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Stabilisationof Soils with Lime: A Review

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Abstract

As of now, the growing environmental issues, economic concerns, and limited land resources have forced engineers to stabilize problematic soils for the construction of roads, buildings, railways and other structures. Soil Stabilization implies adaptation of thermal, chemical, or mechanical methods for improving soil properties so as to have increased soil strength, lesser compressibility, greater durability besides other improvements. Lime alongside cement and fly-ash is considered a traditional soil stabilizer and has been in use for decades now, a significant amount of research has been done on this topic till date to describe the mechanism and influence of lime addition on the soil. In this paper, different aspects of lime stabilization covering varied opinions of researchers have been described in detail. Here, we discuss how cation exchange, flocculation, and pozzolanic reactions collectively improve soil properties, and the influence of lime quantity, lime quality, curing time and temperature on soil strength, permeability, soil-moisture relation, compressibility, plasticity characteristics and other soil properties. Also, soil stabilization through lime-columns, lime treatment of pavement layers and lime-based embankment stabilization as important applications of lime stabilization have been discussed. Considering the impact of lime treatment, it can be inferred that soil strength, durability and fatigue strength show an increase while as plasticity, compressibility and dry density show a net decrease, however, this increase and decrease does not continue indefinitely rather it slows down, stops and in some cases even reverses and is dependent on a Number of factors which have been discussed amply in the following sections.

1. Introduction

Soil Stabilization is the process of improving the properties of soil through a multitude of operationsthat may involve compaction, mixing with chemicals/additives,or other non-destructive methods to have better strength and durability besides other improvements. Soil stabilizers are generally categorized as traditional and non-traditional stabilizers, traditional ones include cement, lime,and fly ash while non-traditional ones include sulfonated oils, asphalt, and ionic stabilizers [1]. The soil-stabilizer mechanism and the properties after stabilization vary considerably for each one of these and these variations are due to heterogeneity in soil composition, differences in micro and macrostructure, the difference in geologic deposits,and due to differences in chemical and physical interactions of the soil-stabilizer mix [1,2]. Considering the availability of materials, ease of mixing, economic perspective,and an overall improvement in properties, Lime along with cement are the most preferred stabilizers used by geotechnical engineersespecially for treating problematic expansive soils [2].

Stabilization of soil with lime is not a new process rather Chinese and Indians have been using this particular mix throughout history for construction of dams, bridge footings, and underground chambers. Romans used a lime-soil mix for sub-bases in roads. However, they never had a written procedure or any specifications [2]. However, lime stabilization with proper specifications and a definite procedurestarted only after 1945 [3]. Later this technique of stabilization was used on large scale in subgrade improvement, for embankment stability, in bridge abutments, replacement material in sliding slopes, and in building foundations using lime-columns [4].
Lime stabilization refers to the usage of Quick lime (CaO) or Hydrated lime ($Ca(OH)_2$) as a stabilizing agent for the stabilization of soil and is best suited for fine-grained soils having considerable clay content. Quick lime is more often preferred because of its effectiveness and higher strength development. Bell [5] states that clays having higher Silica content react more with lime or in simple terms 3-layered clay minerals like montmorillonite expose silica on both sides, hence are more reactive as compared to 2-layered minerals like illite having single silica surface exposure. Clay rich soils when treated with lime results in a decrease of liquid limit, maximum dry density and plasticity index, and an increase in the optimum moisture content, strength and shrinkage limit [6,7]. Generally, 1 to 3 percent of lime is needed for soil modification i.e., reduction in the plasticity of soil and 2 to 8 percent is the requirement for actual stabilization i.e., cementation [5]. Optimum Lime Content is the percentage of lime required for complete modification and stabilization of soil i.e., lime content which provides for improved workability and reduced plasticity, and also increases strength, durability and stiffness [8]. Clayey soils having moderate to high plasticity i.e., PI > 15 are best suited for lime stabilization [9].

2. Mechanism of Lime stabilization:

The lime stabilization process essentially is a two-stage process according to Eades and Grim [10]. X-ray diffraction and differential thermal analysis (DTA) were used for the identification of reactions taking place between lime and clay [8]. The initial stage of modification takes a few hours or days for completion, and in this stage, Cation Exchange, Flocculation, Carbonation and some short term pozzolanic reactions also occur depending on the mineralogical composition of the soil [1]. In this stage plasticity and workability of soil is primarily changed. The second stage is also known as long term treatment involves pozzolanic reactions responsible for improvements in strength and durability.

2.1. Short-term Treatment:

Upon addition of water and lime to the clayey soil, lime dissociates into Ca^{2+} and OH^-, the calcium ions replace monovalent ions like Na^+, Li^+. etc which are adsorbed to the clay mineral surface, this process is also called a cation exchange (CEC) process [11]. This CEC typically depends on the pH of the soil water and on the clay mineralogy, Montmorillonite rich clays have the highest CEC and Kaolinite ones have the lowest CEC [12]. This attachment of Ca^{2+} ions with the clay minerals results in a net decrease of repulsive forces and also reduces the thickness of the diffused water layer, consequently soil particles come closer and this process is also called as Flocculation [13]. According to Little and Nair [1], this process of flocculation results in large-sized particle aggregates, less plastic, more friable and workable soils. Dal dredged soil when treated with lime exhibited a change in structure from deflocculated form to flocculated form as confirmed by SEM micrographs [14].

2.2. Long term Treatment:

As the dissociation of lime produces OH^-, there is a subsequent increase in the pH [15]. When the pH value exceeds 12.4, the silicate and alumina present in the clay minerals become soluble and free from soil, and then react with calcium ions produced from lime hydration to form cementitious hydrates i.e., Calcium Silicate Hydrate (C-S-H) and Calcium Aluminate Hydrates (C-A-H) [12, 10].Chemical reactions involved in pozzolanic cementation are as follows [11, 16]:

$$Ca(OH)_2 + SiO_2 \longrightarrow CaO\text{-}SiO_2\text{-}H_2O \quad (1)$$

$$Ca(OH)_2 + Al_2O_3 \longrightarrow CaO\text{-}Al_2O_3\text{-}H_2O \quad (2)$$

Brandl [17] stated that the strength improvement rate decreases with time and is predominant in the initial two years, beyond seven years there is no increase in the strength. He also stated that a time-dependent increase in strength is linear with the logarithm of time. Puzzolanic reactions depend on temperature, pH value, calcium percentage and quantity of silica and alumina present in soil minerals [10, 18]. Little and Nair [1] states that pozzolanic reaction is a cooperative mechanism between lime and clay wherein lime induces high pH environment thereby solubilizing silica and alumina, and also provides calcium-free ions which combine with silica and alumina to form cementitious materials.

3. Changes in soil properties due to lime stabilization:

Soil properties of fine-grained soils show a marked variation when treated with lime, changes occur inconsistency limits, permeability, swell and shrinkage potential of soils along with the improvement in strength. However, the changes in physical properties depend on lime quality, lime quality, soil type, time, temperature and moisture [19]. The effect of temperature and time on reactivity, pH and strength is quite significant [20]. Thompson [21] categorizes lime treated soils as reactive and modified, UCS value of reactive soils exceeds 345 kPa upon lime treatment and modified ones show less than 345 kPa UCS value increase but these soils show remarkable changes in plasticity, swell potential, soil texture and overall workability.Following is the quantitative and qualitative analysis of changes that occur in soil properties due to lime treatment:

3.1. Effect of lime treatment on Plasticity:

There occurs a considerable decrease in the plasticity of soil when treated with lime and often soil becomes non-plastic [20]. This reduction occurs due to the increase in the plastic limit and decrease in the liquid limit [4,14,22]. However, Zolkov [23] observed an increase in the liquid limit and Croft [24] attributed this increase to the affinity modification of clay surface with water due to hydroxyl ion presence. Dash and Hussain [22] state that lime treatment causes an initial decrease in liquid limit due to a reduction in diffuse double layer thickness and later an increase in liquid limit occurs owing to fabric changes in soil structure accompanied by the production of water holding gelatinous products due to pozzolanic reactions. They also concluded that the reduction in thickness of diffuse double layer increases charge concentration and hence viscosity of pore fluid, this consequently increases the shear resistance among particles and we see a net increase in the plastic limit. The increase or decrease in liquid limit depends on the soil type [25] . Bell [5] used lime treatment for 3 soils each having Kaolinite, Quartz and Montmorillonite as main minerals and he observed that the largest increase in plastic limit typically occurs in soils with montmorillonite as a principal clay mineral. If the plasticity index and clay content are on the higher side then more is the lime requirement for achieving non-plastic conditions, the percentage of lime required to reach the non-plastic stage is known as lime fixation point [26] .Often 1 to 3 percent of lime is required to modify soil i.e., for plasticity changes, and quick lime appears to be more effective than hydrated lime with respect to improvements in shrinkage characteristics [5]. The texture of soil also undergoes significant change and with soil having more friable texture the workability increases thereby making soil placement easier.

Lime treatment of clayey soils also leads to areduction in swell potential and consequently decrease in moisture absorption [27]. Dash and Hussain [22] reported a significant initial decrease in swell potential upon lime addition owing to higher electrolytic concentration and decreased thickness of the diffuse double layer, and further lime addition caused an increase in swelling due to silica gel formation, this phenomenon is predominant in silica-rich soils. Seed, Woodward and Lundgren [28] developed a relation between the plasticity index and swell potential which states:

$$\text{Swell Potential} = 0.00216 \times \mathbf{PI}^{2.44}$$

Where: PI is Plasticity Index

3.2. Effect of lime treatment on Moisture density relations:

Due to Cation Exchange and flocculation process, the grain size increases leading to an increased void ratio and a subsequent decrease in the maximum dry density accompanied by an increase in optimum moisture content [29]. Due to the flattening of the compaction curve upon a lime treatment, it is possible to achieve prescribed density over a wider range of moisture content [11,14]. Jan and Mir [14] relate these changes with the reduction in thickness of the diffuse double layer due to increased cation concentration.Bell [5] concluded that montmorillonite rich clay shows maximum changes in optimum moisture content and dry density, even there is a possibility of compaction curve distortion. He also stated that a decrease in density depends on the time interval between mixing and compaction. Lime treatment generally increases optimum moisture content by 2 to 4 percent and a reduction in dry density ranges from 48 to 80 Kg/m^3 [30].

3.3. Effect of lime treatment on Strength:

Researchers around the world have used UCS (Unconfined Compressive Strength), CBR (California Bearing Ratio) and Triaxial testing for verifying the influence of lime on soil strength. Generally, lime treated clays show considerable improvements in strength due to the development of pozzolanic products exhibiting a cementitious effect on soil particles. Thompson et. al [30] states that due to pozzolanic reactions the UCS strength showed around 60 percent increase after 28 days curing.The properties having a profound influence on strength gain include clay minerology, soil pH, silica-alumina percentage, type of lime, moisture content, temperature and curing time [11,31]. Soils with large clay fraction require more lime for strength gain as compared to low clay content soils because later ones require lesser lime percentage for plasticity amendment and have more lime available for pozzolanic reactions [22]. Curing is considered a major factor governing strength gain, in the initial 7 days strength gain is rapid andbeyondthat,thestrengthincrease rate is slowing down [32]. After conducting UCS on 6 soils with different minerology, Eades and Grim [8] concluded that soil minerology and lime percentage are main strength gain governing factors.The lime stabilization in the acidic environment yielded less UCS change as compared to alkaline one [33]. Upon the lime treatment of low plasticity California soils (Clayey silts and Silty clays), the strength gain was substantial and it was inferred that low percentage of reactive clay may be sufficient for considerable strength gain [34].

Strength does not increase continuously with an increase in lime content, rather beyond an optimum value, it tends to decrease because the presence of too many Ca^{2+} ions leads to deflocculation and splitting of clay particles thereby inducing cracks even at small loads, hence reduced UCS value [14]. Bell [32] states that lime has negligible cohesion and friction, any lime addition beyond an optimum value only lubricates soil particles consequently causing strength reduction. There is a considerable increase in the cohesion of fine-grained clay soils along with a minor increase of angle of internal friction [21]. Thompson [21] related cohesion and Unconfined compressive strength with the following expression:

$C = 9.3 + 0.292\sigma_c$ (3)

Where C is cohesion(psi) and $\sigma_c$is unconfined compressive strength (psi).

Undrained Triaxial tests were conducted on plastic Jordanian clay to check for improvements in strength parameters and the results signified a considerable increase in undrained cohesion and angle of internal friction, these changes were attributed to the percentage of lime added and curing time [35]. Jan and Mir [14] after conducting Direct Shear tests on treated and untreated dredged soil concluded that up to an optimum lime content (8%) there occurs a significant increase in both cohesion and angle of internal friction and beyond that the values show a downward trend. Mateos [36] observed that soil treated with lime at a temperature of 35^{o}C developed twice the strength of the similar soil specimen treated at a temperature of 25^{o}C, thereby implying higher temperature accelerated curing and hence greater strength. Below a temperature of 4^{o}C, the lime-soil pozzolanic reactions retard considerably and may even cease [37]. Tensile strength also improves with an increase in unconfined compressive strength due to lime treatment. For design purposes, the ratio of tensile strength to unconfined compressive strength is approximately 0.13 and the ratio of modulus of rupture to unconfined compressive strength is 0.25 [38].

3.4. Effect of Lime Treatment on Permeability:

The influence of lime treatment on permeability has been quite variable, some researchers advocate a net decrease of permeability while others have an opposite opinion based on their studies. Lime treatment of clayey soil causes flocculation thereby increasing void spaces and hence permeability increase, the increase depends on the clay fraction, more clay fraction means higher permeability [39]. McCallister and Petry [40] treated 70 expansive clay samples with lime and observed the permeability changes, they concluded that the permeability increases substantially. Khattab et al.[41], Nalbantoglu and Tuncer [42], Singh et al. [43] conducted permeability tests on different clayey soils treated with varying lime percentages and all of them concluded that the permeability of treated soils is invariably higher as compared to untreated soil samples.

Onitsuka et al. [44] treated two different remoulded clays from Araike with 2,10 and 20 percent lime at a moisture content of 185 percent and conducted falling head permeability tests on each, they concluded that the pore space contracts with the formation of cementitious products and hence the permeability of

soil reduces. Alhassan [45], Milburn and Parsons [46] also conducted similar experiments and concluded that the permeability decreases when clayey soil is treated with lime.
However, some researchers like Kassim and Uuey [47], De Brito Galvao et al. [48] believe that permeability of lime treated soils increases up to a definite lime addition point and beyond that, a net decrease in permeability occurs. This point of inflection is called Lime Modification Optimum (LMO) by these researchers. They attributed the initial increase in permeability with the flocculation stage and the decrease of permeability with the formation of cementitious products which changes the void network size and structure.

3.5. Effect of lime treatment on Compressibility:

The compressibility of soil is one of the major factors governing the stability of roads, buildings, etc. Numerous studies have been carried out to work out the influence of lime treatment on the compressibility characteristics of soil [6,43,48]. Rajasekaran and Rao [6] used the injection technique and lime column work to investigate the effect of lime treatment on the compressibility of marine clay. Consolidation tests were carried out after 30 to 45 days and they observed a decrease of compression index from 0.85 to 0.36 and considerable betterment incompressibility of soil from one-half to one-third of untreated soil. The resistance against compression increases up to a certain lime addition point and beyond that no increase occurs [48].
Tedesco [49] after conducting multiple experiments concluded that reduction in compressibility of lime treated soil is due to the short-term reactions and pozzolanic reactions had little influence. He also stated that the compressibility of lime-soil was lower when compaction is done on the dry side of optimum. Singh et al. [43] reported a reduction in the Compression index and an increase in the Coefficient of Consolidation when they conducted consolidation tests on lime treated Nawanshahr roads in India.

3.6. Effect of lime treatment on durability and fatigue strength:

Often soils are subjected to alternate wet-dry and freeze-thaw cycles which in turn have adverse effects on soil stability and strength, the ability to withstand these effects is also known as durability. Mallela et al. [11] suggests usage of soaked strength test and cyclic freeze-thaw test to check the durability of soil treated with lime. Thompson [50] conducted soaked and un-soaked compressive strength tests on lime treated soil and concluded that the ratio of soaked to un-soaked strength is between 0.7 to 0.85. Autogenous healing of lime-soil mix helps soil regain stability after winter freeze-thaw cycles, hence the distress is not cumulative [51]. Brandl [17] concluded that the lime-soil mix has poor heat conductivity owing to the increased void ratio on account of flocculation and this, in turn, reduces frost penetration depth and rate.Mallela et al. [11] states that fatigue strength signifies the load cycles tolerated by the material at constant stress. For the lime-soil mix, fatigue strength is increased due to the development of strength continuously over time [11, 52].

4. Applications of Lime Treatment:

According to Jalal et al [53], Calcium based stabilizers like lime are used due to a No.of reason like (a) replacement of fine-grained problematic soils with coarse-grained soils is often costly (b) the presence of Ca^{2+} speeds up pozzolanic reactions and reduces swell potential (c) other techniques like pre-wetting are time-consuming, hence unsuitable (d) environmental and economic benefits are associated with this kind of soil stabilization. As of now, there are a No. of areas where lime treatmentof soils is being used as a primary method of soil stabilization and advanced technology is being used to workout new techniques of lime treatment in varied fields, some of these areas and techniques have been discussed below:

4.1. Lime Columns:

Broms [54] states that the behaviour of soft clays can be improved by in situ mixing of soil with lime by using special augers. Initially, it was assumed that the stabilized soil column acted as a pile thereby supporting the superstructure, however, more research clarified that lime can diffuse in the surrounding soil and stabilize a larger volume of soil. According to Broms [54], the shear strength of stabilized soft clay will be higher than the untreated soil about 1 to 2 hours post mixing even in highly sensitive clays and after a year an increase of 10 to 50 times is expected in case initial shear strength is 10 to 15 kPa. He also concluded that the stabilization of soil due to the lime column is a 3-stage process. Initially, consolidation of surrounding soil occurs as the quick lime absorbs water from the soil which causes slaking and hence swelling of lime.

$$CaO + H_2O \longrightarrow Ca(OH)_2 + 15.6\ Kcal/mol \qquad (4)$$

Ekstrom and Trank [55] observed that the water content of soft clay decreased from 60 percent to 45 percent when treated with 10 percent lime. After initial consolidation, the Ion Exchange process sets in and the Ca^{++} ions from slaked lime are absorbed by the clay surface, consequently, clay particles bond together and a net increase in shear strength is observed. Finally, Puzzolanic reactions take place and contribute towards the long-term shear strength gain.Brandl [17] conducted triaxial tests at low cell pressures and observed that the angle of internal friction increased with an increase in lime content.Bell and Tyrer [56] reported that stabilized soil has low compressibility, reduced sensitivity around 1 to 3 and less plasticity as compared to the untreated soil. The texture of soil after treatment changes to grainy and is usually firm to hard, also it behaves like an over-consolidated clay [57].

Deep Mixing method was developed in Japan wherein a No. of mixing units are held on a single barge, these mixers are closely spaced and have greater efficiency [58]. In India, China and Malaysia, Predrilled holes are filled with unslaked lime and with time the soil between boreholes consolidates owing to the expansion due to slaking of lime [59,60]. Fig. 4.1 is the pictorial representation of the elements and processes involved in lime column manufacture and Fig. 4.2shows Lime-Column installation rig typically used for large scale soil stabilization.

According to Broms [54], lime columns help in a significant reduction of total and differential settlements of buildings, increase consolidation and hence the settlement rate of heavy structure, and make embankments, trenches and slopes more stable. Apart from using Lime-columns, Lime Slurry injection and Lime precipitation techniques are increasingly being used for deep stabilization of expansive soils. Kumar and Thyagaraj [61] compared these 3 techniques and experimentally verified the influence on surrounding soil due to each one of these, they found that lime column influences soil properties like pH, salinity, microstructure and index properties upto 0.8d from central hole, lime slurry technique influences up to 1.5d and lime precipitation influences up to 2.5d, where ‘d’ is the diameter of a central hole.

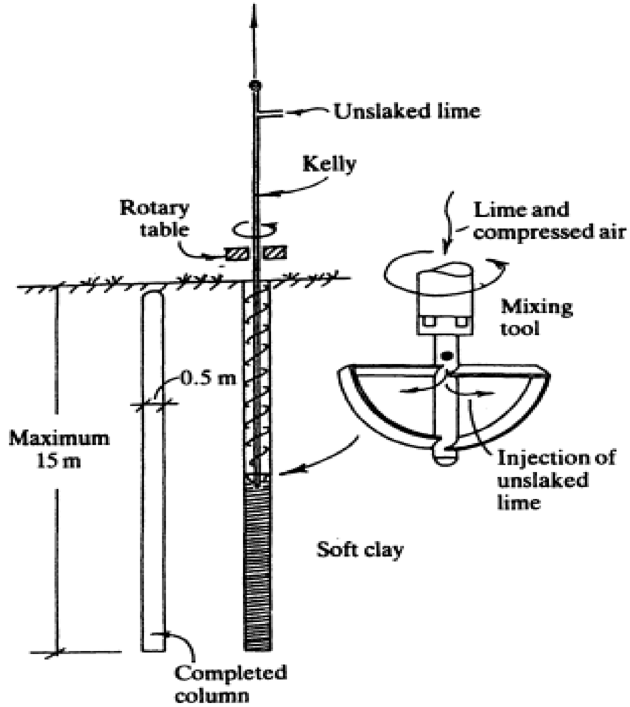

Fig. 4.1 Manufacture of Lime Columns

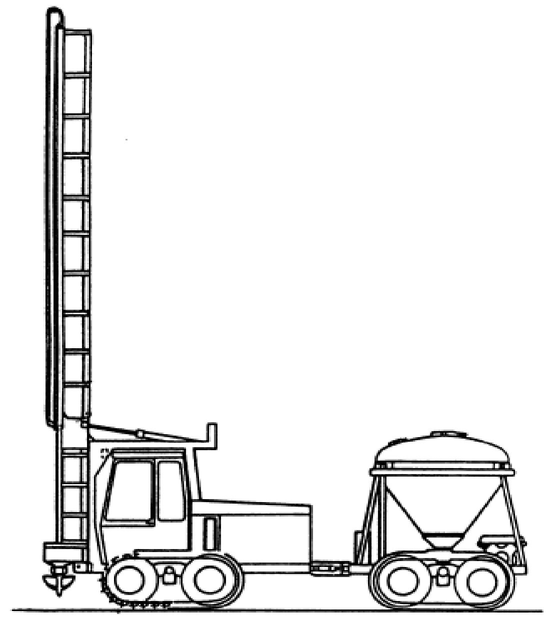

Fig. 4.2 Lime Column Rig

4.2. Pavement Stabilization:

Lime as a stabilizer has been used for improving the load-bearing characteristics and other properties of subgrades and base courses for decades now. Resilient Modulus is a parameter which is used for characterizing the soil, it is determined through the dynamic testing wherein load is applied in a uniaxial compressive mode. Maxwell and Joseph [63] used a field vibration test and Little [64] used Falling Weight Deflectometer (FWD) for evaluation of resilient modulusof lime stabilized soil subgrades and subbases. Little and Nair [1] states that the increase in cohesive strength of soils and aggregate systems due to plasticity reduction and pozzolanic reactions upon lime treatment results in considerable stiffening effect as reflected in resilient modulus magnitude. Fossberg [65] reported 20 times to increase in the resilient modulus of montmorillonite cohesive soils when treated with lime and prepared at high moisture content and low densification level. Fig. 4.3 shows on field lime stabilization of the subgrade with heavy machinery for compaction and mixing purposes.

Little [64] used FWD for resilient modulus evaluation of sub-bases of six pavement sections near Phoenix, Arizona, all of these had similar cross-sections and similar materials of construction. However, three of these subbases were stabilized with 1 percent lime and the other three were un-stabilized.

Fig. 4.3 Subgrade Stabilization with Lime.

Table 4.1: Parameters of Phoenix, Arizona Pavements [4].

S.No.	Base Course	Average Resilient Modulus(kPa)	Predicted Fatigue Life (ESAL's)	Tensile Flexural Strain (m/m x 10^{-6})	Subgrade Compressive strain (m/m x 10^{-6})
1	AB(1% lime)	375,723	10^6	200	290
2	AB(1% lime)	1,545,290	2 x 10^7	60	110
3	AB(1% lime)	2,805,858	10^8	50	125
4	AB(un-stabilized)	239,911.2	7 x 10^5	280	390
5	AB(un-stabilized)	92,379.6	7 x 10^4	360	370
6	AB(un-stabilized)	136,501.2	9 x 10^5	320	450

From the table presented above, it can be inferred that lime treated subbases when compared with un-stabilized ones have much better resilient modulus and increased fatigue life. Also, the compressive subgrade strains and tensile flexural strains are much lower owing to the better load spreading capabilities of stabilized subbases. Nowlin et al. [66] used FWD for back-calculating resilient modulus of lime stabilized soil subgrades of 12 sections of pavements with varying subgrade soil properties within Texas State. He observed that the increase in resilient modulus upon lime treatment is highly dependent on the individual subgrade soil properties as some subgrades displayed significant improvements while other low plastic soils witnessed a net decrease in resilient modulus. These tests were carried out after a long time and the stiffness increase bears witness to durability and permanency of structural changes due to lime stabilization. Little [67] conducted road tests on highly plastic Burleson clay stabilized with 5 percent lime without any pavement layers and measured resilient modulus with FWD before and after trafficking pavement with 5,000 applications of 80kN axle load. From the results, he concluded that there occurs a significant increase in resilient modulus of clay subgrade due to lime stabilization and this increase was maintained even after two years of exposure to significant rainfall and 5,000 applications of 80kN single axle load.Peterfalvi et al, [68] constructed three experimental roads to determine the bearing capacity of lime stabilized soil layer and to study traffic resistance of roads built on stabilized soil, and after evaluating results they recommended a lime stabilized subgrade depth of 0.25 to 0.35 metres for good long-term performance of road pavements on cohesive soils.

4.3. Lime Stabilization for Dams and Slopes:

Lime stabilization has been effectively used to reduce the susceptibility of Dams and Slopes to erosion, piping failures, and slip surface failures around the world especially in developed countries, and in this regard, a No. of studies have been carried out. Friant-Kern canal which was built in 1951 withmontmorillonite clay, had suffered damages at many sections and was repaired with soil lime mix in 1973-77. Researchers observed that due to lime treatment, maintenance operations were quite limited, no slides or failures were reported and only minor erosion of surface at some places took place, thereby proving the effectiveness of lime treatment [69,70]. Lime was also used for stabilizing the slopes of Mississippi river Levees at more than 150 failure spots and the treatment yielded positive results [71].
Herrier et al, [72] conducted extensive research to work out best-suited procedures for use of lime treatment in hydraulic structures and to study the influence of lime on soil properties. After conducting experiments,they observed less permeability upon lime treatment owing tothe reduction in pore size as confirmed by mercury intrusion porosimetry and they attributed kneading compaction and high moisture content as favourable conditions for achieving low permeability. They also reported 5 to 10 times reduction in swell potential and 25 times increase in cohesion and attributed these changes to cementation and adhesion of particles. Both internal and external erosion resistance tests were conducted and significant improvements were reported. They concluded that lime stabilization led to a reduction in permeability, improvement in mechanical properties, volume stability, and better erosion resistance, and these are primary factors on which the design, construction, and durability of hydraulic structures depend.

Conclusions

Lime as a stabilizer is being widely used in the geotechnical field of engineering. In this study, different aspects concerning Lime stabilization have been reviewed concerning the literature available. The basic mechanism of lime stabilization involves cation exchange and flocculation in the initial stage and then pozzolanic reactions occur which continue for a longer period of time.
Significant changes occur in soil properties but these changes are dependent on soil mineralogy, lime type, time, temperature, etc. In the initial stage, we see a marked decrease in the soil plasticity owing to the reduction in diffuse double layer thickness and increase in the viscosity of pore water due to flocculation and cation exchange. However, these changes in consistency limits witness a decrease and sometimes a reversal beyond a particular lime content. The moisture density relation also shows marked variations with an increase in optimum moisture content and a decrease in dry density. Researchers have conducted UCS, CBR and Triaxial tests to check for the influence of lime treatment on the overall soil strength and they reported a net increase in shear strength, tensile strength and bearing capacity up to an optimum value of lime addition owing to the cementation process due to continuous pozzolanic reactions. Studies show differences among researchers about the permeability changes with some reporting an increase while others observed a decrease and a few more reported variabilities in values with increasing lime content. Soils treated with lime have also shown a remarkable decrease in compressibility and have an increased resistance against strength loss due to alternate wetting-drying or freezing-thawing cycles.
Lime stabilization has been and is being used in a great number of areas like, we have Lime Columns which help in stabilizing soils underneath buildings, embankments and roads, these columns reduce settlements, dewater soils, increase strength, etc besides other benefits. Similarly, lime treatment of soils

in multiple pavement layers has seen an increase of lately owing to economic considerations and environmental concerns around the world. Lime treatment of soils provides a better alternative to many other costly stabilization techniques and nowadays lime-cement and lime-fly ash combinations are being used in the field to have greater influence over soil properties.

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