introduction

The road engineers today are facing the dual problems of tightening budgets and rising specifications for regulatory compliance. The price of both buying and importing additions typically used for enhancing road structure like gravel or road base continues to skyrocket, while municipal road budgets (particularly those linked to maintenance) are shrinking every year. Meanwhile, environmental regulations monitoring of the dust and sediment for unpaved roadways and shoulders are just getting more stringent.

The sufficient treatment allows the additive to attain the full engineering properties for the soil, as the weather and humidity of critical factors, as treatment can possess a direct impact on soil stabilization, generally, no less than seven days are required to guarantee appropriate treatment. during treatment, soil samples are taken up to measure moisture content.There is a group of standards that help engineers to recognize the properties of soil for the intended purpose of designing and building roads and highways. The most crucial of which are the ones that change the soil condition from the solid state of spandex and the plasticity index, which is the limit between the plastic and liquid condition.

II. The objectives

The comparison of studying road stabilization allows us to know which the material is within the cost budget and efficient to build stronger roads more cost-efficiently than any traditional approach, Unlike expensive additions without previous study. The stabilization techniques improve road strength while also increasing moisture resistance, reducing the risk of cracking and extending the life of the road. The main objective of the study is to make a proper comparison in cost between the more effective material in soil stabilization by using the actual results taken from the highway project.

III. The methodology

Study of different types of clay soil additives, analysis of their components, selection of one and carrying out a laboratory testby using a California bearing ratio test (CBR) and clarifying the amount of reduction in cost is the method used for this study.

IV. The soil stabilization

Soil stabilization aims at improving soil strength and increasing resistance to softening by water through bonding the soil particles together, waterproofing the particles or combination of the two, [1]. Usually, the technology provides an alternative provision structural solution to a practical problem. The simplest stabilization processes are compaction and drainage (if water drains out of wet soil it becomes stronger). The other process is by improving gradation of particle size and further improvement can be achieved by adding binders to the weak soils, [2].

4.1Additive stabilization:

Additive stabilization is usually achieved by the addition of appropriate percentages of cement, lime, fly ash, bitumen, or combinations of the components to the soil.

The selecting of type and determination of the percentage of additive to be is utilized depends upon the soil classification and the degree of improvement in soil quality desired. Generally, small amounts of additives are required when it is simply desired to modify soil properties such as for example gradation, workability, and plasticity.

4.2 The stabilization in highways

Pavement design is founded on the premise that minimal specified structural quality will certainly be achieved for each layer of material in the pavement system. Each layer must resist shearing; prevent extreme deflections that cause fatigue cracking within the layer or in overlying layers, and stop excessive permanent deformation through densification. As the quality of a soil layer is increased, the ability of that layer to distribute the load over a greater area is generally increased so that a decrease in the mandatory thickness of the soil and surface layers could be permitted.

4.3Selectionsof the Stabilizers

The select a type of stabilizer based on soil classification (gradation and PI) and the goals of soil stabilization, the preparation of a proper mix design its essential to determine the optimum amount of the selected stabilizer on a project basis for the desired engineering performance. Moreover, the evaluation of the required tests to ensure the engineered mix meets the goals and requirements of soil stabilization. The ideal method to select the proper material to treat the soil and matching the objectives can follow the important points below:

- Goals of treatment : dry up, PI, strength, modulus, shrink/swell
- Soil type: classification, mineralogy, sulphate, and organics
- Construction costs and time
- Traffic load and volume
- Design life of pavement structure
- Environmental conditions: drainage condition, ground water table, precipitation, temperature
- Overall benefits of the improved structural, material, and construction performance:cost savings vs. benefits,[3].

4.3.1 Mechanical methods

Mechanical Stabilization is the process of improving the properties of the soil by changing its gradation. This process includes soil compaction and densification by application of mechanical energy using various sorts of rollers, vibration techniques and sometime blasting.

The stability of the soil in this method relies on the inherent properties of the soil material. Two or more types of natural soils are mixed to obtain a composite material which is superior to any of its components. Mechanical stabilization is accomplished by mixing or blending soils of two or more gradations to obtain a material meeting the required specification, [4].

4.3.2Chemical stabilization

On this category, soil stabilization depends mainly on chemical reactions between stabilizer (cementations material) and soil minerals (pozzolanic materials) to achieve the desired effect. A chemical stabilization method is the fundamental of this review and, therefore, throughout the rest of this report, the term soil stabilization will mean chemical stabilization. Through soil stabilization, unbound materials can be stabilized with cementations materials (cement, lime, fly ash, bitumen or combination of these). The stabilized soil materials have higher strength, lower permeability, and lower compressibility than the native soil, [5].

The method can be achieved in two ways, namely;

1) In situ stabilization and

2) Ex- situ stabilization.

Note that, stabilization not necessary a magic wand by which every soil properties can be improved for better. The decision to technological usage depends on which soil properties have to be modified. The chief properties of soil which are of interest to engineers are volume stability, strength, compressibility, permeability and durability, [6, 7].

Goals of Stabilization
- Dry up construction site and provide a working platform
- Reduce soil PI and clay/silt- sized particles
- Improve compact ability
- Reduce shrink/swell of expansive soils
- Improve strength and stability
- Reduce moisture susceptibility
- Utilize local or salvaged materials

In general the methods that can be accomplished the soil stabilization are two, mechanical and chemical,[3].The major chemical sub-methods of soil stabilization:

4.3.2.1. Cement Stabilization

The **PCA** (Portland Cement Association) has collected considerable amount of information regarding the soil type and quantity of cement required for adequate soil hardening.Cement reaction is not dependent on soil minerals, and the key role is its reaction with water that may be available in any soil [8]. This can be the reason why cement is used to stabilize a wide range of soils, [9].The quantity of cement required for stabilization increases as soil plasticity increases. For highly plastic soils as much as 15 to 20 % cement by weight of soil is required for hardening of soil.Sandy soils and gravel mixtures generally are stabilized readily with cement. The amount of cement required to stabilize a granular material depends upon the quantity and quality of fines contained in granular material and final compacted density (void ratio of compacted material). The cement required for sandy soils ranges between 5 and 12 % by weight.

Table 1: The requirements limits adopted for selection of the materials for cement stabilized soil

Components(cement stabilized)	Limits
Max plastic limit	20%
Max liquid limit	40 - 45 %
pH value of the soil-cement	From 12.1
Max content of the soluble salts	Chlorides 8% Sulphates 4%

Moreover, the material must be mixed with the gravel, sand and slag well graded are required by using the special equipment and using the compacting to reach to the actually required compaction percent. Figure (1) below shows the field application in highway project and the process of the cement stabilization, the project data analysis refer to using 15 cm total thickness for the soil-cement stabilization layer.

Figure 1: Blending the layer from soil-cement in the highway project

4.3.2.2. Lime stabilizer

Lime is an effective stabilizing agent for plastic soils and can be used to improve their workability, reduce settlement and increase strength. Two types of lime commonly used in stabilization are hydrated lime [$Ca(OH)_2$] and quicklime [CaO], [10]. Addition of hydrated lime improved the workability of potentially expansive soils by reducing their plasticity. A significant increase of California Bearing Ratio found with an increase in hydrated lime content, the peak increase is found at optimum hydrated lime content. desired properties of typical Subgrade and sub-base materials were attained by stabilizing the potentially expansive soils with optimum hydrated lime,[11].

4.3.2.3. Soil-Bituminous Stabilization

The essential principles of soil-bitumen stabilization as achieved to highways construction are the methods of designing and mixing local aggregates or soil in general with bituminous materials to make a waterproof base course and stable. The base course of the soil-bitumen resists the deformation through cementing action of bitumen which ties the soil parts, the high quality of water-resistant and the defects resistance already provided by the coating of the bitumen layer accrued between soil structures.

Table 2: The requirements limits adopted for selection of the materials for Bitumen stabilized soil

Components (Bitumen Content)	Limits
Sand	4-10%
Fine grained soil	4 - 8 %
Gravel and sand gravel	2-6 %
Max content of the soluble salts	Chlorides 8% Sulphates 4%

4.3.2.4.Cement residues for soil stabilization.

One of the famous and large effects of air pollution of the cities where there are factories for the manufacture of cement. Where the dust of the **BY-Pass**environmental problem and health caused by the waste during the use of the dry method of cement industry and the seriousness of cement dust on the public health of workers in these factories and residents in the surrounding areas of these factories, as well as that these wastes are buried in large areas of the land surrounding the factories producing cement and the impact on the negative impact of these lands due to the spread of salinity from buried dust and the cost of transport and its composition, and the high smoothness of this industrial residue it is between 20-100 microns the proportions of chlorides, sulphates, alkali, and lime.

The scientific and laboratory studies refers to the possibility to use the soil resulting from the manufacture of cement and the nominate BY Pass by adding a chemical with special specifications, white sand and ordinary Portland cement with special rates to convert the dust of the **By-Pass** to an economic product has environmentally friendly uses and this leads to profits instead of loss Paid for the costs of dealing with the dust of the By-Pass in the transfer exposed outside the cement companies, causing environmental problems and leads to the safe disposal of environmental problem to an economic product.

Economically, the cost of paving using cement residues, Portland cement, sand, and water is not more than **55%** of the value of asphalt used for asphalt paving, which provides at least **45%** of the cost.

Input extensions:

It can be applied dry or wet, when the application is dry, where it is deployed in a square yard or a sprinkler plant. Some projects require multiple layers of treated and compact soil. For quick setup properties for extensions.

Figure 2: Preparing the layers before residues cement deployed in the highway project

Figure 3: Deployed the layer from residues cement in the highway project

For a successful stabilization, a laboratory test followed by field tests may be required in order to determine the engineering and environmental properties. Laboratory tests although may produce higher strength than corresponding material from the field, but will help to assess the effectiveness of stabilized materials in the field.Results from the laboratory tests will enhance the knowledge on the choice of binders and amounts,[8,9]. One of the most important tests used in road projects is:

V. California Bearing Ratio (CBR):

A method used to find soil bearing strength (sub-grade, sub- base, base coarse). The method is used for paving works (design works under pavements). At present and because it represents reality, the method is done by using the necessary force to introduce a standard piston inside the soil for a certain distance to the force required to enter the same piston and the same distance within a standard model,equation(1), values range for the CBR is ((0 –100).

$$CBR = P/Ps \times 100 \quad (1)$$

CBR [%]

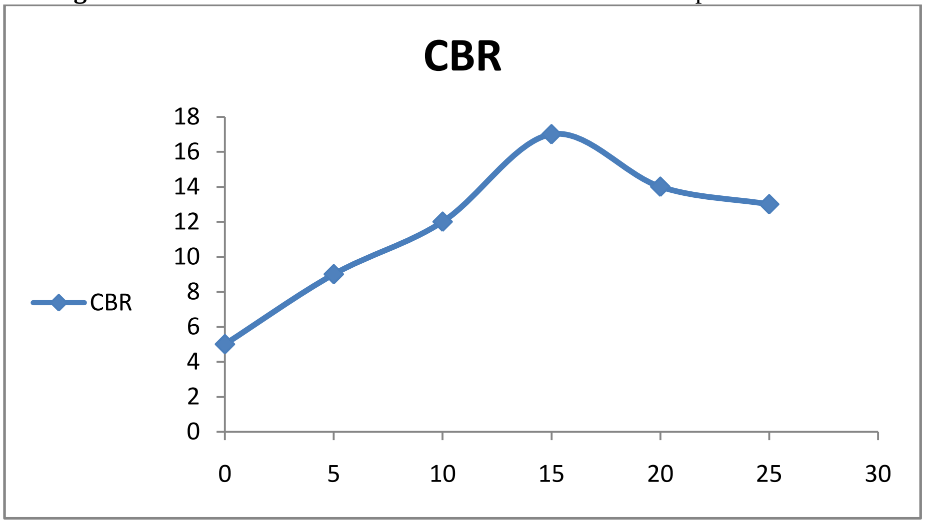
ASTM D1883-05 (for lab samples)

AASHTO T193 D4429 (in situ samples)

Where: P= measured pressure for site soils [N/mm²]

Ps = pressure to achieve equal penetration on standard soil [N/mm²]

Figure 4: Illustrate the relation between the residues cement percent and CBR



According to the soil classification system (from AASHTO M 145 OR ASTM D3282), the situ soil is classified as clayey soil.Figure (4) shown the California bearing test increases with the increase of the amount of additives up to 15% to be the max point, then the curve goes down, the reason is the increase of the soil plasticity. This soil preparation and laboratory tests were done by making the adding cement residues at specific rates 5,10,15,20,25 % respectively with a plasticity index (PI=14) of the untreated soil.

VI. Conclutions

1. The ideal proportion of the residues of cement residues must be not exceed 15 % withgood bearing strength.
2.The additives to the soil makes it more elastic.
3. Economically, the cost of paving using cement residues, Portland cement, sand, and water is not more than 55% of the value of asphalt used for asphalt paving, which provides at least 45% of the cost
4. Increase structural integrity and loading capacity (CBR).
5. Improve long-term performance of un-surfaced and surfaced roads.
6. Offer a cost-effective alternative to asphalt.7. Improve aging control to reduce cracking and moisture damage.

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