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A Case Study on Soil Stabilization Techniques

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ABSTRACT: The soil often is weak and has no enough stability in heavy loading. The aim of the study was to review on stabilization of soil using low-cost methods. Several reinforcement methods are available for stabilizing expansive soils. These methods include stabilization with chemical additives, rewetting, soil replacement, compaction control, moisture control, surcharge loading, and thermal methods. All these methods may have the disadvantages of being ineffective and expensive. Based on literature, Portland cement, lime, fly ash and scrap tire are low-cost and effective to soil stabilization.

KEYWORDS: Lime, Fly ash, Scarp Tire, Soil Stabilization

I. INTRODUCTION

Soil is an aggregated deposits or mixture of minerals, organic matter and fragments covering large portion earth crusts. Hence there are different types of soil is present and also vary throughout the world and hence the properties of soil is also vary equally. Nearly 20% of land in India contains expansive soil. We know that the soil loose their property of shear strength in wetting condition. Hence to construct any civil engineering structure soil must have sufficient strength. Therefore when it is necessary to improve the engineering properties of soil and suitability of soil methods of soil stabilization is used. Soil stabilization is the process of changing one or more properties of soil using soil stabilizer to improve the performance of soil. Hence stabilization is being used for variety of engineering works. The most common application being in the construction of roads and air fields pavements, where the main purpose is to increase the strength or suitability of soil for these the soil stabilization are used. We all know that the landslide occur due to the excessive rainfall, earthquake, snow melting and human activities etc. due to this the properties of soil is disturbed. In many countries landslide occurs in such cases soil stabilization is used to avoid the landslide. Mechanical stabilization and chemical stabilization are the two important methods used for the stabilization of soil. In chemical stabilization Chemical admixture is used to enhance soil stability and to obtain this stability certain chemical compound is added in expansive soil. Sometimes, Mechanical stabilization is not economical or not possible and even it is not suitable to replace undesirable soil with desirable soil. Generally fly ash, cement and lime are the main chemicals are used for soil stabilization. These are combined with the help of machines or the method that depend on the location. This method changes the soil property such as strength of soil, compressibility, Hydraulic conductivity and change in the volume of the soil. Mechanical stabilization is the process in which mechanical energy is used with the help of rollers, plate compactors, tampers etc. to improve the soil properties by compaction. It is mostly used for construction of Embankment of roads, railways etc. mechanical stabilization is the simplest method of stabilization. Mechanical stability depends upon the degree of compaction normally compaction is done at optimum moisture content. it is used to improve the sub-grades of low bearing capacity and also for construction of bases, sub-bases, and surfaces of roads. Generally the cement and lime stabilization are the common methods of stabilization of clay in pavement construction work

II. MATERIAL USED FOR SOIL STABILIZATION

2.1 Sodium hydroxide additive:

Sodium hydroxide is highly reactive and it is white, odorless and non-volatile solution. It can generate enough heat to ignite combustible materials nearby and also reacts violently with water and various encountered materials. The main advantage of sodium hydroxide is it can be a great compaction aids by giving higher density for the same compactive effort when react with water (Olaniyan *et al.*, 2011).

2.2 Fly Ash Geopolymeric Binder:

Geopolymerisation or alkaline activation of aluminates materials is alternative to cement (Hardjito and Rangan, 2005), due to the reduction of CO₂ emissions from the activation of ashes and/or slags with the absence of high



temperature in calcinations step compared to cement production (Cristelo *et al.*, 2013). The reduction is as high as 80% based on the activating solution; dissolved solids of Na₂O and SiO₂ content (Duxson *et al.*, 2007). In strength development of alkaline activated systems, sodium hydroxide concentration plays a very important role (Cristelo *et al.*, 2012). Sodium hydroxide concentration significantly influenced the strength development (Cristelo *et al.*, 2012; Cristelo *et al.*, 2013). In geotechnical applications, alkaline activation (geopolymeric binder) of fly ash was tested for soil improvement since waste material was obtained as binder in most of other geopolymer applications (Cristelo *et al.*, 2012). Alkaline-activated materials showed better performance since durability and stability can be increased, improvement from mechanical aspect compared to cement and also improved bond between the soil particles and binder (Torgal *et al.*, 2012; Villa *et al.*, 2010). Alkaline activation generally was a reaction concerning alumina-silicate materials and alkali or earth substances' alkali. At a molecular level to natural rocks, materials formed from reactions between silica, alumina and alkali cations were very alike in term of stiffness, durability and strength (Cristelo *et al.*, 2012).

2.3 Ashes:

Fly ash and bottom ash are part of combustion of non-combustible residue or combustion of sub-bituminous coal which had been generated in such a huge quantity in electric plants and they are by-product of burning coal (Fauzi *et al.*, 2010; Prabakar *et al.*, 2004; Ferguson, 1993; Misra, 1988) that can be used without activators for soil stabilization (Ferguson, 1993; Misra, 1988). Fly ash is actually the portion of ash which escapes from the chimney or stack, while on the wall of the furnace is clinkers which formed from bottom ash and will fall to the bottom in a long run (Fauzi *et al.*, 2010). Fly ash can be classified to two classes based on the present of calcium content. Class C fly ash usually has calcium percentage above 20% and it was resulted from sub-bituminous coal while class F fly ash, resulted from combustion of bituminous coal usually has calcium percentage which is not higher than 10% (Cristelo *et al.*, 2013). Application of other ashes, such as sewage sludge ash to the soft soil was also investigated and it has been combined with other material, cement (Chen and Lin, 2009). This further investigation was due to the several researches which proved that the properties of soil and strength of the soft cohesive subgrade soil can be improved with the application of sewage sludge ash and hydrated lime (Lin *et al.*, 2007) and workability and compressive strength of concrete also can be improved by replacing cement with incinerated sewage sludge ash in the making of concrete (Tay and Goh, 1991).

2.4 Cementitious Binders:

Mix underperforming soil or soft soils with Cementitious binder is one of the major techniques to overcome the created problems and cement and/or lime based are the common binders used. Through chemical reaction, binders such as cement and lime can bond the soil particles together (Cristelo *et al.*, 2012; Cristelo *et al.*, 2013) but not through physical reactions (Cristelo *et al.*, 2013). For civil engineering purposes, lime or cement had been used for improving the handling of soils as well as the mechanical properties (Sherwood, 1993). Cement application in soil however becomes an issue related to environment and durability (Cristelo *et al.*, 2013) since it releases high levels of CO₂ during production (Garcia *et al.*, 2009) and chemical vulnerability due to sulphates attack in ground or chemical wastes when use in soil improvement or structural foundations (Tomlinson, 2001). The major reaction between lime and soil was to bind together the soil particles through a tough and water insoluble gel (Diamond and Kinter, 1965). For short-term pozzolanic process, the exchanged of ion between calcium ions from lime and cations that closed to the clay particle surface, can transform soil to a strong flocculated structure from weak dispersed structure. Meanwhile for long-term, pH of water increased due to the increased of hydroxyl ions from lime, which then leads to the dissolved of silicate and aluminum sheets of clay. The clay particles were then binded together silica and alumina, and combined with calcium to form calcium silicate hydrates or calcium aluminate hydrates (Rafalko *et al.*, 2008). During the hydration of Portland cements the similar reaction occurred (Way and Shayan, 1989) since pozzolanic component was already integrated in the cement and the reaction only needed water to increase strength (Janz and Johansson, 2002). Gypsum in a form of finely divided powder was reported can be a stabilizing material, not only because of its relatively cost, but it reasonable solubility in water, (Bell and Maud, 1994) but there was not much research conducted by using it as a stabilizer for soft soils (Yilmaz and Civelekoglu, 2009). The performance of gypsum as an additive for soil treatment was studied in term of strength (Yilmaz and Civelekoglu, 2009) due to the positive result obtained from other investigation. Mixture of phosphate soil and gypsum was reported had an incensement at curing period of 360 days (FIPR, 1988). Cement kiln dust is also an effective stabilizer for certain types of soil since it has Cementitious properties (Miller and Azad, 2000). Portland cement is manufactured by mixing the correct portions of lime, silica, alumina and iron. The mixture was then passed through the upper end of a kiln at a controlled rate of the kiln slope and speed. Burning fuel with temperature of 1400-1650°C at the lower end of a kiln changed the mixture to cement clinker. So, this was the operation where cement kiln dust which also material in the form of dust was collected. The raw materials used and



how the cement kiln dust was collected from plant to plant might caused varying physical and chemical properties. The cement kiln dust typically has consistent composition if it was collected from the same kiln which produced the same cement type (Baghdadi *et al.*, 1995). Ladle furnace slag is useful in application of improving the soil and usually known as basic slag, reducing slag, white slag and secondary refining slag (Manso *et al.*, 2013). Since ladle furnace slag has majority presence of calcium and magnesium oxides, silicates and aluminates (Manso *et al.*, 2013), it can be considered as a dusty material which has limited hydraulic reactivity (Papayianni and Anastasiou, 2006). Ladle furnace slag has common chemical features (Shi, 2002) in terms of the presence of dicalcium silicate, calcium aluminates, free lime and free magnesium oxide (Manso *et al.*, 2013), and it was useful in improving soils by considering the application of these substances (Manso *et al.*, 2005). Its volumetric instability has been concerned (Wang *et al.*, 2010) due to the weathering and exposure to air and water, but the use of it in low proportion (less than 10%) in soil mixtures was irrelevant for this expansiveness (Manso *et al.*, 2013).

2.5 Soil Stabilization Process by Using Different Material: Sodium Hydroxide Additive:

Sodium hydroxide pellets are added to water to obtain sodium hydroxide solution and varied percentages ranging from 7% to 16% were used to the soil sample while keeping other constituents; 100% filler (sand), 18% water and 100% clay to see the effect of varying sodium hydroxide content. To see the effect of varying filler percentages ranging from 50% to 200%, 13% sodium hydroxide, 18% water and 100% clay soil were kept constant. After obtaining NaOH solution by adding NaOH pellets to water, the solution was added to the clay-sand mixture. Those specimens then put in an oven at 80°C for 24 hours. After that, they were all subjected to three conditions; some were put in an oven at 40°C for 2 weeks, some were put in demineralised water for 2 weeks and some were subjected to cycles of wetting and drying (Olaniyan *et al.*, 2011).

2.6 Fly Ash Geopolymeric Binder:

A combination of sodium silicate and sodium hydroxide were used as the alkaline activator solution. The flake form sodium hydroxide was dissolved in water to obtain different concentration before being mixed with sodium silicate which in solution forms. A ratio of sodium silicate to sodium hydroxide used was 2:1 by mass (Cristelo *et al.*, 2012; Cristelo *et al.*, 2013). The value of 2 was concluded by Villa *et al.* (2010) can enhance the strength, where higher ratios resulted in higher level of strength. In research done by Cristelo *et al.* (2012) the soil was oven dried and sieved down before being mixed with low calcium content (class F) fly ash and lastly the alkaline activator was added and mixed. The sample was stored in an oven at 60°C for 12 hours before being removed from the moulds, and put into the sealed bag and stored again in the oven for 2 hours without changing the temperature. Winnefeld *et al.* (2010) reported that curing temperature at 60°C was chosen because curing at temperature higher than 80°C might damage the properties. Curing periods were considered by Cristelo *et al.* (2012) at 1, 3 and 7 days. To see the effect of NaOH concentration; 7.5, 10, 12.5 and 15 molal were used. Same concentrations of sodium-based activator; 10, 12.5 and 15 molal were investigated by Cristelo *et al.* (2013) with different fly ash percentages; 20%, 30% and 40%. The samples were tested at different curing periods of 7, 28, 90 365 days. Before the activator was added, soil and fly ash were mixed homogeneously. After 3 min of mixing, the mixture was cast on the moulds by tapping the moulds then they were left in a sealed container. The samples were removed after 48 hours later and were wrapped in cling film. The samples then were exposed at ambient temperature of 19-23°C and relative humidity of 40-50% before tested for unconfined compressive strength.

2.7 Scrap Tire:

Tire wastes can be used as lightweight material either in the form of whole tires, shredded or chips, or in mix with soil. Many studies regarding the use of scrap tires in geotechnical applications have been done especially as embankment materials (Ghani *et al.*, 2002). Tires have been reused in many different applications mainly related to production of new rubber based materials. Another major form of tire recycling is burning tires for fuel at tire derived fuel (TDF) facilities. There have also been reports that describe construction related applications for waste tires such as crumb rubber modifiers for highway pavement and shredded tires as fill material. The reuse application for tires is dependent on how the tires are processed. Processing basically includes shredding, removing of metal reinforcing, and further shredding until the desired material is achieved (Carreon, 2006).



FIGURE 1 Scrap Tire

III. CONSTRUCTION STEPS

- **Initial preparation**
Frist soil brought to the line and grade and then correct unstable subgrade areas. Scarification and pulverization of soil can be done if it is necessary. And then reshape to crown and grade.
- **Mixing** There are two methods first is mixed-in-place method in this method Portland cement is spread and then mix with soil and water. And second method is central mixing plant in this method soil, cement and water is mixed in proportion and hauls this mixture to placing areas. And also spread this mixture uniformly over the entire area.
- **Compaction**
After completion of mixing immediately start a compaction with the help of pneumatic-tired and sheep foot rollers. And then using steel wheeled roller surface finishing is done.
- **Curing**
Sufficient moisture contain require for adequate cement hydration. Here bituminous materials and also other materials such as waterproof paper or plastic sheets, wet straw or sand, fog type water spray, and wet burlap are used for curing.

IV. CONCLUSION

From this review paper it can be concluded that the several methods are implemented for modification of various properties of soil. And different types of materials are used as soil stabilizers and an above discussion is helpful to decide the effective materials for soil stabilization. Also we can decide the percentage of materials added to the soil. However this review paper is also helpful to focus the different properties material depends upon the experimental results.

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