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USING STABILIZED SOIL LAYERS AS EARTH REINFORCEMENT

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Abstract- This study deals with the evaluation of effect of stabilizing alternated soil layers with soil layers on the strength and compaction characteristics of fine soil chosen from Nizwa area, using lime as stabilizer. In evaluation, the stabilized layers considered as sheet reinforcement. The treatment of alternated soil layers by lime indicates an increase in unconfined compressive strength. In addition, and accordingly, the quantity of water needed for stabilization, time and effort of mixing soil with the stabilizer will reduce relatively to the case of fully stabilized soil.

Keywords – Fine soil, Compressive strength, Lime, Reinforcement, Compaction

I. INTRODUCTION

The improvement of soil properties is developed rapidly in recent decades. It can be done by different methods based on chemical or mechanical mechanism. Addition of lime, cement, or some chemicals indicates an improvement in soil properties on the base of chemical action. Mechanical stabilization of soil can be done by mixing the soil with different soil followed by compaction in order to improve the properties of the first soil. Using soil reinforcement like strips, grids or sheets for improving the soil mechanical properties is also considered as mechanical stabilization [1, 2, 3].

Lime stabilization is considered the most suitable method to improve the cohesive soil properties. It includes a short and long term actions of alteration the soil properties. The short term stage deals with the modification of plasticity and gradation of soil. The followed stage of long term stabilization from pozzolonic reaction result an alteration of soil mechanical properties like strength, compaction, consolidation, and swelling properties [1,4,5,6].

Effect of lime on soil index properties has been studied by many investigators. A modification of the soil plasticity and gradation as well as improving the compaction characteristics were reported (1, 4, 5, 6, 7, 8,9). On the other hand, lime stabilization was found to increase the strength of fine soil remarkably with different degrees for various stabilizer content [7, 8, 10, 11, 12].

Soil reinforcement technique for improving soil properties originally attributed to the French engineer Henry Vidal who developed it in 1960s [13], and subsequently investigated it in many countries for strengthening the soil to be used for construction of roads, foundations, railway embankments, retaining walls and slopes. Reinforcing the soil creates a composite materials formed by friction between the soil and reinforcement. The force developed in soil transfers to reinforcement to form additional frictional cohesion. Many studies concerned soil reinforcing and its effects have been reported, that the soil strength is appreciably improved and a higher stability is obtained as a results of using different types of reinforcement [13, 14, 15, 16, 17, 18].

In this study, a combination of stabilization by additive using lime as a stabilizer, and a mechanical stabilization using alternated stabilized soil layers with soil as reinforcement is used to improve a fine soil taken from Nizwa area (175 kM South – West Muscat, Sultanate of Oman). This is done by conducting a treatment of alternated soil layers with untreated soil layers (sandwich method).

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II. MATERIALS AND METHODOLOGY

Soil

A representative samples of fine soil are taken from the site (15 kM to Nizwa city center) after excavating (0.5 – 1.0) m from the ground surface to avoid the weathered zone of top soil.

Lime

The hydrated lime [$Ca(OH)_2$] is used for treatment the studied soil. It is of a with powder in nature has 96% finer than 0.075 mm (#200sieve) and has a specific gravity of 2.24.

Water

A potable water is used for treatment of soil with lime and for compaction process in all case of study.

Experimental Program

Figure (1) shows the program used for practical works of study.

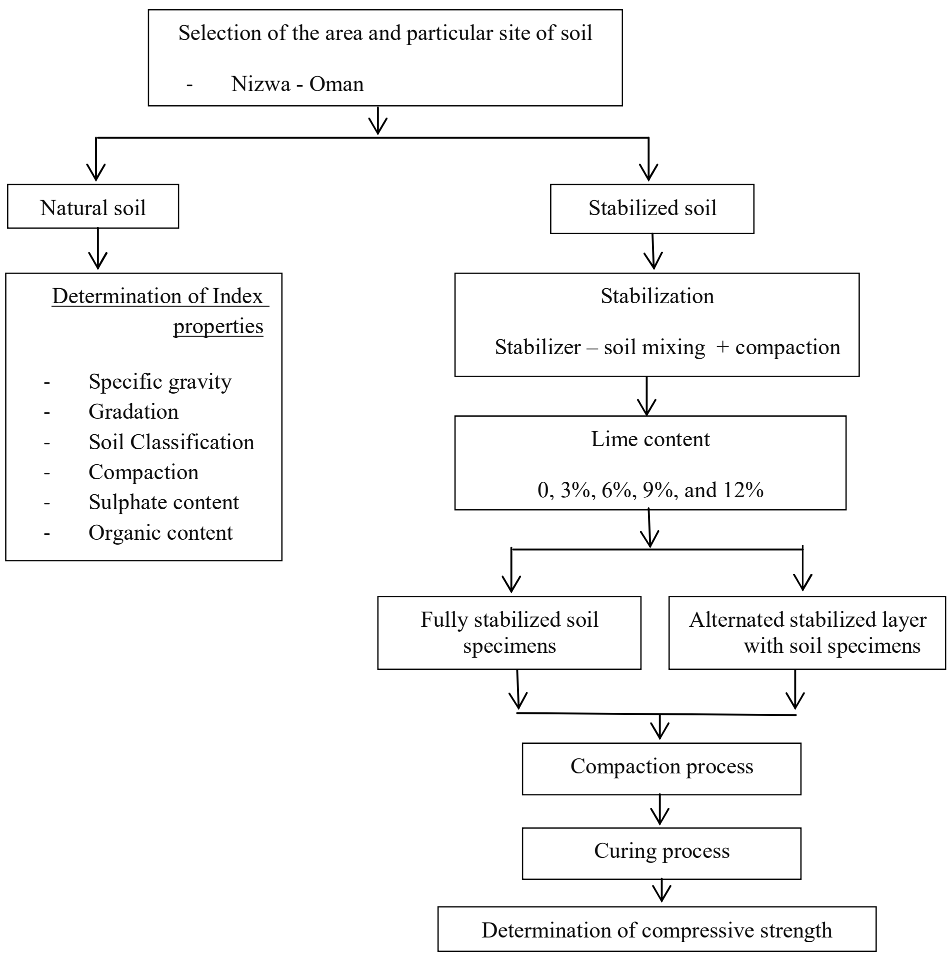

Figure 1. Experimental program

Preparation of specimens and testing

Diagrammatic sketches of the prepared specimens are shown in Figure 2. Essentially, two types of specimens are used, fully stabilized soil specimen with 5 equal treated layers, and alternated stabilized layers with soil specimens using three alternated treated layers with two untreated soil layers.

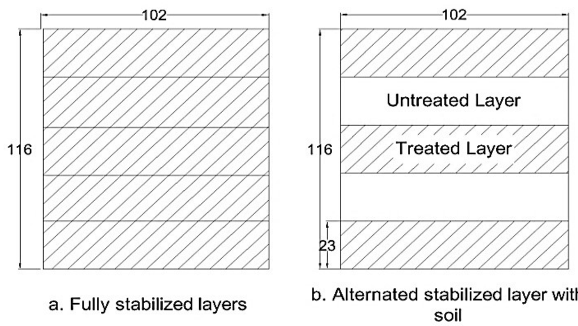

Figure 2. Composition of stabilized specimens.

For a significant study, the soil is treated with different percentages of lime. Namely; 3%, 6%, 9% and 12%. The required amount of lime is added to air dried pulverized soil and thoroughly mixed. The necessary amount of water required for compaction is added and mixing continued for approximately five minutes. After mixing the mixture is tightly covered to prevent moisture loss and to mellow for 30 minutes before compaction. Compaction is done in cylindrical mold 102 mm in diameter and 116 mm high and in five equal layers. Unified AASHTO compactive energy is used. After compaction the specimens are wrapped tightly with aluminum foil paper and waxed to maintain the moisture content during curing time of 7 days at laboratory temperature (22± 2°C). After completion of the curing period, the specimens are subjected to unconfined compressive loading to determine their compressive strength.

III. RESULTS AND DISCUSSION OF RESULTS

Index Properties of soil

The index properties of soil used in study are given in Table 1.

Table 1. Index properties of soil

Characteristic	**value**
Liquid limit, %	31%
Plastic Limit,%	22%
Plasticity Index, %	9%
Specific gravity of solid	2.71
Maximum unit weight, kN/m^3	17.61
Optimum moisture content,%	15%
Organic content,%	0.95%
Sulphate content,%	0.001%
Classification (USCS)	ML

The soil is classified as (Silt with low plasticity) according to Unified Soil Classification System (USCS). Figure 3 shows the gradation of the natural soil used in study.

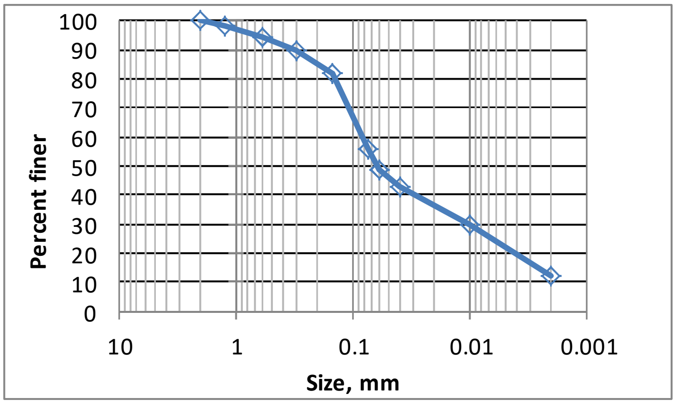

Figure 3. Grain size distribution curve of soil

Compaction characteristics

Natural soil

Figure 3 shows the compaction characteristics of the natural soil. It can be seen that the optimum moisture content is 15% produced a maximum unit weight of 17.61 kN/m^3. The general shape of the relationship is of a systematic one of the soil.

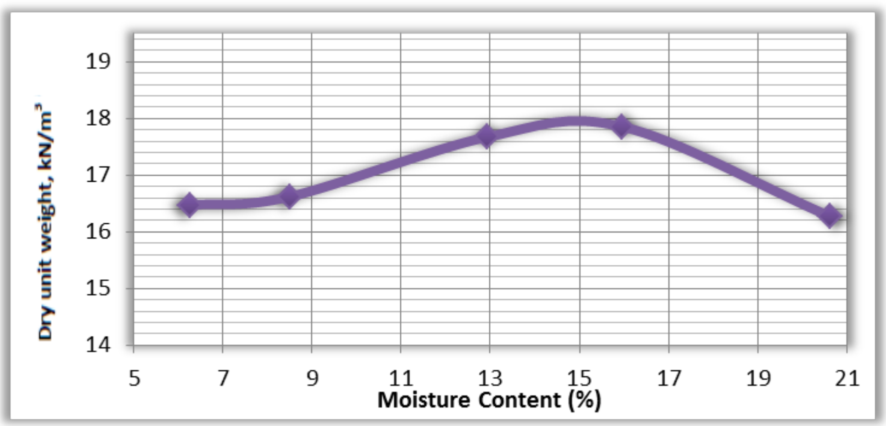

Figure 4. Compaction characteristics of natural soil

Fully stabilized soil

The compaction curve for fully stabilized soil treated with 0, 3%, 6%, 9% and 12% of lime is shown in Figure 5. Identical compaction behavior is obtained for the various lime content. In general; the rate of increase of dry unit weight with moisture content in dry side of optimum moisture content is shown to be lower than that in wet side of optimum for same lime content.

The effect of lime content of maximum unit weight is given if Figure 6. It can be seen that as the lime content increases the maximum dry density decreases. This is due to the lower specific gravity of lime than the soil particles. On the other hand, increasing the lime content cause a slight increase in optimum moisture content.

This can be attributed to a higher affinity of lime to water and to additional moisture needed for hydration of calcium cation [19,20] , see figure 7.

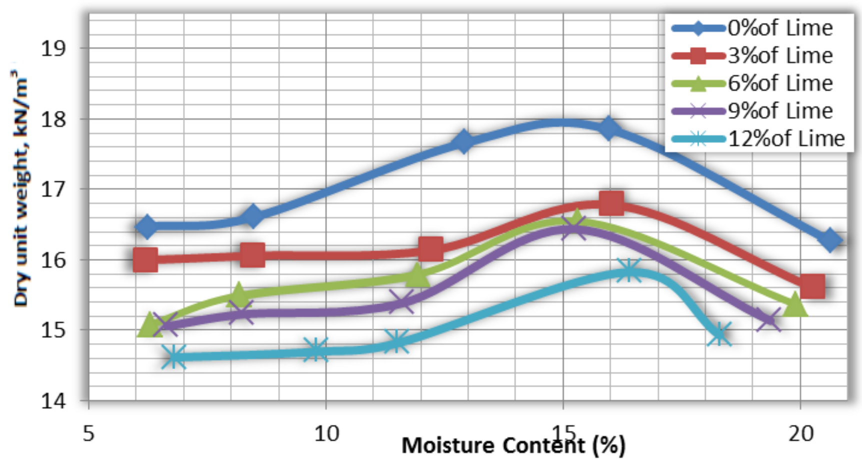

Figure 5. Compaction Characteristics of fully stabilized soil for various lime content

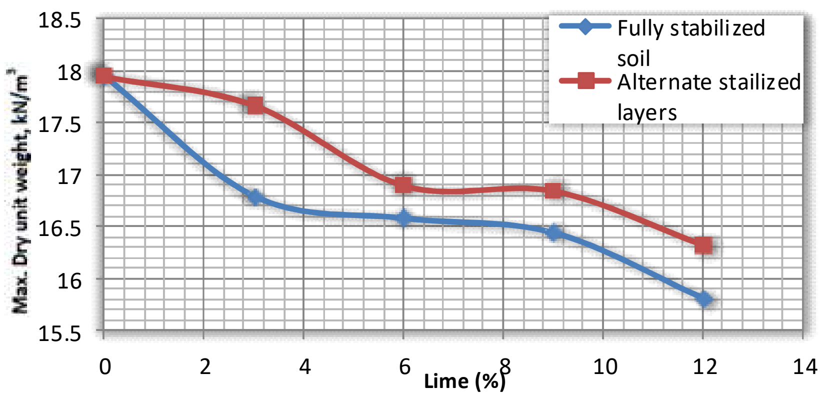

Figure 6. Effect of lime content on maximum dry unit weight

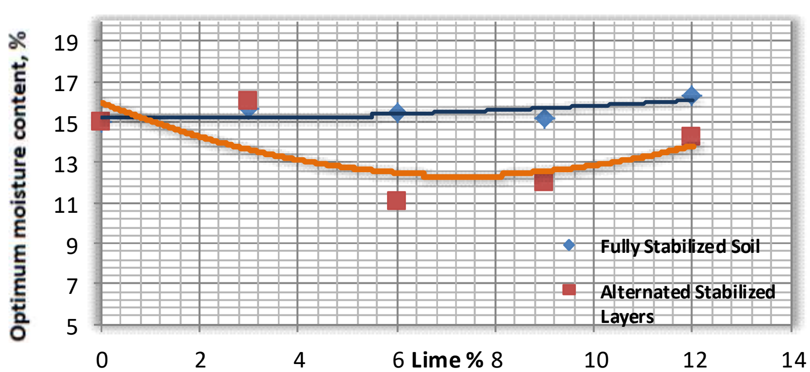

Figure 7. Effect of lime content on optimum moisture content

Alternated stabilized soil layers with soil (Sandwich method) .

The compaction behavior of soil stabilized in sandwich method is shown in Figure 8. Identical compaction relations are found. Regarding the rate of increase and decrease of dry unit weight with moisture content t, the effects are shown to be similar to fully stabilized soil. Figure 6 shows a decrease of maximum unit weight with the lime content and it is due to same reasons mentioned for fully stabilized soil case. No defined pattern of lime effect on optimum moisture content is obtained (see figure 7). This can be attributed to the non- uniform interaction between the soil and stabilized layer.

The reduction in maximum dry density of sandwich stabilized method shown to be less than that on fully stabilized soil method as seen in Figure 6. This is expected effect since the quantity of lime used in sandwich method is smaller than the fully stabilized soil method at any lime content.

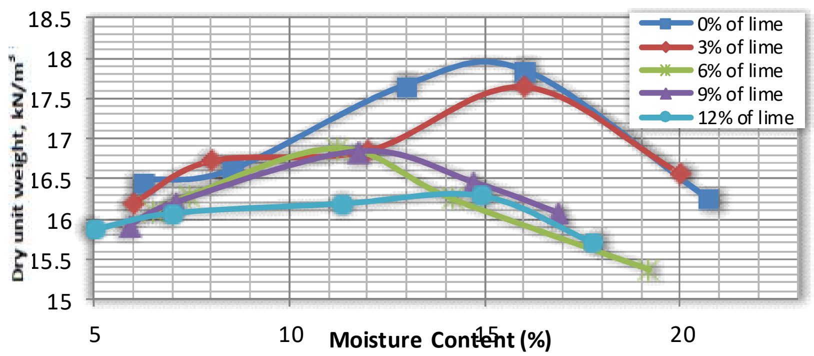

Figure 8. Compaction characteristics of alternated stabilized layers with soil

For different lime content

Unconfined compressive strength characteristics

The strength – moisture content relationships for various lime content are shown in Figures 9 and 10 for fully stabilized soil and sandwich method of stabilization respectively. These behaviors show an increase in strength with moisture content up to maximum strength, then it decreases for higher moisture content. This behavior is identical for all lime content and similar to compaction behavior for various lime content, which indicates that the created dry density is one of the items affecting the produced strength.

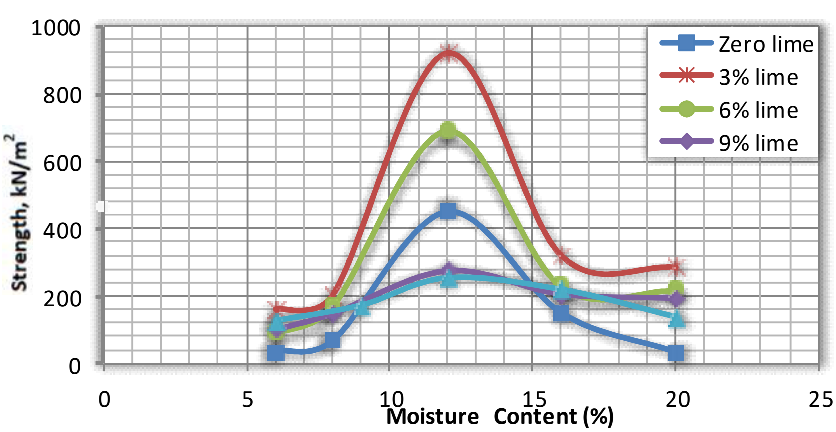

Figure 9. Strength- Moisture content relationship of fully stabilized soil for different lime content

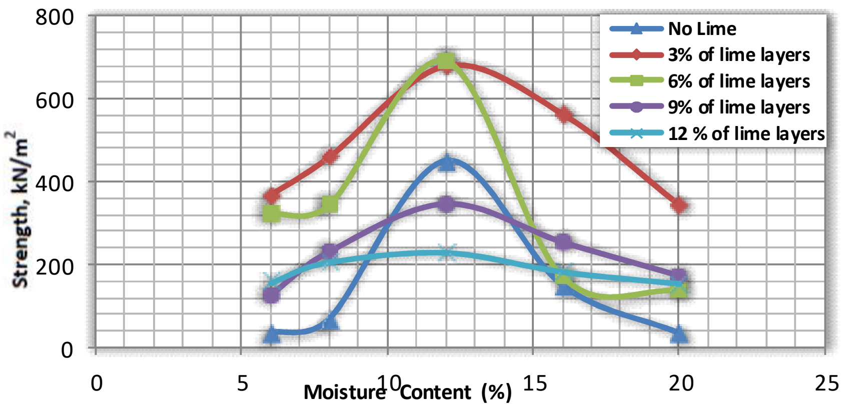

Figure 10. Strength - Moisture content relationship of sandwich stabilized

Soil for different lime content.

. Figure 11 shows the effect of lime content on maximum strength for both fully stabilized soil and soil stabilized in sandwich method. For both cases of stabilization the maximum strength starts to increase with lime content up to ultimate strength corresponding to optimum lime content. For higher percentage of lime than optimum the strength starts to reduce continuously.

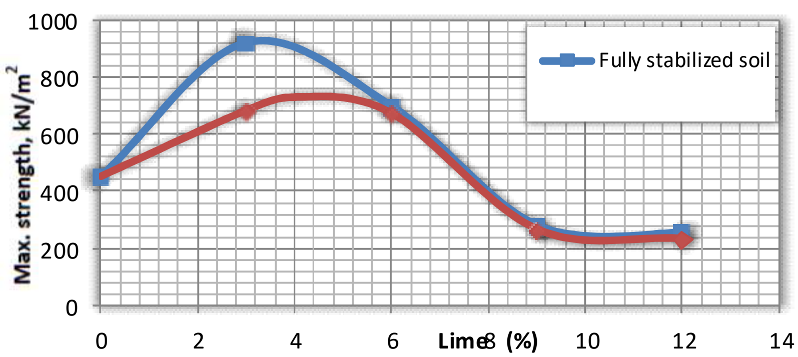

Figure 11. Effect of lime content on maximum strength of stabilized soil

The ultimate strength of 930 kN/m^2 and 750 kN/m^2 shown to be corresponding to optimum lime content of 3.5% and 4.4% for fully and sandwich stabilized soil respectively.

The increase of strength in fully stabilized taken place due to the pozzolnic reaction of lime treatment as a major factor. In case of alternated stabilized layer the increase of strength can be explained as follows: Three alternated layers out of five in specimen are treated with lime and producing a harder layers than the untreated bounded layers due to long term pozzolonic reaction. This system of specimen composition can be considered as a reinforced soil fabrication since the hard layers working as sheet reinforcement. Therefore, based on reinforced earth mechanism, a shear resistance induced at the contact faces between the treated and untreated layers due to the development of additional friction and interaction between these faces. This is producing an increase in overall carrying capacity of the soil mass of the specimen [(13, 14].

Significance of alternated stabilized layers with soil

The effectiveness of alternated stabilized layers with soil from the strengthening point of view can be discussed by determining the Strength Ratio (SR), which means the ratio between the strength of the

alternated stabilized layers with soil to the strength of fully stabilized soil, at the same lime content as:

$$SR = \frac{\text{Strength of altrnated stabilized layers with soil}}{\text{Strength of fully stabilized soil}} \times 100$$

The strength ratio (SR) is plotted against lime content and shown in Figure 12. Since the amount of lime used in alternated stabilized layers specimen is 60% of the amount used in fully stabilized specimen, therefore, a strength ratio (SR) of 60% will be considered as the limit to check the effectiveness of sandwich stabilized method upon the fully stabilized method. This limit is plotted in Figure 12. It can be seen that the variation of SR with the lime content is within the range of (74% - 98%) . This means that the range of advantages, higher than 60%, is (14% - 38%) giving an average of advantages of 26% if only the strength is considered.

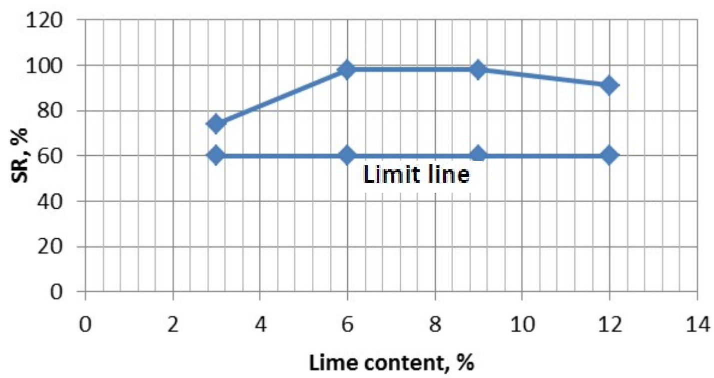

Figure 12. Strength Ratio (SR) versus Lime content

On the other hands, the amount of lime used to stabilize the soil in sandwich method , effort and time of mixing lime with the soil are making 60 % of these of fully stabilized soil. This means that 40% is saved regarding these items.

IV. CONCLUSIONS

1- The maximum dry unit weight of lime treated soil is decreasing as the lime content increases.
2- The maximum compressive strength increases with lime content up to ultimate strength corresponding to optimum lime content and as lime be higher than the optimum, the maximum strength decreases.
3- The optimum lime content is 3.5% for fully stabilized soil and 4.4% for alternated stabilized layers with soil.
4- Regarding the compressive strength of lime treated soils, a significant advantage of an average of 26% is shown when using the alternated stabilized layer with soil method upon the fully stabilized soil method.
5- Secondary advantages of using the sandwich method have considered, namely; using less amount of lime, needs shorter time of mixing soil with stabilizers and consumes less effort for stabilization.

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