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Review article

A REVIEW OF THE STABILIZATION OF PROBLEMATIC SOILS

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ABSTRACT.

Geotechnical properties of problematic soils such as the Nigerian deltaic marine clays (locally called Chikoko) are improved by various stabilization methods, in order to minimize the cost of earth work, where good earth may not be available at nearby source. These stabilization methods include density treatments (e.g. compaction and preloading), pore pressure reduction techniques (such as dewatering or electro-osmosis), the bonding of soil particles (by ground freezing, grouting and chemical stabilization), and use of reinforcing elements (such as geotextiles and stone columns) most of which may be ineffective and expensive.

This paper reviews the use of stabilizing agents such as lime, fly ash, cement, rice husk and scrap tyre for low cost and effective stabilization.

Keywords: Stabilization, Lime, Fly ash, Cement, Rice husk, Scrap tyre, Low-cost.

INTRODUCTION.

Problematic marine clays (peat) exhibits high compressibility, low strength and volume instability (Wong et al 2008). Islam and Hashim (2008), Huat (2007); Otoko and Aitsebaomo (2009) have all shown that the bearing capacity of peaty clays are very low. The problem becomes more difficult to handle if the superficial soils are permeable (Hebib and Ferrel 2003), as in many parts of the study area.

Chikoko is a very soft marine clay and its collection in undisturbed state most times have been very problematic. As such, engineers have resorted to insitu strength tests more so, as the soils tend to be sensitive and disturbed easily.

Different methods can be used to stabilize the soils, by treating it insitu. These methods include density treatments (e.g. compaction and preloading), pore pressure reduction techniques (such as dewatering or electro-osmosis), the bonding of soil particles (by ground freezing, grouting and chemical stabilization), and use of reinforcing elements such as geotextiles and stone columns (Powrie 1997).

Vosteen 1998, 1999 reported the investigation and development into construction procedures, the use of cement and lime for stabilization. Stabilization of weak soils include both physical stabilization (such as dynamic compaction) and chemical stabilization.

Figure 1: Peat (chikoko) site at Eagle lsland, Port Harcourt, Nigeria.

Chemical stabilization involves mixing chemical additives with natural soils to remove moisture and improve strength of the soil by either reinforcing of the bonds between the particles or filling of the pore spaces. The chemical stabilizing agents are expensive, most of which are not available in Nigeria. Cement, bitumen and lime are the commonly used stabilizing agents in Nigeria.

The quality of the sub-grade soil used in pavement application is classified into 5-types (soft, medium, stiff, very stiff and hard sub-grade) depending on unconfined compressive strength values (Thorne and Watt 1965). The quality of the subgrade soil used in pavement applications is classified into 5-types (very poor, poor to fair, fair, good and excellent) depending on the CBR values (Bowles 1992). Sub-grade CBR values of 0-7% are very poor and poor to fair and sub-grade unconfined compressive strength (UCS) of 25-100 kN/m^2 are soft and medium. These are unstable sub-grades and need to be stabilized.

SOIL STABILIZATION BENEFITS.

(i) These is substantial savings in stabilizing existing sub-grade instead of replacing existing sub-grade with suitable materials.

(ii) During rainy seasons, weather related delays can be reduced by stabilizing the soil in order to continue site work. This can impact on construction schedule in a positive way and save cost of having to wait for good weather to continue work.

(iii) In the riverine Niger Delta, Nigeria, where aggregate supply is cost prohibitive to import, soil stabilization becomes a cost effective alternative.

(iv) Stabilizing of the sub-grade can also reduce the section of the base material and asphalt paving, thus reducing cost.

MATERIALS.

A. Lime Stabilization.

The benefits of sub-grade lime stabilization was incorporated by Qubain et al (2000), for the first time, into the design of a major interstate highway pavement in Pennsylvania. For clayey sub-grade such as experienced in the project, lime improves the strength of clay by three mechanisms; hydration, flocculation and cementation. While the first and second mechanisms occur immediately after introducing lime, the third mechanism is a long term effect. Qubain et al (2000) investigation showed significant increase in strength by introduction of lime; which when incorporated into design, reduced the pavement thickness and resulted in substantial savings.

White (2005) investigated the effect of curing and degree of compaction on loam stabilized with different additives. He got best results at ambient temperature, while the lime continued reacting on cured specimens. He also noticed that the behaviour of the stabilized specimens were affected by the degree of compaction, which led to brittle failure behaviour at maximum densities.

Ismaiel (2004) studied materials and soils from some part of Germany, which includes petrological, mineralogical studies and scanning electron microscope analysis. He stabilized these materials with lime (10%), cement (10%), and lime/cement (2.5%/7.5%). He determined consistency limits, compaction characteristics, and shear and uniaxial strength; and concluded that the optimum moisture content was inversely proportional to the maximum dry density, while the strength parameters was directly proportional to the stabilizing content.

Ampera & Aydogmust (2005) treated clayey soil with lime (2,4 and 6%) and cement (3, 6 and 9%), and conducted compaction, unconfined compressive strength and direct shear tests on untreated and treated specimens. They concluded that the strength of cement-treated soil was generally greater than that of lime; and that lime stabilization is in general, more tolerant of construction delay than cement stabilization and more suitable for the clayey soils. The direct shear tests and unconfined compressive strength tests gave similar relationships.

B. Fly Ash Stabilization.

Use of fly ash (by-products) for soil stabilization has been studied by a number of workers (Watt and Thorne 1965, Hesham 2006, Khan 1993, Margason & Cross 1996, Rouch et al 2002). Edil et al (2002) studied the use of by-products such as fly ash, bottom ash, boundary slag and boundary sand for soil stabilization. Unconfined compression testing showed that 10% by dry weight of fly ash was sufficient to provide the strength necessary for construction. Laboratory data such as UCS, soil stiffness and dynamic cone penetration index on undisturbed samples were obtained before and after fly ash placement. CBR of 32% was reported for the stabilized sub-grade, which is rated as ‘good’ for sub-base highway construction. CBR of the untreated sub-grade was 3%, which is rated as “very poor” according to Bowles, 1992.

White (2005) reported:

- Iowa self-cementing fly ashes are effective at stabilizing fine-grained Iowa soils for earthwork and paving operations.
- Fly ash increases compacted dry density and reduces the optimum moisture content.
- Strength gain in soil-fly ash mixtures depends on cure time and temperature, compaction energy, and compaction delay.

- Rapid strength gain of soil-fly ash mixtures occurs during the first 7 to 28 days of curing, and a less pronounced increase continues with time due to long-term pozzolanic reactions.

- Fly ash effectively dries wet soils and provides an initial rapid strength gain, which is useful during construction in wet, unstable ground conditions. Fly ash also decreases swell potential of expansive soils by replacing some of the volume previously held by expansive clay minerals and by cementing the soil particles together.

- Soil-fly ash mixtures cured below freezing temperatures and then soaked in water are highly susceptible to slaking and strength loss. Compressive strength increases as fly ash content and curing temperature increase.

- Soil stabilized with fly ash exhibits increased freeze-thaw durability.

- Soil strength can be increased with the addition of hydrated fly ash and conditioned fly ash, but at higher rates and not as effective as self-cementing fly ash.

- CaO, $Al2O_3$, SO_3, and Na_2O influence set time characteristics of self-cementing fly ash.

C. Cement Stabilization.

Portland cement is hydraulic cement made by heating a limestone and clay mixture in a kiln and pulverizing the resulting material (Kowalski et al 2007). The same type of pozzolanic reaction are found in cement and lime stabilization. Both contain the calcium required for the pozzolanic reactions to occur. With lime stabilization, silica is provided when the clay particle is broken down. With cement stabilization, the cement already contains the silica and is therefore, independent of the soil properties process; but need only water for hydration process to begin.

D. Rice Husk Stabilization.

Musa Alhassan (2008) studied rice husk stabilization and came to conclusion that there is a general decrease in the maximum dry density and increase in the optimum moisture content with increase in rice husk ash (RHA). There was also slight improvement in the CBR and UCS with increase in the RHA content. He also concluded that there is a little potential 6.8% RHA for strength improvement of A-7-6 lateritic soil.

Brooks (2009) investigated soil stabilization with fly ash and rice husk ash. UCS showed that failure stress and strains increased by 106% and 50% respectively when the fly ash was increased from 0 to 25%. When the RHA content was increased from 0 to 12% UCS increased by 97% while CBR improve by 47%. Therefore an RHA content of 12% and a fly ash content of 25% are recommended for strengthening the subgrade soil.

E. Soil Reinforcement Method.

Using natural or synthesized additives to improve the properties of soils is called soil reinforcement. Several reinforcement methods are available for stabilizing problematic soils; and which can be classified into categories (see fig 2). Some of the methods in fig. 2 may be ineffective and/or expensive (Hejazi et al 2012). Use of scrap tyre rubber (STR) may be a viable and sustainable inexpensive alternative (Carraro et al 2008).

F. Scrap Tyre.

Waste tyres generated every day in Diobu part of Port Harcourt, Nigeria, can be used as light weight material either in the form of whole tyres, shredded or chips, or in mix with soil. Many studies regarding the use of scrap tyres in geotechnical applications have been done (Ghani et al 2002). The re-use applications for tyres depends on how the tyres are processed. Processing basically includes shredding, removing of metal reinforcement and further shredding until the desired material is achieved (Carreon, 2006).

Bernal et al (1996) reported of the technical, economic and environmental benefits of using tyre shreds and rubber-sand; which includes reduced weight of fill, adequate stability, low settlements, good drainage and use of large quantities of local waste tyres, which would have a positive impact on the environment.

Akbulut et al (2007) studied the modification of clayey soils using scrap tyre rubber and synthetic fibres and concluded that they improve the strength properties and dynamic behaviour of clayey soils.

CONCLUSION.

Most of the stabilizing methods using particularly chemical additives are ineffective and/ or expensive; and some of which are not even available in Nigeria. A review of the use of stabilizing agents like lime, fly ash, cement, rice husk ash and scrap tyre are presented as low-cost and effective to soil stabilization. The benefits of soil stabilization are also outlined.

Annually a lot of waste rubber and particularly waste tyre are generated and occupy a great space, causing undue environmental problem. From this review, one way to solve this environmental problem is use of different size of waste rubber in soil reinforcement.

In conclusion, it is beneficial to use the outlined stabilization agents in this review as they are low-cost and effective to soil stabilization, particularly the scrap tyre, as it has the added advantage of solving the environmental problem that it creates.

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