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A REVIEW ON STRENGTH EVALUATION OF CLAY SOIL USING FLY ASH AND LIME

Mirhamza Noorzai[1], AmanpreetTangri[2]

[1]*ME Research Scholar, Civil Engineering Department, Chandigarh University,*
[2]*Assistant Professor, Civil Engineering Department, Chandigarh University, Punjab, India,*

Abstract— Soil stabilization is a process of improving inadequate geotechnical properties of soft soil and to improve the performance of soil as construction material and to reduce the cost of earthwork in case of inaccessibility of good earth at the adjacent source. Several mechanical and chemical methods have been applied to take rise the bearing capacity of soft soil. In this review paper, the most recent published research studies have reviewed, the majority of the studies chemical stabilization methods. Cement and lime generally use as soil stabilizers. It observed from recent studies, usage of waste material such as fly ash, GGBS, silica fume, rice husk ash, Waste tire cord and Waste Stone Powder as these are responsible for hazardous effects on the environment.

Keywords— Soil stabilization, geotechnical properties, bearing capacity, chemical stabilization methods, waste material.

I. INTRODUCTION

Expansive soils are clays having the trend to soften and swell when their moisture content is increased, or shrink and cracked when their moisture content decreased. Clay soils are generally stiff in the dry areas but drop their stiffness when received water. Soft clays had high compressibility but low bearing capacity, causes strength reduction, excessive settlement, and bearing capacity failure Ghobadi M. H. et al 2013[1].
Numerous soils have recognized to be problematic in geotechnical engineering for the way they expand, disperse, collapse, undergo extreme settlement, and have a distinct lack of strength, high water content, and low workability.
Expansive soils change its volume with change in water content, which causes severe damage to structures, for controlling such changes in soil volume is to stabilize the soil with admixtures such as lime, fly ash, GGBS, and etc Zha F et al 2008[2]
The improvement of engineering properties of soil with the addition of chemicals such as lime, fly ash or a blend of these often changes the chemical and physical properties of the treated soil. Generally, there are two main techniques by which chemicals develop the performance of the soil alters:

1. Particle size increment causes shear strength increment, plasticity properties alteration, and deformation potential reduction of soil, due to cementation.
2. Absorption and chemical binding of moisture that will facilitate compaction.

From many years, researches had focused on stabilization of soil using various additives such as cement, lime, industrial waste products, fly ash, calcium chloride, potassium nitrate, phosphoric acid, and etc. (Miller and Azad 2000 [3]; Rao et al. 2001 [4]; Aiban et al. 2006 [5]; Segetin et al. 2007 [6]; Harichane et al. 2011 [7]; Sunitsakul et al. 2012 [8]; Negi et al. 2013[9]; Bahathan et al. 2017 [10]; Ganta 2017 [11]; Asgari 2013 [12])
Apart from the issue of stabilization of expansive soil for which using industrial waste is a proper choice. Finding a suitable way to reuse the wastes is a high need for sustainable development. Recent research studies demonstrated acceptable results by mixing industrial wastes with soil stabilization Kamon and Nontananandh 1991 [13].

Fly ash stabilization:
As per Unified Soil Classification System fly ash has considered as nonplastic fine silt, and it is a heterogeneous pozzolanic material where similar size fly ash have different mineralogy and chemistry. The engineering behavior of fly ash upgraded by adding of lime or cement. The composition of fly ash varies significantly relying on the properties of the coal burning in the power plant operating system traits. Under ionized conditions fly ash can provide a sufficient group of multivalent cations (Al3+, Ca2+, Fe3+, etc.) therefore they can support flocculation of discrete clay particles. Thus, by exchanging cations using fly ash expansive soils can be stabilized.

Lime stabilization:
From the last few decades, lime has been using as a stabilizer because it helps to reduce volume change characteristics of the soil. Generally, the required quantity of lime for stabilization of clay soil is 2 to 8%by weight, with adding lime to clay abundance of magnesium ions (Mg2+) and calcium ions (Ca2+)can provide. These ions can exchange other cations such as potassium (K+) and sodium (Na+) in a process known as cation exchange. With replacing potassium and sodium ions with calcium ions plasticity index of the clay reduces significantly. A decrease in plasticity usually conveyed by the swelling reduction potential.

II. LITERATURE REVIEW

Several experimental studies have been carried out by researches to evaluate the effects of additive such as cement, lime, industrial waste products, fly ash, Silica Fume, potassium nitrate, phosphoric acid, GGBS, and etc., on the CBR (California Bearing Ratio), UCS (Unconfined Compressive Strength), compaction properties, index properties, and swelling properties, splitting tensile strength, stiffness, shear strength and consolidation properties of expansive soil.

Bhrathan R et al (2017) in this paper, Silica Fume and Cement were used to stabilize soft soil. Various experimental tests have conducted like Specific gravity test, plastic limit, liquid limit, Proctor compaction test and unconfined compressive strength test to evaluate geotechnical properties of soil. Experimental work of this paper contains four trails with various values of silica fume (5%, 10%, 15%, and 20) and cement (10%). As a result, taken from the experimental work, Settlement in clay soil can be decreasing by adding a silica fume, improve the strength, increase density, decrease permeability and improve shear strength [14].

Mahvash S et al (2017) In this paper, the effect of fly ash (FA) on compaction properties of fine sand through a set of experimental investigations have evaluated. The main scope of this paper is to define the optimum amount of (FA) content to stabilize the soil. To achieve the goal standard Proctor test has been carried out on the soil. Three proportions of fly ash (5, 10 and 15%) and constant 3% of cement as activator have used to stabilize the soil. The reports of the paper show MDD reduction, OMC increment due to increasing of fly ash, only (3% in weight of the sample), the OPC used still have a huge influence on the dry density of the soil [15].

Tangri A and Jha J (2016) In this paper, blast furnace slag and lime used to stabilize soil collected from Lohatbaddi (Distt- Ludhiana, Punjab), classified as (CI) as per Indian standard classification system. Investigating the effects of blast furnace slag and lime on the soil is the main aim of this study. Several experimental laboratory tests including (unconfined compressive strength tests, standard Proctor test, and durability tests) have been carried out on soil with (7, 14, 28, 56) days curing by researchers, in which various percentages of blast furnace slag (10%, 20%, 30%, 40% ,and 50%) and lime (2%, 4%, 6% ,and 8%) used. 4% lime, 30% blast furnace slag and soil mixture indicate optimum results with 8.69 times increment in U.C.S. value compared with virgin soil[16].

Dash S.K & Hussain M (2015) in this paper, the effect of lime on the shrinkage of soil has studied.Lime improves the strength and decreases the swelling in clayey soil. Various percentages of lime used was 1%, 3%, 5%, 9%, 13%. The curing period in this paper has taken as 3,7,21 and 28 days. It has found that lime rises the shrinkage limit of soils. Further, it has found that the volumetric shrinkage continues to decrease up to 5% and after that, there was a marginal reduction so 5% lime has taken as the optimum amount. The curve between void ratio and water content of lime treated soil during shrinkage was found to be linear [17].

Noorzad R and MotevalianIn S (2015) Reports show that the addition of lime and the mixture of lime and sludge can bring remarkable changes in the engineering properties of soil. Such as adding stabilizer caused the reduction in plasticity index, enhanced optimum moisture content, and reduced MDD of the soil. It has been stated the stabilized soil strength increases with increasing the time of curing [18].

Gaafer et al (2015) this paper illustrates various techniques to stabilize saturated clayey soils in situ, and its functions, methods to install, the soil types and cost of those techniques. Many techniques have assessed in the paper: 1- improvement of soil without admixture (soil replacement, pre-compression or preloading, vertical drain) 2- Soil improvement with admixtures or inclusions (stone column) 3- Soil improvement using stabilization with additives and grouting methods (Chemical Stabilization -Cement stabilization, Lime stabilization, Fly-Ash stabilization, deep mixed column, Jet Grouting) 4- Improvement of soil using thermal methods (Soil Heating, Soil Freezing). Another thing, which has considered while selecting one of these techniques, is the cost of the technique [19].

Kavak A and Bilgen G (2014) In this paper the motive is to make the effective use of slag and lime in the stabilization of road material. In this study the percentage of slag used was 3.33%, 5% and of lime was also 3.33%, 5%. Unconfined compressive strength and CBR test were conducted in this study. Maximum U.C.S was obtained at 5% lime and 3.33% slag. Soaked C.B.R value increases by 46 times than that of a virgin sample [20].

Athanasopoulou A (2014) In this paper, a set of laboratory tests have been performed to evaluate the improvement in engineering properties when the soil has stabilized with fly ash and lime related to high way design and construction. California bearing ratio (CBR) tests are included in the experimental program to evaluate the bearing capacity of stabilized soils. The amount of fly ash used in this investigation were (4%, 8%, 12%, 16%) the amounts of lime added to soil was (4%, 8%, 12%). the results of this paper showed that the addition of fly ash and lime reduced the plasticity index of soil in a large amount, decrease gradually, the maximum dry density with the addition of fly ash and lime, considerable improvement in the CBR value with the addition of lime [21]

Ghobadi M. H. et al (2013) this paper reports the outcomes of geotechnical and mineralogical investigations carried out on clay soil treated with lime placed in Hamedan City, Iran, and influences of pH variants on shear strength characteristics.Lime added in (1, 3, 5 and 7 %) by weight, laboratory experiments conducted after curing times (7, 15, 30 and 45 days). The outcome of laboratory experiments showed addition 7% of lime as the best result for stabilization. And also the paper reports the relationships between geotechnical properties of lime-treated soil and variations of lime and curing time and demonstrates high regression coefficients for the proposed relationships. And also many laboratory tests performed on lime-treated and untreated clay soil with the addition of pore fluid unlike PH values (3, 5, 7 and 9). Low PH (PH=3) pore fluid mixed, with lime-treated clay soil shows better, shear strength parameters, test results. The result shows friction angle values and maximum cohesion achieved at (PH=9) [22].

Asgari M.R. (2013) In this paper, the problems of large deformation and low strength of soil have solved with the addition of lime or cement. The researcher conducted several experimental works to evaluate the geotechnical properties of soil treated with lime or cement. Several values of cement or lime (3, 5, 7, and 9 % weight of soil) have used, Steadied soils have tested in (7, 14, 21, 28, and 60-day periods). Standard Proctor test outcomes show that the effects of lime are more than the effect of cement on maximum dry unit weight and optimum moisture content and of soil. Unconfined compressive strength increases with an increase in cement content. Curing time have a significant effect on Unconfined Compressive Strength results [23].

Sivapullaiah P.V and Sharma A.K (2012) In this paper, lime and blast furnace slag was used as a binder to stabilize the expansive soil. Lime utilized in this study to increase the (PH) value of soil to cause to active pozzolanic reactions it has found that blast furnace slag with or without the use of fly ash has a significant effect on the soil when used in combination with the lime . Various experimental tests programs have followed in the study such as compaction test and unconfined compressive strength test to investigate the geotechnical properties of soil. The curing period for unconfined compressive strength test was 7, 14 and 28 days. The percentages of slag used in the study were Slag-20%, 40%, 60%, and the lime were 2%, 3%, 4%. From the experimental results, it has concluded that both O.M.C and M.D.D decrease with the addition of slag. Unconfined Compressive Strength increases with an increase in the quantity of slag, but a slight discontinuity has discovered between 20%- 30% [24].

Mishra N.K (2012) In this paper, strength properties of soil have improved so that it could be used in subgrade by the help of fly ash and lime. In this paper the amount of fly ash used was 10%, 20%, 30%, 40% and 50% and percentage of lime used was 1%, 2%, 3%, 4%, and 5%. In this study, it has found that 3% lime and 30% fly ash mixture with virgin soil shows improvement in the C.B.R values. Further from the values of CBR elastic modulus of subgrade and subbase was evaluated. With the addition of lime and fly ash the optimum moisture content of mixture increases whereas maximum dry density decreases. In this study, it has found when the percentage of lime has increased by just 1% the CBR value increase by 16.25% [25].

Zha F et all (2008) In this paper fly ash, which is an industrial waste and a large environmental hazardous and being produce by million tons every year in China, has been used as a soil stabilizer. Paper discusses the influence of fly ash on geotechnical properties of expansive soil. Fly ash content has increased by steps of (0%, 3%, 6%, 9%, 12%, and 15%) of oven dried weight of soil, and lime has added by (0%, 1%, 2%, 3%) of oven dried of soil. The reports of the experimental work show some remarkable results, shrinkage and swell potential of the soils reduce with increase in fly ash content. Fly ash and lime-fly ash treated-soil swelling pressure and swell potential properties decrease with increases in curing time.Unconfined compressive strength remained almost unchanged without curing. (9–12%) of fly ash content is optimum to treat the soil in 7 days curing time [26].

Jha J.N and Singh K (2002) In this paper, the stabilization effect of blast furnace slag and lime in different proportions have studied on clayey soil. The strength of various mixes has evaluated in terms of California Bearing Ratio (Under both soaked and Unsoaked conditions) and Unconfined Compressive strength test, Proctor test was conducted on all the proportions. Lime was added in this study to trigger the hydraulic activity of slag. This paper reports the geotechnical characterization of blast furnace slag and soft soil. The percentage of slag used in this study was 20%, 30%, 40%, 50%. The percentage of lime used was 1.5%, 3%, 4.5%, 6%. They concluded that slag when used with local soil, can be used in the sub-base layer. As the percentage of lime increased, optimum moisture content also increases and maximum dry density decreases, further unconfined compressive strength also increases with an increment in the percentage of lime [27].

III. CONCLUSIONS

To improve the poor geotechnical properties of soft soil, besides several mechanical methods, chemical stabilization methods have applied with the addition of additives to soft soil. Majority of researchers utilized industrial wastes such as GGBS, fly ash, silica fume as stabilizers because of their tremendous environmental hazards and positive effects on soft soil treatment. .in numerous research studies, researchers used cement or lime as binders simultaneously for more effectiveness. Improvement of CBR (California Bearing Capacity), UCS (Unconfined Compressive Strength),

compaction properties, index properties, and swelling properties soft soil made more focus area of most of the researches but just a few of them focus on, splitting tensile strength, shear strength, consolidation properties, stiffness and hydraulic conductivity of expansive soil. Studies on, effects of impurities on geotechnical properties of stabilized soil, mineralogical studies, economic and durability phase of stabilization are limited in the literature. Very few studies have conducted regarding, stabilization of expansive soil using red mud, copper slag, foundry sand, lime sludge, phosphogypsum, kimberlite, jerosite, silica fume, waste glass, waste plastic, and carpet wastes.

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