Soil Stabilization In Pavement Construction Using Chemical Additives- A Review

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ABSTRACT *-In today's world, Infrastructure is a major sector that propels overall development of the economy. Fast growing population needs better roads, bigger cities and industrialization to produce livelihood, stabilization of soil becomes necessary as it improves soil properties to withstand the loads from infrastructure. The paper attempts toreview soil stabilization techniques focusing on different type of chemical additives used in soil stabilization. Use of non-traditional additive such as Lime, fly ash, jute etc. not only improves soil properties but also solves the problem of waste disposal.*

KEYWORDS –Soil Stabilization, Infrastructure, chemical additives

INTRODUCTION

Long term performance of a pavement structure largely depends on the stability of underlying soil foundation. A minimum acceptable stiffness requirement for pavement subgrade is often specified in the pavement design and construction.The necessity of improving the engineering properties of soil has been recognised for as long as construction has existed.

Many ancient cultures including the Chinese, Romans and Incas utilised various techniques to improve soil suitability, some of which were so effective that many of the buildings and roadways they constructed still exist today.

During construction, mechanical methods such as rolling are used to improve the stability and when questionable soils are encountered, removal and replacement with better materials is usually employed. However, when a large percentage of projectarea needs subgrade improvement, chemical stabilization methods such as cement, lime,fly ash are used.

Objective of subgrade stabilization compared to "remove and replace" option is that it provides a more uniform support for the pavement structure throughout the project.Also, stabilization provides a better platform for construction equipment to speed up the construction activities.

SOIL STABILIZATION–It refers to any physical, chemical, biological or combined method of changing a natural soil to meet an engineering purpose. Such as increasing the weight bearing capabilities, tensile strength, and overall performance of in-situ subsoils, sands, and other waste materials in order to strengthen Road surfaces.A strengthened subgrade may allow for thinner layers of expensive asphalt concrete as well as a more durable system. Lime and cement are used to improve subgrade soils in many highway and transportation projects.

This paper is a review paper highlighting the performance of various chemical additives used for soil stabilization.

A. COMBINING INDUSTRIAL WASTES WITH LIME FOR SOIL STABILIZATION, 1991

Masashi Kamon and SupakijNontananandh examined the potential for burning various industrial wastes combined with lime, in certain proportions, to produce a by-product having cementing characteristics similar to ordinary Portland cement (OPC).

They concluded that a new stabilizer produced from the incineration of various proportions of industrial wastes, combined with lime in specific chemical compositions, has self-cementing characteristics similar to ordinary Portland cement. It can be added to loam soil containing a high moisture content and organic matter, for subgrade stabilization purposes. (The results of this study bring to light some characteristics of ettringite in stabilizing loam soils.)

B. SOIL STABILIZATION USING OIL-SHALE SOLID WASTE, 1994

John P. Turner usedOil-shale solid wastes in his study as soil stabilizers. Significant increases in strength, durability, and resilient modulus were obtained by treating a silty sand with combusted western oil shale, Solid waste from eastern oil shale appeared to be feasible for soil stabilization only if limestone is added during combustion.

He concluded that Oil shale solid waste has the potential to be used as a low-cost construction material. This potential is a result of the cementing properties of spent shale observed when it is mixed with water. The mechanism involves particle bridging and void filling by small particles of hydrated spent shale consisting of unknown compounds of magnesium, silicon, calcium, aluminium, and sulphur.

C. STABILIZATIONOF SOFT SOILSBY SOIL MIXING, 2001

Kenneth B. Andromalos, Yasser A. Hegazy and Brian H. Jasperse summarised the use of soil mixing for providing stabilization of soft or loose soils.A primary concept is to enhance the soil strength and elastic properties by forming an integrated matrix of soil-cement columns and the original soil. A treatment ratio is typically 20% to 35%. Three case histories of soil mixing to provide resistance to static loads were illustrated in the paper. Soil cement columns have been used to stabilize soft cohesive and loose cohesionless soils for control of their movement. Soil mixing has been conducted to form gravity retaining structures including, VERT wall, usually composed of continuous columns at the front row and staggered columns at the back rows. External stability of the VERT wall must be checked against sliding and overturning. Bearing capacity is also evaluated making sure that the wall base is primarily in compression.

They concluded that the performance of the VERT wall at Texas A&M, NGES site was verified to be satisfactory using in-situ measurement of the internal stresses and vertical and horizontal deformations of the wall.

D. EXTENDING DURABILITYOF LIME MODIFIED CLAY SUBGRADES WITH CEMENT STABILIZATION, 2007

Marshall B. Addison and Frank A. Polmaused lime and cement in combination and was contemplated as a means to possibly provide an easily workable, yet durable, method to stabilize paving subgrades in high plasticity soils.Further laboratory and a field-testing program was then undertaken to determine various parameters such as durability.

The laboratory and field-testing program revealed that using lime to pretreat high plasticity clays before stabilizing with cement has the potential to increase durability of the treated subgrade.

E. RESEARCH ON APPLYING GLASS FIBRE CEMENT SOIL TO STRENGHEN SOFT SOIL SUBGRADE, 2009

YIN Yong and YU Xiao-junstudied the reinforcement effects of glass fibre, the possibility of applying glass fibre to strengthen soft soil subgrade was discussed in this paper. More than 100 groups of cement soil samples' laboratory testing results were presented and compared.

The analysis of test results concluded that glass fibre mixed in cement soil can improve the strength and deformation characteristic of cement soil in a certain degree. It could also be used as a possible replacement of soft soil subgrade. The findings were a new contribution to the soft soil subgrade treatment techniques.

F. UTILIZATIONOF PUMICE WASTE FOR CLAYEY SUBGRADE OF PAVEMENTS, 2011

Mehmet Saltan, YücelKavlak and F. SelcanErtemanalysed the potential of pumice waste of the Isparta-Gelincik region, which has been categorized under the lightweight aggregate class as a stabilizing additive to problematic clayey subgrade of pavements. The physical properties of lightweight aggregate material were analysed.Large quantities of pumice, which is formed during explosive volcanic eruptions, are found in Turkey, particularly in Isparta were used.

It was concluded that after the stabilization process, liquid limit and plastic index values of the mixture were reduced in their specification conditions by increasing the amount of pumice. Mixtures consisting of 40% pumice and 60% clayey subgrade produced the best performance.

G. SOIL STABILIZATIONWITH CALCINED PAPERSLUDGE: LABORATORYAND FIELD TESTS, 2012

AmaiaLisbona, Iñigo Vegas, Javier, Ainchil and Carolina Ríos aimed to establish basic standards for the use of calcined paper sludge (CPS) in the stabilization of soils. The soils were stabilized with CPS and with mixtures of CPS and cement (C). The total percentage of binder was between 3% and 6% by weight.

It was concluded the mixture of CPS and Portland cement leads to mechanical improvementsinthestabilizationofsoils.Unconfinedcompressivestrengthat7daysofabove4.5M Paanddeflectionaverages ofapproximately33:5×10 mm2areachievedforCPS:cement ratios (in weight) of approximately 25:75.

H. PAVEMENT SUBGRADE STABILIZATION USINGPOLYMERS: CHARACTERIZATIONAND PERFORMANCE, 2013

Srinath R. Iyengar, EyadMasad, Ana K. Rodriguez, Hassan S. Bazzi, Dallas Little and Howard J. M. Hanley conducted a laboratory investigation aimed at evaluating the potential of polymer binders to stabilize pavement subgrades in Qatar.The mechanical properties of the stabilized and unstabilized soils were incorporated in the analysis of asphalt pavement sections using the state-of-the-art protocol for pavement design and analysis.

The results of the performance analysis using the ME-PDG (Mechanistic-Empirical Pavement Design Guide) clearly suggested that incorporation of a stabilized subgrade layer decreases the rutting in the subgrade, effectively transferring the deformation to the upper pavement structure. This allows the foundation of the pavement structure to remain intact longer and could delay major rehabilitation of the roadway for many years.

I. PERFORMANCE EVALUATION OF CEMENT TREATED/STABILIZED VERY WEAK SUBGRADE SOILS, 2014

Murad Abu-Farsakh, Sanjay Dhakal and Qiming Chenperformed a research to evaluate the performance of cement treated/stabilized very weak subgrade soil specimens moulded at high water content condition. Three soil types of different plasticity indices were considered in this research study.The overall stabilization process for soil-cement mixtures in the presence of water can be summarized into four different processes: cation exchange, flocculation and agglomeration, cementitious hydration, and pozzolanic reaction (Prusinski and Bhattacharja, 1999; Mallela et. al 2004).

It was concluded that the proper selection of cement content for very weak and wet subgrade soil can substantially improve their performance in terms of resilient modulus and permanent deformation for working table and subbase applications.

The resilient modulus and permanent deformations were found to be a function of water cement ratio; such that the resilient modulus increases, and the permanent deformation decreases with the decrease in water/cement ratio.

J. ADDITION OF LIME AND FLY ASH TO IMPROVE HIGHWAY SUBGRADE SOILS, 2014

A. Athanasopoulouconducted testsin order to evaluate the improvement in engineering properties relevant to highway design and construction obtained when clayey subgrade soils are stabilized with lime or fly ash. The experimental program included California bearing ratio (CBR) tests to evaluate the bearing strength of stabilized soils used as working platforms during highway construction. Two types of soil S1 and S2 were chosen.

In conclusion theadditionofflyashandlimegreatly reduced the plasticity index of both soils, with the effect of the fly ash being more pronounced for the S2 soil, particularly at higher contents in the mix. The same trend has been observed for the lime content, but the rates of increase are higher for the S1 soil, also admixture of lime or fly ash resulted in a gradual reduction of the maximum dry density indicative of the increased resistance offeredbytheflocculatedstructuretothecompactioneffort.

K. PAVEMENT SUBGRADE STABILIZATION USING RECYCLED MATERIALS, 2015

NishanthaBandara, Tarik Habib Binoy, Haithem S. Aboujrad, and Juliana Sato used recycled materials for subgrade stabilization is explored because Recycled materials not only provide cheaper alternatives for subgrade stabilization, they also alleviate landfill problems.This paper presents the preliminary results of using cement kiln dust, lime kiln dust (2 types-lime stone based, and dolomite based), fly ash and concrete fines for soil stabilization or modification of a very soft clay (AASHTO classification A-6 and USC of CL) soil sample.

Laboratory studies such as freeze-thaw durability testing and field evaluation of pavement sections stabilized with recycled materials are still underway as part of this research project

L. STABILIZATION OF PAVEMENT SUBGRADE SOILS CONTAINING RICH CHLORIDE SALTS, 2018

Xin Yu, Yuhong Wang and Yingtao Liadded various amounts of Portland cement, lime, and their combinations were used to treat a chloride-dominant saline soil. The engineering properties and microscopic structures of the treated and untreated soils were systematically examined. In addition, soils of different saline contents were artificially created to study the interactions between treatment effectiveness and saline content.

In conclusion cement stabilization developed strength quickly, whereas lime stabilization developed strength relativelyslowly butis equally effectivein the long term. A combined use of cement and lime yielded better results in strength and durability against moisture. All the soil properties deteriorated as saline content rose, and threshold application ratesappeartoexistforthetreatmentstobeeffectiveatdifferentsalinelevels.

CONCLUSION - Chemical additives like cement, lime, fly ash, rich chloride salts, polymers and waste materials like calcined paper sludge, oil shale solid wastes are used that improve soil properties to a great extent.Combining two or more additives can improve their effectiveness. Even though all techniques mentioned above have their own merits, they are the traditional methods whereas a new approach may be to use the glass fibre mixed in cement soil. Which can improve the strength and deformation characteristic of cement soil in a certain degree,it could also be used as a possible replacement of soft soil subgrade.

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