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Study of Soil Stabilization Using Lime & Fly Ash

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Abstract: This review paper focuses on the study of soil stabilization using lime and fly ash to improve the engineering properties of weak soils. Lime reacts with clay minerals to reduce plasticity and enhance strength, while fly ash provides additional pozzolanic reactions that improve durability. The combined use of lime and fly ash significantly increases bearing capacity, compaction characteristics, and California Bearing Ratio (CBR) values. Based on past research, this method is found to be cost-effective, environmentally friendly, and suitable for subgrade and foundation construction. The study highlights its potential for sustainable geotechnical engineering applications.

Keywords: Fly ash, Lime, Stabilization

I. INTRODUCTION

Soil stabilization is a vital technique in civil engineering used to enhance the strength and durability of weak or problematic soils. Many construction sites face challenges due to the presence of expansive or soft soils that exhibit poor bearing capacity, high plasticity, and low shear strength. Without proper treatment, such soils can lead to settlement, cracking, and structural failure. Hence, improving their engineering properties becomes essential for safe and economical construction.

Among various stabilization methods, chemical stabilization using lime and fly ash has proven to be highly effective and sustainable. Lime reacts with clay minerals through cation exchange and pozzolanic reactions, reducing plasticity and improving workability and strength. Fly ash, an industrial by-product from thermal power plants, contains reactive silica and alumina that further react with lime to form cementitious compounds, enhancing soil performance.

The combination of lime and fly ash not only improves strength and stability but also offers environmental benefits by recycling industrial waste materials and reducing the use of conventional cement. Several studies have shown that these additives significantly increase soil strength parameters such as Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR), while improving durability and reducing swell potential.

This review paper focuses on analyzing past research related to soil stabilization using lime and fly ash. It aims to summarize their combined effects on soil properties and highlight the potential of this technique as a cost-effective and eco-friendly solution for modern construction projects.

II. STABILIZATION

Soil stabilization is an important technique to enhance the engineering properties of weak soils for construction works. Chemical stabilization, achieved by adding suitable binders such as lime and fly ash, significantly improves soil strength, durability, and workability [1], [2]. Lime reacts with clay minerals through cation exchange and pozzolanic reactions, thereby reducing plasticity and swelling characteristics [3]. Fly ash, a by-product of thermal power plants, provides silica and alumina that form cementitious compounds in the presence of lime and moisture [4], [5].



The combined use of lime and fly ash results in both short-term and long-term improvements in soil behavior. Short-term effects include enhanced compaction and reduced shrinkage, while long-term effects arise from continuous pozzolanic activity, increasing strength and stability [6], [7]. Furthermore, the utilization of fly ash promotes environmental sustainability and cost efficiency, making lime-fly ash stabilization suitable for roads, embankments, and foundations [8], [9]

III. MAIN PREVIOUS STUDY IN THE LITERATURE REVIEW

A. Lime

One of the most frequently used chemical stabilization method is lime stabilization, which was found a well-established technique for developing plastic properties and strength of cohesive soil. Investigation on lime indicated that, improve the soil resistance was one of the most noticeable benefits of lime stabilization. Due to the cations exchange, flocculation agglomeration, lime carbonation and pozzolanic reaction soil particles stick to each other and make larger particles [7], [9].

Some surveys have been reported that, lime had no efficient effect on compaction parameters; however, in comparison to other binder lime create a quick and extensive chemical reaction with soil particles. Changing the characteristics of soil as result of chemical interaction lead to progress in the soil properties, such as compaction and strength characteristics of soil [1], [7], [9]. In comparison with un-stabilized soil, lime treatment not only form a remarkable increase in optimum moisture content, but also the results indicated the decrease in maximum dry density after lime stabilization [1], [7], [8], [12], [13].

In investigation on the stabilized specimens with lime were detected a shear failure mode such as failure in brittle materials [8], [11], nevertheless, more studies [7]- [9], [17], [20] established about the effective role of lime for progressing in the strength characteristic of soils. Based on several reports, the reaction between soil and lime particles called pozzolanic reactions, which causes to increase the soil strength [9].

Scholars revealed that, reduction in plasticity index was caused by increase the amount of lime in the chemical stabilization. In some cases, the obtained results reported the multiplied reduction in plasticity index of pure soil after lime treatments. In addition, plasticity index of soil has directly associated with swelling pressure and swell potential of soil.

Therefore, swell pressure reduction was the direct result of decrease in the plasticity index of stabilized soil [1], [7]-[9].

B. Fly ash

In recent years, the potential for applying natural resource and industrial mineral in soil stabilization has been explored. In this field, fly ash has been used as an additive in chemical stabilization. Fly ash is divided into class C and class F fly ash based on the type of coal burned [2], [10], [18]. Regarding to low unit weight and compressibility [21], pozzolanic reactivity characteristic [17], [21], cost-effective, and energy saving benefit [19] fly ash has found one of most plentiful and flexible waste materials that extensively applied for progressed properties of soft soil in geotechnical engineering constructions [5], [7], [21].

Some studies [2], [15] have argued about the effect of fly ash on soil plasticity index. It can be observed that, fly ash treatment could lead to decrease the plasticity index as a result of increase in liquid values. Subsequently, reduce the soil plasticity related with lessen the degree of damaging sulphate-heave and potential for swelling. On the other hand, the results of the other studies revealed that, applying only fly ash might be insufficient for developing the properties of highly plastic soil [12] - [13], [15].

Several researches regarding investigation on compaction characteristic of soil [2], [13], [18], [19] have established that, adding fly ash to soils changed the range of porosity and void ratio of soils. Through the soil stabilization, soil particles can attract more amount of water. This interaction directly leads to an increase in optimum moisture content and a decrease in maximum dry density

Furthermore, many studies [7], [10], [15] [16] reported about the effectively of fly ash in the strength of soil. The obtained results indicated that incorporation of fly ash with soil particles resulted in significantly improvement in strength property of soil. Therefore, the bearing capacity of fly ash treated soil might be effectively developed due improvement the shear strength, and cohesion of soil.

The experiment results reported that, the small amount of coefficient of secondary compression in fly ash treated specimens. This advantage can reduce the possibility of settlement due to secondary consolidation of structures [20].

On the other hand, some scholars studies about the effect of combination of lime and fly ash on soil. The investigations revealed that, might be the effectively of stabilization increased by the utilization of mixture of lime and fly ash. In this field, the workability and strength behaviour of soft soils, and freezing-thawing (durability) were notably improved [7], [13], [21] in comparison with fly ash stabilization or lime treatment alone.

IV. SUMMARY

In order to modify the inadequate properties of soft soil were implemented several methods. Chemical stabilization as a common technique was applied by addition of some additives such as lime, fly ash to the soil.

The numerous studies were established about the effect of lime and fly ash on soil properties; however, the obtained results were extremely different about the efficiency and affectivity of stabilization with lime and fly ash.

Investigation on the compressibility of soil revealed that, fly ash could improve the optimum moisture content and decrease the maximum dry density of soils. Although lime treatment method was known as an effective method for compaction properties of soil, in some cases lime had not sufficient effect on soil.

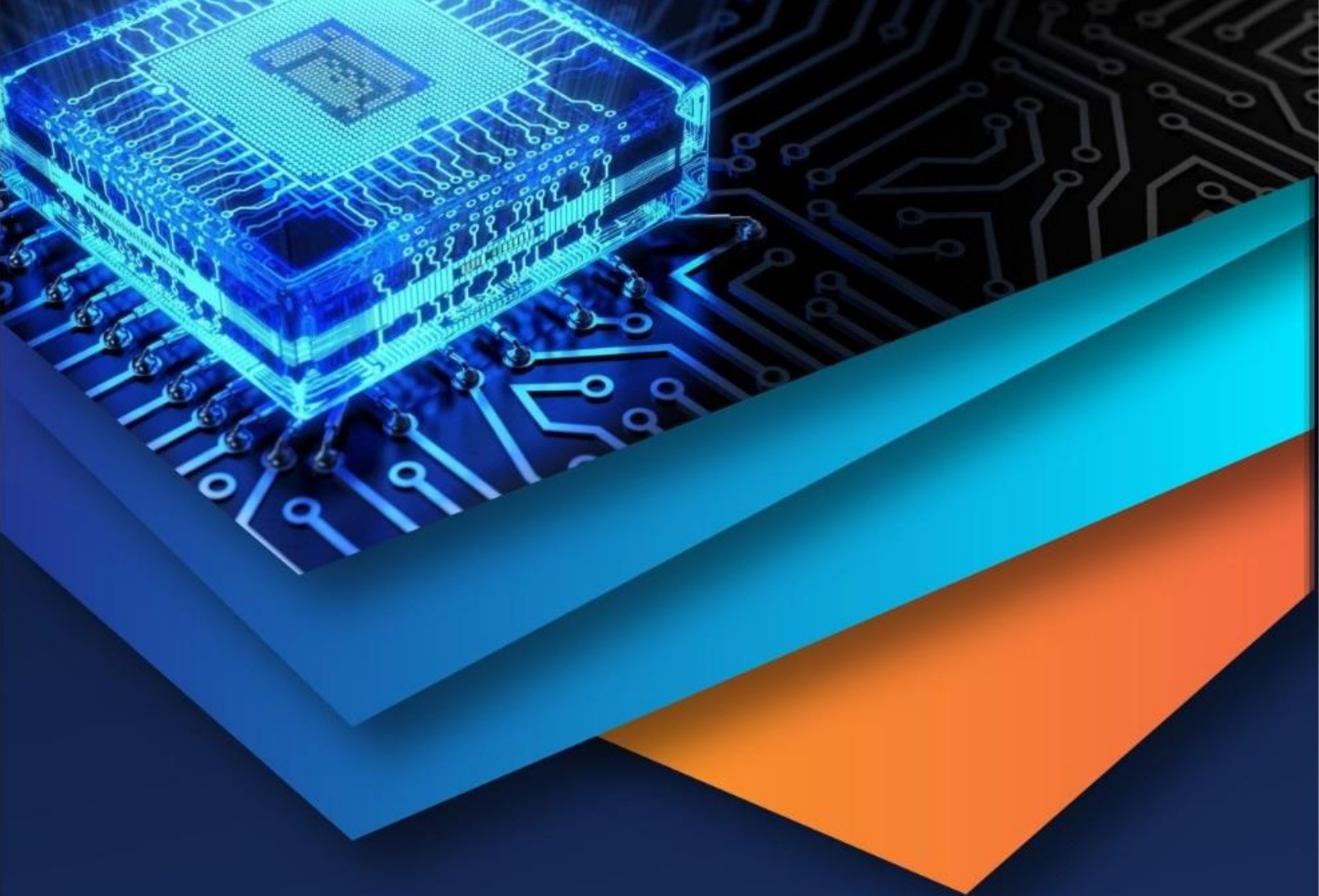
Moreover, about the efficiency of lime and fly ash treatment on strength characteristic of soils, has not been achieved the same result. In general utilization of fly ash led to improve the soil strength. Although, some scholars observed a shear failure mode in lime stabilized soil, lime stabilization was applied as a successful method for increasing the strength of soil.

In spite of insufficiency of fly ash treatment for decreasing the plasticity index of highly plastic soil, in the other cases fly ash stabilization were effective in the reduction of plasticity index of soil as well as applying lime stabilization method for inadequate soil.

On the other hand, it seems still there are some major questions about the appropriate amount of lime and fly ash, and applicable combination of the additive in soil stabilization, which are, needs to be taken more into account. It can be clearly seen from the previous studies, most of researches were carried out on fine-grained soil. Therefore, in order to obtain a more comprehensive result need to be taken more researches on the different kind of soil such as coarse-grained soil.

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