International Science and Technology Journal
المجلة الدولية للعلوم والتقنية

Volume 33 العدد
Part 2 المجلد
January 2024 يناير

تم استلام الورقة بتاريخ: 5/ 1/2024م وتم نشرها على الموقع بتاريخ: 31/ 1/2024م

The effect of adding hydrated lime on the geotechnical properties of sandy soil

Abir A. Elazzabi
Tripoli University, Faculty of engineering, Civil Engineering
abirelazabi@gmail.com

Abstract:

When the soil is not suitable, the best solution for engineers is stabilization operations, because it saves a lot of time and millions of moneys compared to the method of removing and replacing unstable soil. It ensures good stability of the soil so that it can support the load of the superstructure effectively. Sand stabilization is one of the main challenges faced by those working in the field of construction and engineering projects. With the rapid technological progress, many modern technologies have emerged that facilitate and improve the installation process and provide final solutions to soil problems.One of these challenges is eliminating the phenomenon of desertification to get rid of the threats and damage caused by the movement of sand dunes to industrial buildings, agricultural crops, and some residential neighborhoods and villages in the desert, as one of the solutions to areas threatened by desertification. It is one of the goals of studying this type of soil.

Stabilization of sand and soil is done by chemical or mechanical means in order to enhance the geotechnical properties of the soil, thus increasing the bearing capacity of the soil, protecting it from weathering processes, reducing soil permeability and soil mass compression, and increasing shear strength. This practical study includes studying some of the properties of sandy soil treated using cheap local materials, namely hydrated lime in different proportions (2%, 4%, 8%) and mixing it with water. These proportions were chosen based on similar studies of other types of soil available in literature because it gave good results and was between 2 and 10%.The study included a number of tests. The results showed that the maximum dry density of the soil increased from 1.662 g/cm^3 to 1.696 g/cm^3 and the optimum water content decreased from 15.2%

تم استلام الورقة بتاريخ: 5/ 1/2024م وتم نشرها على الموقع بتاريخ: 31/ 1/2024م

to 12.3% with increasing lime content. It is noted that the California bearing Ratio increases with increasing lime content from 8.252% to 41.264%. The soil also showed a noticeable improvement in the angle of internal friction of the soil from 29.2° to 37.23° and the cohesion of the soil from 0 kPa to 28 kPa for soil treated with lime. While adding lime did not lead to a significant change in the specific gravity. The best percentage that could be used of hydrated lime was 8% for the purposes of stabilizing the selected SP soil for treatment time 24 hours.

Keywords: Stabilization, lime, Maximum Dry Density, California Bearing Ratio, Cohesion, Internal Friction Angle, Specific Gravity.

تأثير إضافة الجير المطفأ على الخواص الجيوتقنية للتربة الرملية

عبير أحمد العزابي
جامعة طرابلس، كلية الهندسة، الهندسة المدنية
abirelazabi@gmail.com

الملخص:

عندما تكون التربة غير مناسبة فالحل الأمثل للمهندسين هو عمليات التثبيت، لأنه يوفر الكثير من الوقت وملايين الأموال مقارنةً بطريقة إزالة واستبدال التربة الغير المستقرة، فهو يضمن الاستقرار الجيد للتربة حتى تتمكن من دعم حمل البنية الفوقية بشكل فعال. ويعد تثبيت الرمال أحد التحديات الرئيسية التي يواجهها العاملون في مجال البناء والمشاريع الهندسية. و مع التقدم التكنولوجي السريع ظهرت العديد من التقنيات الحديثة التي تعمل على تسهيل وتحسين عملية التثبيت وتقدم حلولا نهائية لمشاكل التربة.ومن هذه التحديات القضاء على ظاهرة التصحر للتخلص من التهديدات و الأضرار التي تحدثها حركة الكثبان الرملية للمباني الصناعية والمحاصيل الزراعية و بعض الأحياء والقرى السكنية في الصحراء باعتبارها احد الحلول للمناطق المهددة بالتصحر . وهو إحدى أهداف دراسة هذا النوع من التربة. ويكون تثبيت الرمال بالوسائل الكيميائية او الميكانيكية من أجل تعزيز الخواص الجيوتقنية للتربة. وبالتالي زيادة قدرة تحمل التربة وحمايتها من عمليات التجوية

تم استلام الورقة بتاريخ: 5/ 2024/1م وتم نشرها على الموقع بتاريخ: 31/ 2024/1م

وتقليل نفاذية التربة وانضغاط كتلة التربة وزيادة قوة القص. إن هذه الدراسة العملية تتضمن دراسة بعض خواص التربة الرملية المعالجة باستخدام مواد محلية رخيصة الكلفة ألا و هو الجير المطفأ بنسب مختلفة (2%، 4%، 8%) ومزجه مع الماء, و قد تم اختيار هذه النسب بالاستناد على دراسات مشابهة لأنواع أخرى من التربة لأنها أعطت نتائج جيدة وقد كانت بين 2الى 10%.وتضمنت الدراسة عددا من الاختبارات. أظهرت النتائج أن الكثافة الجافة القصوى للتربة زادت من $1.662g/cm^3$ إلى $1.696g/cm^3$ و المحتوى المائي الأمثل انخفض من 15.2% إلى 12.3%مع زيادة محتوى الجير. ويلاحظ أن نسبة تحميل كاليفورنيا تزداد بزيادة محتوى الجير من 8.252% إلى 41.264% كما أظهرت التربة تحسناً ملحوظاً في زاوية الاحتكاك الداخلي للتربة من 29.2° إلى 37.23°و تماسك التربة من صفر كيلو باسكال إلى 28كيلو باسكال للتربة المعالجة بالجير بينما لم تؤدي إضافة الجير إلى تغير كبير في الوزن النوعي. أفضل نسبة ممكن تستخدم من الجير المطفأ كانت 8% لغرض تثبيت التربة الرملية رديئة التدرج المختارة لزمن معالجة 24 ساعة.

الكلمات المفتاحية: التثبيت، الجير، الكثافة الجافة القصوى، نسبة تحميل كاليفورنيا، التماسك، زاوية الاحتكاك الداخلي، الوزن النوعي.

1. Introduction:

Land is used everywhere to create various buildings ranging from simple houses to high-rise structures, bridges, airports, rural roads to highways. As a result of the great leap in engineering construction recently, the safety of these structures requires that they be built on high-capacity soil foundations, while the weakness of the soil may lead to its collapse, which contradicts the major structural leap that only a few soil types cannot bear due to the weakness of the soil and may lead to The cost of the project will increase as a result of replacing the existing soil with suitable soil, which may incur additional costs. The soil on which the buildings will be built must be able to bear the loads that will be placed on it. In order to obtain a qualified soil foundation for construction projects, its geotechnical

تم استلام الورقة بتاريخ: 5/ 2024/1م وتم نشرها على الموقع بتاريخ: 31/ 2024/1م

properties may need some improvement. Therefore, there are various popular soil stabilization methods around the world nowadays to achieve soil stabilization which allows improvement of weak soils.

Installation methods can be broadly classified as mechanical or chemical. Mechanical stabilization is stabilizing the soil by compacting it using mechanisms and then modifying the basic soil structure either by adding fine materials or coarse materials in order to obtain an appropriate granularity and choosing appropriate mixing ratios to reach the highest density. Chemical stabilization changes the chemical properties of soil through the use of chemicals, to improve the properties of the soil and make it stronger and more stable. This is especially required for construction projects that require strong and stable foundations, such as roads, bridges and buildings, if the stabilization process ensures that the ground can withstand the imposed loads without excessive settlement. There are many types of additives used recently to change soil properties to enhance the strength and durability of the soil and its ability to bear the heavy weights of huge building structures and giant facilities, such as strength, compressibility, hydraulic conductivity, and volume change properties such as cement, fly ash, lime, and lime by-products. But the choice of additive depends on the type of soil. One additive works differently for different soil types.

Since lime is an alkaline substance, it provides the appropriate chemical environment to permanently stabilize the soil by raising the soil pH to dissolve the pozzolan present in the soil. Once it dissolves, it becomes available to interact and form cement bonds with the calcium present in the lime, resulting in a very flexible and durable substratum. Lime stabilization is a cost-effective method that reduces soil elasticity, improves soil workability, and raises soil mechanical properties such as CBR values, unconfined compressive strength, shear strength, and tensile strength, and this technique has a great impact on soft soil, and many benefits (Amadi, et al., 2017; Kavak et al., 2007). Usually, a percentage of lime is added, ranging from 2 to 10%, as this percentage improves the properties of the soil. And it can be used by the types of lime used in soil improvement

are high-calcium hydrated lime, monohydrated dolomite lime, quick calcite lime, and dolomite lime. Water may need to be added.
Researchers in (Amadi, et al., 2017) examined the effectiveness of applying quick and hydrated lime to soils of tropical and subtropical regions separately in different proportions (0%, 2.5%, 7.5%, 10%) and the results showed that regardless of the type, there is generally an increase in UCS with higher content of Lime. According to (Neubauer et al., 1972). The UCS strengths increased by approximately 60 % as a result of the pozzolanic processes. Clay minerals, soil pH, silica and alumina content, type of lime, water content, temperature, and curing period are among the factors that have a significant impact on strength gain (Mallela et al., 2004). (Abbasi et al., 2018) The effect of different doses of lime and natural pozzolanic on the geotechnical properties of alluvial sandy soil was studied. The results showed that lime improves the compressive strength of soil, and mixing both lime and pozzolan leads to a significant increase in compressive strength that can reach about sixteen times the strength of untreated soil. It is worth noting that lime is used in many civil engineering projects such as road layers, earth dams, soil foundations, and piles (Al-Rawas and Gozan, 2006). Studies conducted in the literature related to improving the geotechnical engineering properties of soils have led to a significant modification of the properties. As in soil compaction properties, lime addition led to a decrease in the optimum moisture content and an increase in the maximum dry density (Bell, 1996; Gay and Schad, 2000; Guney et al., 2007; Hossain et al., 2007; Hazmi et al., 2019; Chandak and Babu, 2015; Rao et al., 2019; Nalawade and Jadhao, 2020; Abdul Qadir et al., 2020).
Regarding the shear strength properties of soil, in some recent studies (Consoli et al., 2012; Calik et al., 2014; Asad et al., 2019; Kumar et al., 2019; Chandak and Babu, 2015; Al-Alwan, 2019), it was found that adding lime significantly improves soil properties. Moreover, in shear failure of lime-stabilized soil, it showed brittleness characteristics (Lin et al., 2007; Chen and Lin, 2009). Moreover, the strength capacity of lime stabilized soil is greatly affected. This results from a decrease in the percentage of voids due

تم استلام الورقة بتاريخ: 5/ 2024/1م وتم نشرها على الموقع بتاريخ: 31/ 2024/1م

to the increase in the percentage of added lime (Consoli et al., 2012, 2014). This study presents the effect of hydrated lime on the compaction properties, shear strength, CBR value, and specific gravity of sandy soil classified according to the Unified Soil Classification System (USCS). All tests were performed in accordance with ASTM standards.

2. Experimental Investigation:

2.1UsedMaterials

2.1.1 Soil

Toubeya area, figure 1, located in the northwest of Libya in the area between Janzour and Al-Zawiya, which is about 35 km from Tripoli. It is air-dried sandy soil. Natural soil was collected at a depth of 0.5 to 1 m from the natural ground level. Soil laboratory tests were conducted on the samples to determine their geotechnical properties.

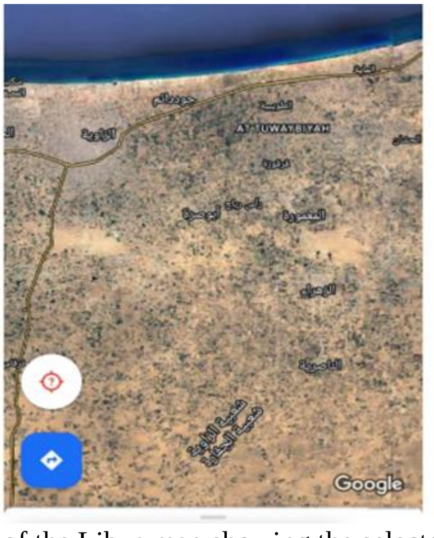

Figure1. Parts of the Libya map showing the selected soil sample location.

The sample obtained was sandy soil. It can be defined as poorly graded sandy soil (SP) according to the Uniform Soil Classification System (USCS) and (A-3) according to the American Society for

Soil Classification System (AASHTO). Figure 2 shows the results of the sand sieve analysis test according to the ASTM D 422 standard method and other characteristics in table (1).

TABLE 1. Geotechnical Properties of natural soil sample

Property	Value
Specific gravity(Gs)	2.634
Maximum dry density (Mg/m^3)	1.662
Optimum moisture content (%)	15.2
California Bearing Ratio, CBR	8.252
Internal friction angle, Ø	20°
Cohesion, C	0 KPa
Soil classification (USCS)	SP
Soil classification (AASHTO)	A-3

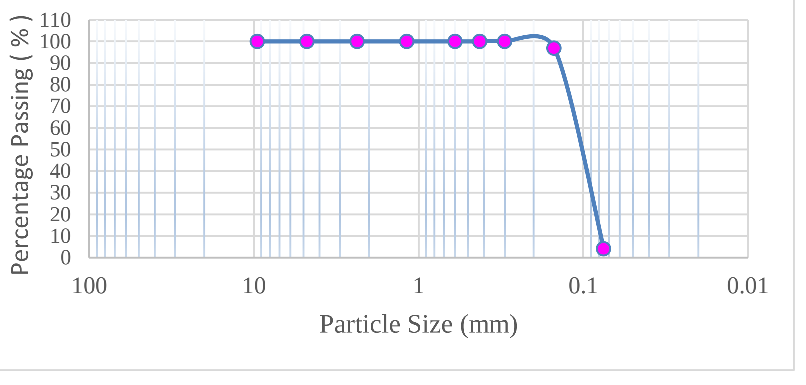

Figure2. Particle size distribution curve for the natural SP soil sample

2.1.2 Hydrated Lime:

Thehydrated lime used in the current study is locally available lime that is commonly used for construction purposes. It is known as calcium hydroxide and has other names, namely hydrated lime and calcium hydrate. It is a chemical compound with the formula $Ca(OH)_2$ and it is a fine white powder. It was obtained from the lime and dolomite factory located in the city of Misrata. The chemical and physical properties of the lime used are shown in table (2).

تم استلام الورقة بتاريخ: 5/ 2024/1م وتم نشرها على الموقع بتاريخ: 31/ 2024/1م

TABLE 2. Physical and chemical properties of theused hydrated lime for stabilization

Chemical Properties (%)	
CaO	92
MgO	3
Fe_2O_3	1
Al_2O_3	1
SiO_2	3
Physical Properties	
Grain size(mm)	25
Colour	Bright white
Density	2.211 gm/cm^3
Melting Point	512 °CDisintegrate
Solubility in water	0.165gm/100ml water
Molar mass	74.093mg/mole
PH value	12.4

2.2 METHODS OF TESTING

The collected soil sample was divided into four equal parts with the same natural characteristics. Then each part was mixed with 0%, 2%, 4% and 8% of hydrated lime, which was replaced from the total dry mass of the natural soil sample, and then the required water content was added, as tap water was used in all experiments except for the specific gravity test, which Distilled water was used.

The mixtures were stored in waterproof containers for 24 h to allow homogenization. Test specimens were prepared for all geotechnical properties proposed for this study. These prepared samples were made for all hydrated lime proportions specified above. Four laboratory tests performed , which were specific gravity, standard Proctor compaction, shear strength tests and CBR value. All these laboratory tests were conducted on natural and stabilized soil samples respectively.

3. RESULTS AND DISCUSSIONS

3.1 Effect of hydrated lime on Moisture density relations:

The method given in ASTM D1557.07 was applied to determine the maximum dry density (γdmax) and optimum moisture content (OMC) of natural soil samples stabilized by hydrated lime.

تم استلام الورقة بتاريخ: 5/ 2024/1م وتم نشرها على الموقع بتاريخ: 31/ 2024/1م

Adding hydrated lime in different proportions to soil samples increases their maximum dry density and reduces their optimal moisture content for the same compaction effort, as shown in figure 3. The added hydrated lime absorbs a proportion of the water added for compaction purposes. This resulted in a decrease in the amount of water required to achieve γdmax. This can be significantly observed in the increase obtained in the value of γdmax for the soil sample improved with 8% hydrated lime, reaching 1.696 gm/cm^3 with an optimum moisture content of 12.3 compared to the natural soil sample.

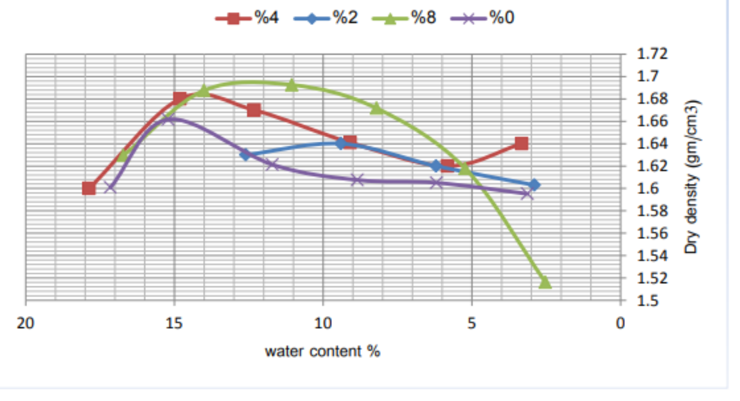

Figure3. Water content – density relationships from the performed compaction tests on the natural and stabilized soil samples with various percentages of hydrated lime.

3.2 Effect of hydrated lime on California bearing Ratio:

The method presented in (ASTM D1883-16) was applied to determine CBR on natural and stabilized soil samples with hydrated lime. The value of CBR affected with the characteristics of compaction such as the moisture content, dry weight, energy conditions and the method of compaction, compacted soil with a moisture content higher than optimum moisture content will have lower CBR value as shown in the CBR value for 4% hydrated lime. The soil samples in this study show an increase in CBR with the addition of hydrated lime until the optimum hydrated lime content

وتم نشرها على الموقع بتاريخ: 31/ 2024/1م   تم استلام الورقة بتاريخ: 5/ 2024/1م

is reached as shown in figure 4. The optimal percentage of hydrated lime added to the natural soil sample increased the CBR values from 8.252% to 41.264%. The addition of hydrated lime generates bonds between soil particles, which firmly bind the particles together and strongly resist any externally applied forces. This can be significantly seen in the increase obtained in the CBR value due to 8% hydrated lime.

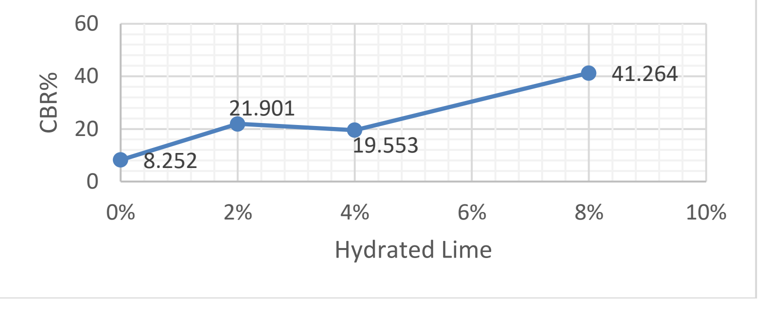

Figure 4. Variation of CBR values for the natural and stabilized soil samples with various percentages of hydrated lime

3.3 Effect of hydrated lime on Parameters of Shear Strength (Direct Shear tests):

The method contained in (ASTM D 3080-11) was applied to determine the value of the angle of internal friction and the value of cohesion for natural soil samples stabilized by hydrated lime. The results in table (3) indicate that the value of the angle of internal friction and the cohesion value of the soil increased with the increase in the percentage of the additive.

TABLE 3. Cohesion –angle of internal friction results for various additive contents

Additive (%)	Cohesion (Kpa)	Angle of Internal Friction
0	0	29.2
2	16	37.23
4	20	34.98
8	28	35.7

تم استلام الورقة بتاريخ: 5/ 1/2024م وتم نشرها على الموقع بتاريخ: 31/ 1/2024م

3.4 Effect of hydrated lime on specific gravity

The method contained in (ASTM C 127) was applied to determine the specific gravity on natural and stabilized soil samples with hydrated lime. The results in Figure 4 show that adding lime to soil samples does not lead to a significant change in the specific gravity of the soil because the specific gravity falls within a narrow range.

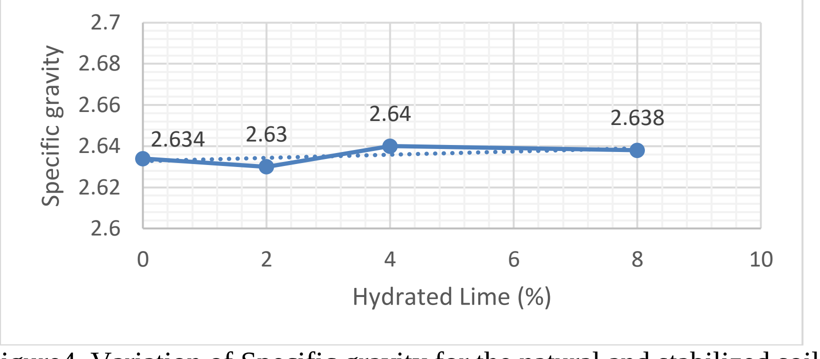

Figure4. Variation of Specific gravity for the natural and stabilized soil samples with various percentages of hydrated lime

4. Conclusions:

Locally available lime generally causes positive changes in the natural properties of these soils and improves the engineering performance of the soil. Based on the test results, the following conclusions can be drawn:

1) The results of geotechnical laboratory tests generally showed the important role of hydrated lime in the geotechnical properties of sandy SP soil, as the best percentage that could be used of hydrated lime was 8% for the purposes of stabilizing the selected SP soil and treatment time 24 hours, which could be due to various reasons. Such as particle size distribution, percentage of sand minerals, original soil materials, soil depth, and lime composition used.
2) Hydrated lime works perfectly with some geotechnical properties of the soil, as these properties may require materials such as lime to reduce water absorption and increase particle condensation, which can be observed in improving the shear

تم استلام الورقة بتاريخ: 5/ 2024/1م وتم نشرها على الموقع بتاريخ: 31/ 2024/1م

strength properties. The angle of internal friction of the soil increased from 29.2° to 37.23° by coefficient of variation of about 10.25%, and with increasing Soil cohesion ranges from 0 kPa to 28 kPa for soil treated with lime by coefficient of variation of about 73.59%.

3) Stabilization resulted in an increase in maximum dry density by coefficient of variation of about 1.58%and a decrease in optimum moisture content with increasing hydrated lime content by coefficient of variation of about 19.32%.
4) It was found that there was a significant increase in CBR value of sandy soil, as it increases from 8.252% to 41.264% of the hydrated lime content by coefficient of variation of about 60.29%.
5) Adding lime did not lead to a significant change in the specific gravity because the specific gravity of all soil samples falls within a narrow range and the coefficient of variation of about 1.152%.

5. References:

Abbasi, Nader, and Masoud Mahdieh. "Improvement of Geotechnical Properties of Silty Sand Soils Using Natural ozzolan and Lime", International Journal of Geo-Engineering ,2018, 9, 1.

Abdalqadir Z.K., SalihN. B.,and Salih S.J.H.,2020. Using Steel Slag for Stabilizing Clayey Soil inSulaimani City-Iraq. Journal of Engineering, 26 (7), pp., 145-157.

Al-Alwan, A., 2019. Undrained Shear Strength of Ultra-Soft Soils Admixed with Lime. Ph.D.thesis, University of Glasgow, UK.

Al Rawas A.A.and Goosen M.F.A.,2006. Expansive Soils Recent Advances in Characterization and Treatment. Taylor & Francis Group, Balkema.

Amadi, A. A., and A. Okeiyi, "Use of Quick and Hydrated Lime in Stabilization of Lateritic Soil: Comparative Analysis of Laboratory Data.", International Journal of Geo-Engineering, 2017, 8.

Asad,A., Hussain A., Farhan A., Bhatti A. A., and Munir,M., 2019.Influence of lime on low plastic clay soil used as subgrade -J. Mech. Cont. andMath. Sci,14(1), pp., 69-77.

Bell F. G., 1996.Lime stabilization of clay minerals and soils -Eng Geol,42, pp.,223–237.

(Consoli et al., 2012; Calik et al., 2014; Asad et al., 2019; Kumar et al., 2019; Chandak and Babu, 2015; Al-Alwan, 2019),

Chandak N. R.,and Babu A., 2015.Effect of lime sludge on strength and compaction of soil -Journal of Civil Engineering Research,5(1), pp.,18-20.

Consoli N. C., Dolla R. A., Gauer E. A., dos Santos V. R., Moretto R. L.,and Corte M. B.,2012.Key parameters for tensile and compressive strength of silt-lime mixtures -Geotechnique Letters,2(3), pp.,81–85.

Consoli N. C., Prietto. PD. M., da Silva L. L.,and Winter D.,2014.Control factors for the long term compressive strength of lime treated sandy clay soil -Transportation Geotechnics,1(3), pp., 129–36.

Gay G.,and Schad,H.,2000.Influence of cement and lime additives on the compaction properties and shear parameters of fine grained soils -Otto-Graf J,11pp., 19–31.

Guney Y., Sari D., Cetin M.,and Tuncan,M.,2007.Impact of cyclic wetting-drying on swelling behaviour of lime-stabilized soil -Build Environ, 42, pp., 681–688.

Hezmi,M. A., Ahmad K., Yunus N. M. Kassim K. A.,Rashid A. S. A., and Hassan N. A.,2019. Compaction characteristics of lime-treated tropical soil. IOP Conf. Series: Materials Science and Engineering 527, pp., 1-8.

Hossain K. M. A., LachemiM.,and Easa S.,2007.Stabilized soils for construction applications incorporating natural resources of Papua new guinea -Resources, Conservation and Recycling, 51(4): 711e31.

Kavak, Aydin, and Adnan Akyarli, “A Field Application for Lime Stabilization.” Environmental Geology, 2007, 6, 987.

تم استلام الورقة بتاريخ: 5/ 1/2024م وتم نشرها على الموقع بتاريخ: 31/ 1/2024م

Mallela, J., Harold Von Quintus, and Kelly L Smith, "Consideration of Lime-Stabilized Layers in Mechanistic-Empirical Pavement Design." The National Lime Association 61820 ,2004, 1.

Neubauer, C. H., and M. R. Thompson, "Stability Properties of Uncured Lime-Treated Fine-Grained Soils." Highw Res Rec, 1972 , 38, 20.

Ravindra RDand Jadhao P.D., 2020. Prediction of CBR value of stabilized black cotton soil use for road construction - International Journal of Engineeringand Advanced Technology (IJEAT), 9(3), pp.,2317-2322.