American Journal of Innovative Research and Applied Sciences. ISSN 2429-5396 I www.american-jiras.com

ORIGINAL ARTICLE

EFFECT OF LIME MORTAR GRAVEL COLUMNS TECHNIQUE ON PHYSICAL CHARACTERISTICS OF EXPANSIVE SOILS

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| Received June 03, 2020 | | Accepted July 11, 2020 | | Published July 15, 2020 | | ID Article | Nizam-Ref.1-ajira030720 |

ABSTRACT

Background: Using lime in expansive soil treatments have been proven effective from the many researches on this topic, different methodologies were employed In order to achieve the best exploitation of lime as a cost effective material. The methods such as mixing, injection and lime columns or micro lime piles. Several studies have been conducted on the last two methods and were proven effective and confirmed the diffusion of lime within the soil, but some other studies have indicated a decrease in the resistance of these columns over time, which prompted many researchers to find different methods that increase the long-term resistance of lime columns. These studies were limited to measuring the change in resistance and neglected the study of the changes of physical properties of the soil surrounding the column due to lime diffusion, considering the fact that adding a strengthening material to the column decreases the amount of lime used. **Methods**: This research is based on a laboratory model in which a clay bed of expansive soil is formed within a cylindrical metal mold with a diameter of 30 cm and a height of 30 cm. In the center of the clay bed the lime-gravel column was implemented. The mold was left for curing periods of (7, 28, 54, and 112), and for each treatment period, soil samples were extracted at radial distances from the column starting from one times the column diameter to five times diameter in the form (1D, 2D, 3D, 4D, 5D). The extracted samples were tested for liquid limit, free swelling and direct shear. **Results**: The results showed a clear decrease in the values of LL and free swell index as well as an increase in shear resistance by increasing the treatment period and decreasing the distance from the column. **Conclusion**: Using gravel as a reinforcement for lime columns doesn't hinder the diffusion of lime into the soil block and maintains the process of treating surrounding soil.
Keywords*: Distance from column, liquid limits, free swell, treatment duration.*

1. INTRODUCTION

Soil improvement techniques received increased attention as a result of urban expansion over large areas of land which previously was considered unsuitable, this areas often consist of layers of relatively large thickness of soft soils, which are known for having low bearing capacity and undergoes large volume changes. This research aims to treat expansive soils for large depths using gravel columns with lime mortar, this technique is useful for soil treatment before or after construction by implementing the columns around the building perimeter as the lime effect extends beneath the building and modifies soil characteristics. This method can be considered simple, cost effective and is characterized by its ability to treat soils to great depths. unlike the mixing method which effect is limited to the topsoil layers.

When lime is added to clay soil two types of reactions occur: rapid reactions and slow reactions. Rapid reactions include ion exchange and flocculation and result in an increase in the forces of attraction between the grains causing flocculation and aggregation with a subsequent decrease in soil plasticity. In slow reactions, the most important of which is the pozzolanic reaction, calcium interacts with soluble aluminates and silicates present in clay with the presence of water to produce calcium silicate hydrate (CSH). Calcium Aluminate Hydrate (CAH), Calcium Aluminate silicate Hydrate (CASH), which results in a long-term increase in resistance and improvement in surrounding soil characteristics [1].

Lime columns have been used in many countries such as India, Japan, Taiwan, Singapore and Malaysia, in which dry lime is placed in vertical pits [2,3]. Lime diffuses within surrounding soil with the help of water, leading in increase in shear resistance and a decrease in soil compression, thus reducing settlements. Lime columns were also used in the treatment of cracked hard clay in the United States in about 1960 [4].

The high Earth temperature and pH value (pH> 12) accelerate chemical reactions as the solubility of silicates and aluminates increases with increasing pH value. Even though the resistance of the lime columns may decrease over time [5, 6], which prompted many researchers to study the Use of different materials with lime to raise the columns strength on the long term.

Gravel columns are classified as mechanical improvement or soil reinforcement methods, using well graded grains with diameters between 2mm and 75mm [7]. In which vertical pits are constructed and then filled with stone with compacting, they are used to improve clay and silty soils provided that the shear resistance of these soils is within [15-50] kN/m^2 [8] as the gravel columns attain their bearing capacity from lateral pressure.

This research was built on the integration between gravel columns and lime columns method for treating the surrounding soil by increasing its resistance and improving its properties to great depths.

2. MATERIALS

This study was carried out on swelling soil and the improvement column consisting of lime and gravel. These materials were used to form the laboratory model. The following describes the properties of these materials used.

2.1 Clay:

The clay soil used in this research was brought from Demsarkhu area, located in the north of Lattakia city, where the area is known for its expansive soil after complaints from the residents about uneven floors and cracks appearing in walls. The samples were transferred to the laboratories of the Faculty of Civil Engineering, Tishreen university, The clay sample properties are shown in Tables 1 and 2, where all experiments were performed according to the ASTM [9] specifications:

Table 1: physical properties of clay.

Specific gravity weight	2.73
Moisture content %	29.4
Dray unite weight (KN /m^3)	14.4
Natural unite weight (KN /m^3)	18.6
Liquid limit (LL%)	68
Plastic limit (PL%)	31
Plasticity index (Pi%)	37
Shrinkage limit (SL%)	18.5
Organic matter %	1.75
No.200 %	95.3
Permeability K (m/sec)	4.03×10^{-11}
Classification (ASTM)	CH (fat clay)

Table 2: Mechanical properties of clay.

Young modules E (kN/m^2)	13589.3
Cohesion C (kN/m^2)	42.2
Angle of internal friction Φ(º)	4.2
Swell index (%)	76.7
Swell pressure (KN/m^2) (Different stresses method)	400

2.2 Gravel:

In order to form the column, calcareous gravel of narrow gradient were used (4.75mm >D> 2mm) [10], the vibratory table was used to determine the maximum and minimum dry unite weight, result of test are shown in Table 3:

Table 3: properties of gravel from vibratory table test.

maximum dry unite weight γ_{max} (kN/m^3)	15.51
minimum dry unite weight γ_{min} (kN/m^3)	14.24

2.3 Sand:

A layer of clean quartz sand was used on top of clay bed to ensure uniform load distribution and regular moisture spread as well as protecting clay surface from sudden wetting [11]. Sieve analysis and permeability experiment was conducted on sand sample in order to verify the permeability of water to the clay bed. Figure 1 shows the results of the sieve analysis and Table 4 presents properties of sand:

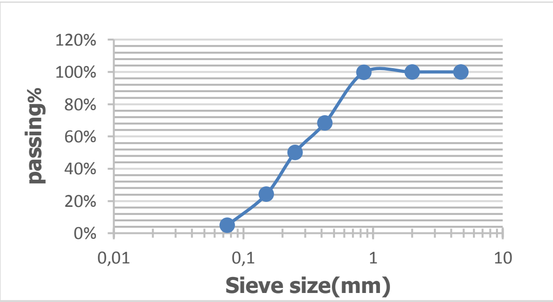

Figure 1: grain size disripution curve of sand sample.

Table 4: properties of sand.

Permeability K (m/sec)	2.1×10^{-5}
Uniformity coefficient Cu	3.684
Coefficient of curvature Cc	0.869
Classification (ASTM)	SP (poorly graded sand)

2.4 Lime:

High-quality commercially available dry lime powder was use for the formation of lime-gravel columns.

3. Methodology

This study was carried out using a cylindrical laboratory model with a diameter of D=50cm and a height of H=30cm, the thickness of the mold walls t_w=0.2 cm and the thickness of the base plate t_b=0.4 cm. The clay bed was formed on layers with a thickness of 2.5cm until reaching a height of 25cm. Each layer was stacked using two metal hammers, each weighing 4.5kg and falling from a height of 45cm. The improvement column was drilled by inserting an iron hollow tube with a diameter of 4.825 cm in the center of the mold, then the tube was gradually withdrawn and the cylindrical pit was filled with a mixture of lime and gravel, where the lime weight ratio was half the weight of gravel. The filling process was carried out in three stages and each layer was compacted manually (so that the unite weight of the column material was 13.5 KN/m^3), the surface of the clay bed was protected from lime by covering the surface surrounding the hole while filling the column with the mixture. Figure 2 shows a chart of the mold dimensions, a section showing the location of stabilization column and horizontal plane shows the locations of the samples extracted for the study.

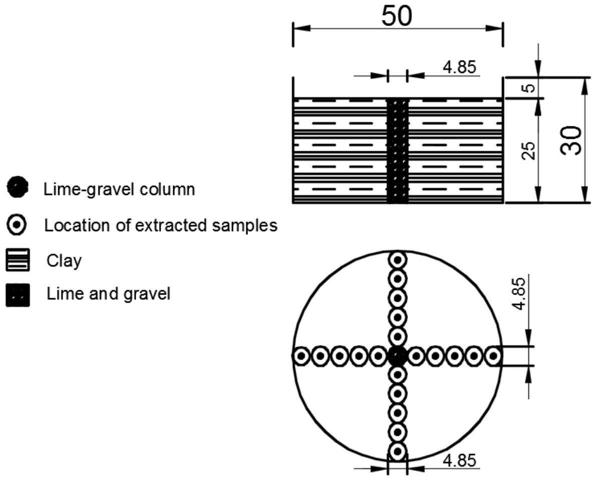

Figure 2: mold and column dimentions and extracted samples locations

After the implementation of the column, the clay bed surface was covered with a thin fabric and then with a layer of sand with a thickness of 2cm, and another fabric layer followed by an iron lid. The lid was of 49.4cm diameter and thickness of 1.3cm used for applying 2.6 kN/m^2 stress to the surface. Then the clay bed was submerged in water till reaching the top of the mold level, the mold was left for treatment periods of (7-28-57-112) days. Upon completion of each treatment period, the loads and sand layer were removed and samples were extracted from the soil surrounding the column using a hollow tube on different spacing from the circumference of the column (1D-2D-3D-4D-5D) where D represents the diameter of the improvement column.

4. RESULTS

The effect of lime-gravel columns on the physical properties of surrounding soil were determined by Atterberg limits, free swells and direct shear test.

4.1 Liquid Limits cone test results

Liquid limits where determined for samples extracted at different dimensions from the column perimeter starting from one time the column diameter 1D up to 5D using cone test. Table 5 presents the values of LL at different distances and curing durations while Figure 3 show the changes in LL with curing time and distance from column, where the changes were calculated using the equation $((LL_0 - LL)/LL_0)$% where LL_0 is the liquid limit of untreated soil. it can be seen that the effect of lime reaches 4D for 7 days curing period, the lime effect keep spreading with time to reach 5D for curing time of 28 days, it also shows that curing time is mostly effective after 28 days and the increase in lime effect continues over time only less palpable.

These results are in accordance with Tonoz et al., (2003) results, where they found that the effect of lime due to diffusion of calcium ions on soil liquid limits is instantaneous, as the changes of soil physical properties are rapid during treatment time of 28 days and with the increase of curing time the changes in LL are less noticeable [12]. This can be explained by the presence of a high level of calcium ions that cause changes in soil properties, this change is due to weakening of negative forces of clay particles and consequently the collapse of the double diffusion layer that is usually found between the clay particles [13].

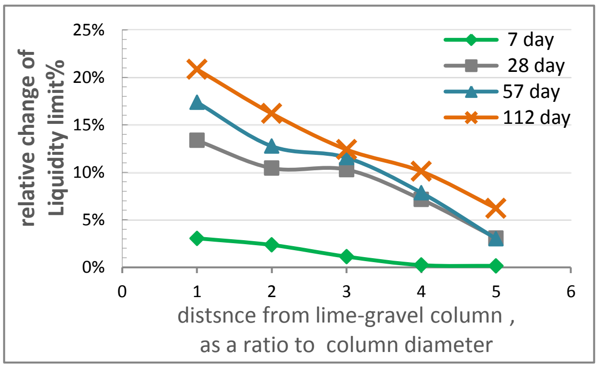

Figure 3: changes in liquid limits with curing time and distance from column.

Table 5: Liquid limits cone test results for different distances and curing periods

Curing time [day]	1D	2D	3D	4D	5D
7	65.93	66.4	67.24	67.85	67.90
28	58.92	60.9	61.0	63.14	65.0
57	56.18	59.33	60.15	62.66	65.96
112	53.82	56.99	59.57	61.14	63.78

4.2 Free Swell test results:

Tube free-swell experiments were conducted on samples extracted at different curing durations and distances from the column, results are shown in table 6, while figure 4 show the changes of swell index (S%) as a percentage of the un treated soil value of swell index S_0% calculated using the equation $((S_0 - S)/S_0)$%. Figure 4 show the increase of lime diffusion with curing time (and regular moistening of model). as Ca^{+2} ions diffuse in the soil block their effect reach 2D from column for curing time of 7 days and reaches distance of 3D for 28 days, 4D for 57 days and 5D for 112 days It can be concluded that Ca^{+2} ions diffusion is related to time and moistening conditions, the reduction of S% increases with time to reach 60% at distance of 1D and curing time of 112 days. The decrease in swelling is due to the decrease in the thickness of the double diffusion layer [14] resulting from the spread of calcium ions within the soil mass and thus the decrease in the number of positive ions needed to modify the charge of clay particle, since Ca^{+2} is bivalent, in addition the spread of calcium ions in the soil causes a decrease in PH values of the pore water solution, which in turn reduces the negative charges OH on the surface of the clay molecule and decreases as well the number of positive ions that the clay particle is bound to and which forms the double diffusion layer.

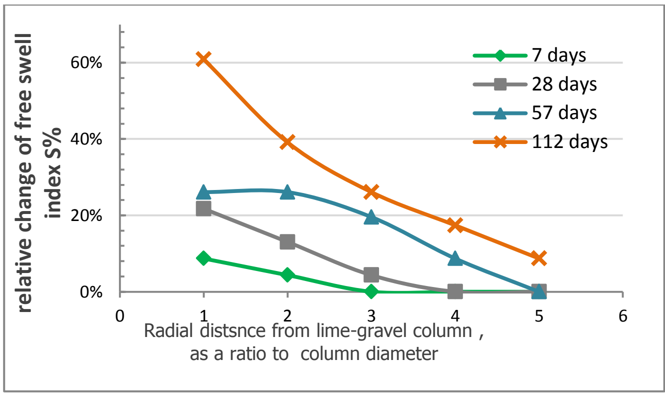

Figure 4: changes in free swell index with curing time and distance from column.

Table 5: Free Swell index, tube test results for different distances and curing periods.

Curing time [day]	1D	2D	3D	4D	5D
7	70.0	60.0	56.7	30.0	70.0
28	73.3	66.7	56.7	46.7	73.3
57	76.7	73.3	61.7	56.7	76.7
112	76.7	76.7	70.0	63.3	76.7

4.3 Direct Shear test results:

Direct shear experiments were conducted on saturated samples, after samples were extracted and dried, shear samples were formed with natural moisture and then placed on the consolidometer where the samples were submerged in water and prevented from swelling or consolidating, the samples were left for four days in this conditions in order to reach saturation when shear experiment was performed. Figure 5 shows shear resistance changes with curing duration for samples extracted from different radial distances from column, the decrees of the lines inclination after treatment period of 28 days indicate a low rate of increase in shear strength after 28 days, especially at distance of 1D while in more distant areas, the shear resistance continues to increase, at rates that increase with the distance from the column. For example, at a distance of 4D from column, the shear resistance increases 10% after 28 treatment days, and this increase becomes 51% after 112 treatment days, while at 1D, the shear resistance increases 91% after 28 treatment days, and this increase becomes 184% after 112 treatment days. The increase in shear resistance can be explained by the spread of lime in the soil that caused the modification of the granular, mineral and physical properties of treated soil and the noticeable increase in strength, hardness and durability which is due to the formation of cementitious compounds as a result of pozzolanic reactions between clay and lime resulting in the formation in strong bonding forces between the soil solid molecules.

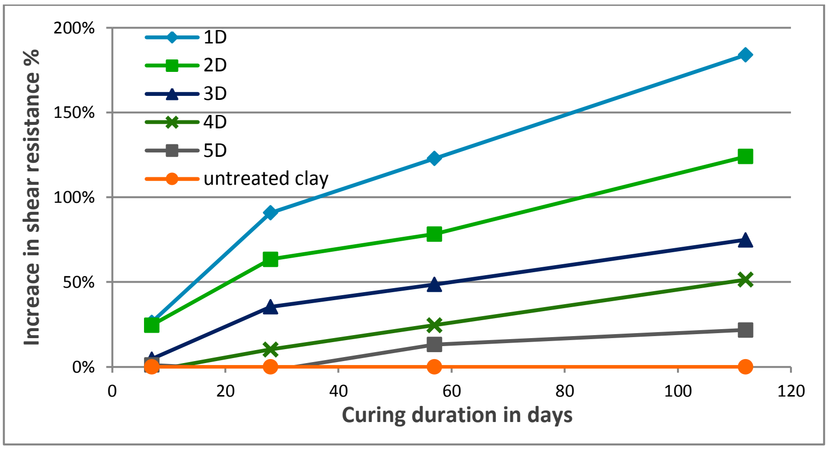

Figure 2: changes in shear resistance with curing time and distance from column.

4. CONCLUSION

The addition of different materials to increase the resistance of lime columns, such as gravel, does not affect the lime treatment mechanism for modifying the physical and mechanical properties of the surrounding soil, resulting from the diffusion of calcium ions in the soil block. Although less calcium was used within the column, the results were similar to the previous studies that used only lime in the columns, and the greatest effect was during the 28-day treatment period, after which further improvement continues, but with a less pronounces effect. And with regard to the diffusion distance the most pronounce effect of lime diffusion is up to three times the column diameter.

5. REFERENCES

1. Hhelen Å. *Swedish Deep Stabilization Research Centre*, 2006, Department of Construction Sciences, LTH, Lund University, Doctoral Thesis.
2. Chui K.H., and Chin, K.Y. *The Second Asian Regional Conference on Soil Mechanics and Foundation Engineering*, 1963, vol1, 387-393.
3. Holeyman A., Franki, S. A., Mitchell, J.K . *Assessment of Quick Lime Pile Behavior*. 8th European Conference, 1983, Vol. 2, 897-902
4. Bengt B.B. *Foundation Engineering Handbook*, Nanyang Technological Institute. Singapore, 1991, pp. 833-855.
5. Cui, Xi., Zhang, N., Li Sh., and Zhang J. *Journal of Performance of Constructed Facilities*. 2016; 30(1).
6. Pham V.N., Brett T., Jinsong H., and Richard K., *Soils and Foundations*. 2017; 57: 645–654.
7. *Indian Standard Code IS: 15284-2003*.
8. Barksdale R.D., and Bachus R. C. *Federal Highway Administration*, U.S Department of Transportation, 1983, Vol 1.
9. American Society for Testing and Materials**,** ASTM Standard C33, 2015, Volume 04.08 Soil and Rock (I); D420-D5876.
10. Malekpoor M.R., and Poorebrahim Gh. R. *International Journal of Engineering, Kerman*, 2014, Vol. 27, No. 2, pp. 315-324.
11. Ashok P., and Reddy G.S. *International Journal of Science and Research*. 2016; 5(11): 1204-1210
12. Tonoz M.C. ; Gokceoglu C. ; Ulusay R. *Bulletin of Engineering Geology and the Environment*, Springer-Verlag 62, 2003, pp.91–106.
13. Abiodun A. A., and Nalbantoglu, Z. *Canadian Geotechnical Journal*. 2015;52: 1-9.
14. Rogers C.D.F., and Glendinning S. *Journal of Engineering Geology*. 1997;47: 243-257.

Cite this article: Norah, Nizam and Rami Ousta. EFFECT OF LIME MORTAR GRAVEL COLUMNS TECHNIQUE ON PHYSICAL CHARACTERISTICS OF EXPANSIVE SOILS. *Am. J. innov. res. appl. sci.* 2020; 11(1): 50-54.