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# Studies on compressive strength of sandy clay soil samples with different percentages of lime and nylon fibres.

# Estudios de resistencia a la compresión de muestras de suelos arcillosos arenosos con diferentes porcentajes de fibras de cal y nailon.

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ABSTRACT

To develop economically feasible and durable methods of ground improvement are some of the major challenges faced by geotechnical engineers. Many commonly available stabilisers like lime, fly ash, rice husk ash has been used in many studies. These stabilisers are known to improve the compressive strength of soil. But in order to improve the tensile properties of soil and increase the ductility characteristics, fibres can be included along with the commonly used stabilisers. In this paper values of compressive strength of sandy clay soil treated with different concentrations of lime and nylon fibre is studied and compared with the values of untreated native soil. The compressive strength of soil increases with increase in lime content up to 10%. The compressive strength of soil also increases with nylon fibre inclusion up to a concentration of 0.3%. With further increase in nylon fibre content, compressive strength decreases in the studied samples. In the present study the difference in the increase in compressive strength shown by composites with random and horizontal layers of nylon fibres as inclusions appears to be very small. The present study concludes that a combination of lime and nylon fibre can be a better stabilizer for ground improvement.

Keywords—unconfined compressive strength, lime, horizontal layer, nylon fibre.

RESUMEN

Para desarrollar métodos económicamente viables y duraderos de mejora del suelo son algunos de los principales desafíos que enfrentan los ingenieros geotécnicos. En muchos estudios se han utilizado muchos estabilizadores comúnmente disponibles como cal, cenizas volantes, cenizas de cáscara de arroz. Se sabe que estos estabilizadores mejoran la resistencia a la compresión del suelo. Pero para mejorar las propiedades de tracción del suelo y aumentar las características de ductilidad, se pueden incluir fibras junto con los estabilizadores comúnmente utilizados. En este trabajo se estudian los valores de resistencia a la compresión de suelos arcillosos arenosos tratados con diferentes concentraciones de cal y fibra de nailon y se comparan con los valores de suelos nativos sin tratar. La resistencia a la compresión del suelo aumenta con el aumento del contenido de cal hasta un 10%. La resistencia a la compresión del suelo también aumenta con la inclusión de fibra de nailon hasta una concentración del 0,3%. Con un mayor aumento en el contenido de fibra de nailon, la resistencia a la compresión disminuye en las muestras estudiadas. En el presente estudio, la diferencia en el aumento de la resistencia a la compresión que muestran los compuestos con capas aleatorias y horizontales de fibras de nailon como inclusiones parece ser muy pequeña. El presente estudio concluye que una combinación de cal y fibra de nailon puede ser un mejor estabilizador para la mejora del suelo.

Palabras clave: resistencia a la compresión ilimitada, cal, capa horizontal, fibra de nailon.

## INTRODUCTION

Soil stabilization refers to any physical, chemical, or biological method, or any combination of such methods, that is employed to improve certain properties of a natural soil to make it adequately serve an intended engineering purpose over the service life of an engineering facility. Through soil stabilization, unbound materials can be stabilized with cementitious materials like cement, lime, fly ash, bitumen or a combination of these. The stabilized soil materials have a higher strength, lower permeability and lower compressibility than the native soil. For a successful stabilization, a laboratory tests followed by field tests may be required in order to determine the engineering and environmental properties. Results from the laboratory tests, will enhance the knowledge on the amount and choice of binders. Many stabilizers have been used all over the world to improve the compressive strength of native soil. But in order to improve the tensile strength and enhance the ductility characteristics, fibres have been used nowadays. Both natural and synthetic fibres are used for this.

## MATERIALS AND METHODS

Sandy clay soil was collected from Thonnakkal region of Thiruvananthapuram district. The soil is sieved and the sample passing through 425 μ was used for the study.

Laboratory tests for parameters such as specific gravity, liquid limit, plastic limit, shrinkage limit, unconfined compressive strength, optimum moisture content, maximum dry density and pH are done with the collected native soil to characterise the native soil collected.

With the collected and sieved sandy clay soil, different mixtures were made by mixing with different percentages of lime so as to get four mixtures containing 5%, 10%, 12% and

15% of lime. Compaction tests were conducted with these four mixtures to find out the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD). The same tests were done with the native soil (with 0% of lime) also. For doing the Unconfined Compression Test after different periods of curing, the native soil collected and the four different soil-lime mixtures prepared as above were used. The tests were conducted with the prepared samples on the day of its preparation (0 days) and also after the curing period of 7 and 28 days.

To study the effect of inclusion of nylon fibres, soil-lime mixtures (10% lime) which showed maximum compressive strength was used. Using this soil-lime mixture (containing 10% lime), composites containing different percentages of 2 cm long nylon fibres (0.1%, 0.2%, 0.3% and 0.4%) were made. Compaction tests were conducted with these four mixtures to find out the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD).

For doing the unconfined compression test on composites containing different percentages of nylon fibres, composites containing different percentages of nylon fibres (0.1%, 0.2%, 0.3% and 0.4%) were made as detailed earlier. Two sets of composites were made. In one the nylon fibres are mixed randomly with the soil-lime mixture and in the other set the nylon fibres are laid in horizontal layers in the soil-lime mixture. In the case of composites with horizontal layer of nylon fibres, the fibres were placed in two layers, each layer at a depth of one-third the mould height (mould dimension 38 mm x 75 mm). Unconfined compression tests were conducted with all the samples before curing and after curing for 7 days.

## RESULTS AND DISCUSSIONS

The values of parameters tested with the native soil are given in Table 1.

Table 1 values of parameters tested with the collected and sieved native soil.

| Property | Value |
|---|---|
| Colour | Light Grey |
| Natural water content (%) | 20 |
| Clay (%) | 48 |
| Silt (%) | 14 |
| Sand (%) | 38 |
| Liquid limit (%) | 49 |
| Plastic limit (%) | 25 |
| Plasticity index (%) | 24 |
| Specific gravity | 2.5 |
| MDD ($kN/m^3$) | 18.3 |
| OMC (%) | 15 |
| UCS ($kN/m^2$) | 28.49 |
| pH | 5.72 |

The values of Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of the native soil and of the four soil-lime mixtures are given in Fig. 1 and Fig. 2 respectively.

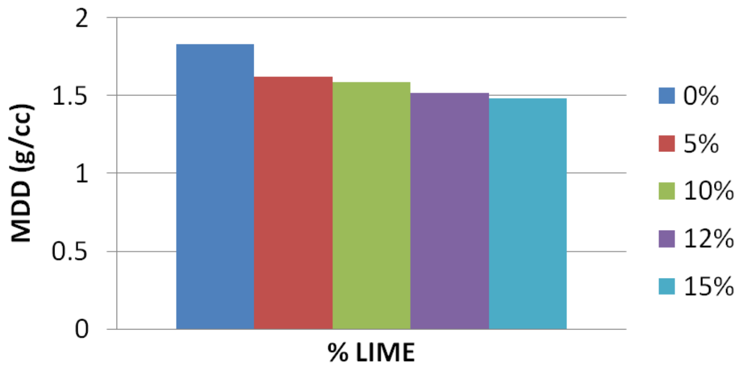


Fig. 1 MDD values for the soil mixtures containing different percentage of lime

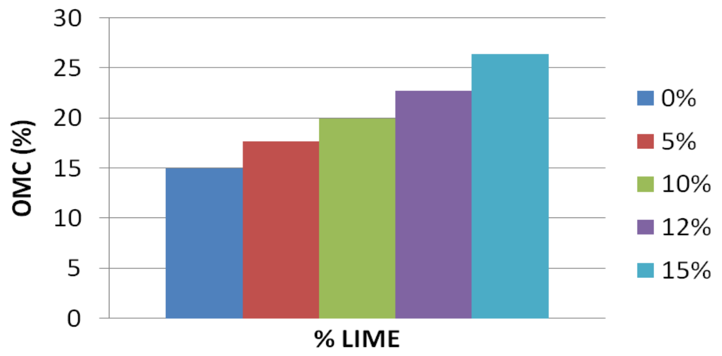


Fig. 2 OMC values for the soil mixtures containing different percentage of lime

From the values shown in Fig 1 and 2 it can be seen that the optimum moisture content increase whereas maximum dry density decreases with the increase in the percentage of lime in the soil mixture (V. Anggraini et al. 2015, N. Das and S. K. Singh, 2019). Similar trend was observed in the study conducted by A. Al-Taie et al. (2016). According to A. Al-Taie et al. (2016) the increase in OMC with increase in lime content is due to more fine and light particles in the mixture. The pozzolanic reaction between clay and lime are also responsible for the increasing OMC of the mixture. For the same reason the MDD decreases with the increase of lime content in the soil mixture.

The values of Unconfined Compression Tests of the native soil collected and the four different soil-lime mixtures after different periods of curing are presented in Fig 3. The values show that the soil-lime mixture containing 10% lime showed the highest compressive strength. In all the samples, maximum UCS is shown after 28 days of curing.

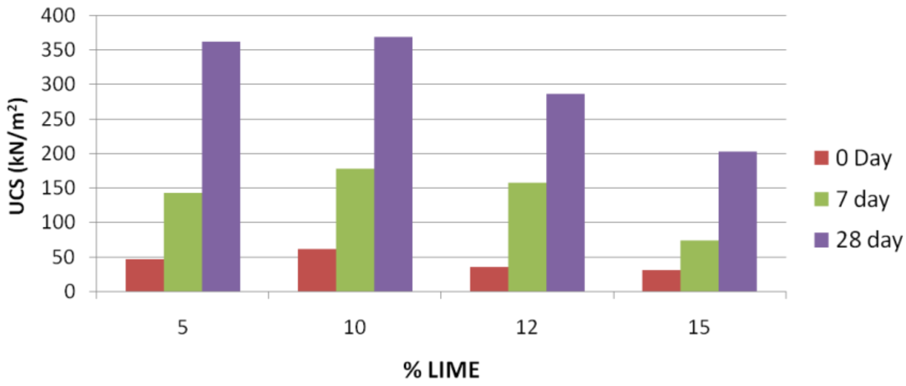


Fig. 3 UCS values of soil-lime mixtures after different curing periods

The values of maximum dry density and optimum moisture content in composites containing different percentages of nylon fibres (0.1%, 0.2%, 0.3% and 0.4%) are given in Fig. 4 and Fig. 5 respectively.

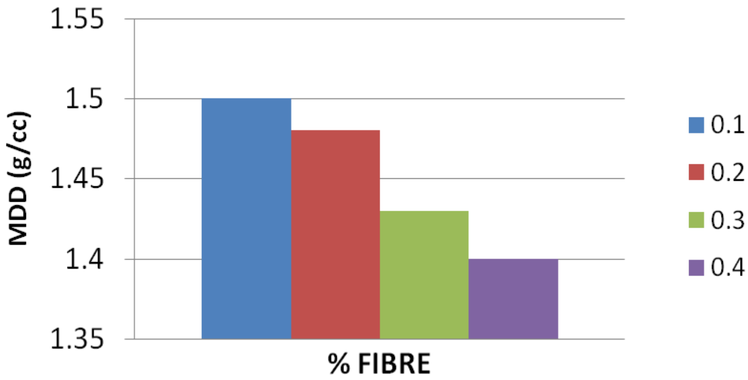


Fig. 4 MDD values in composites containing different percentages of nylon fibres

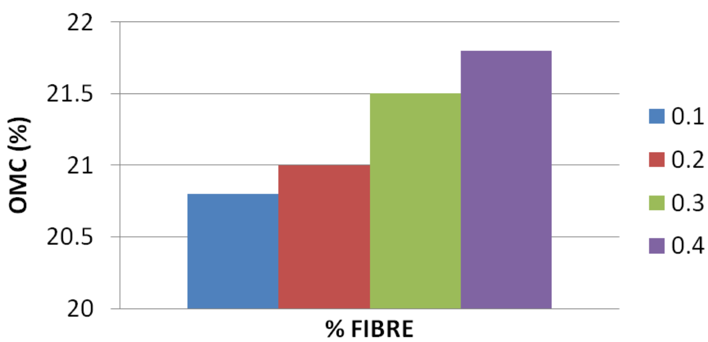


Fig. 5 OMC values in composites containing different percentages of nylon fibres

From the MDD and OMC values given in Fig. 4 and Fig. 5, it can be seen that with the increase in the nylon fibre content in the composite, MDD value decreases and OMC value increases. Same trend was observed in the work done by Arabani M. and. Haghsheno

H (2019). According to them by adding fibres to the soil-lime mixture, a portion of water is absorbed by the fibres and in order to reach the MDD a larger amount of water is needed, leading to an increase in OMC. The decrease in MDD is due to the growth of micro pores which are formed due to the tendency of lime for water absorption and aggregation. The UCS values of the composite with different percentages of nylon fibres arranged in a random manner are given in Fig.6.

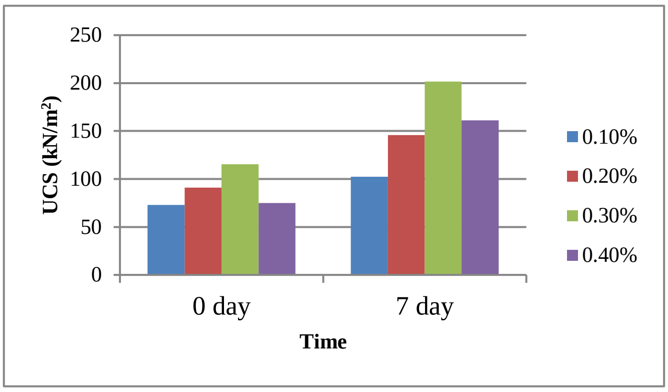


Fig. 6. UCS values of the composites with nylon fibres (random arrangement) after 0 and 7 days of curing

It can be seen that as the percentage of nylon fibre increases up to 0.3% , the UCS values increased and beyond that UCS decreased (Y. Cai et al. 2006). It can also be seen that UCS values were highest in all the composites after the curing period of 7 days. The UCS values of the composite with different percentages of nylon fibres arranged in horizontal layers are given in Fig.7.

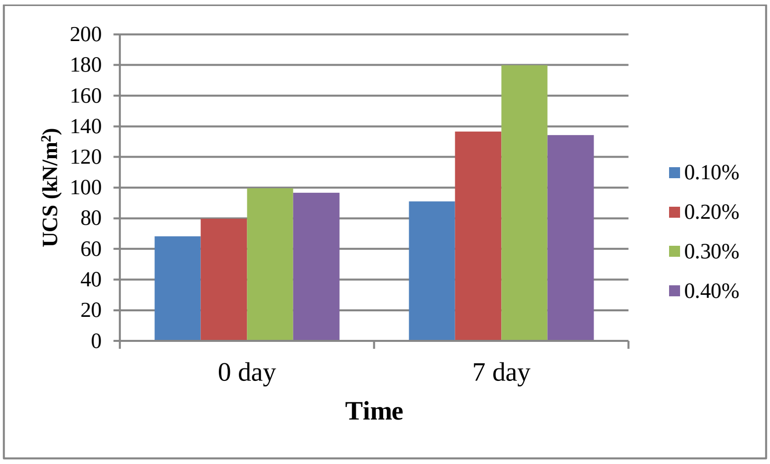


Fig. 7. UCS values of the composites with nylon fibres (horizontal arrangement) after 0 and 7 days of curing

It can be seen that in the composites with horizontal layers of nylon fibres also, as the percentage of nylon fibre increases up to 0.3%, the UCS values increased and beyond that UCS decreased (L. Wei et al. 2018). It can also be seen that UCS values were highest in all the composites after the curing period of 7 days. But it appears that in these composites with horizontal layers of nylon fibres (E. Cicek, 2019), the increase in UCS values is less than the composites with random placing of nylon fibres.

According to Dhar S and Hussain M (2018), the cementitious products formed after lime treatment has rough surfaces and high rigidity, which binds the fibre–soil particles together and provides a compact matrix structure. This helps to increase the effective contact area and interlocking between fibre and modified soil particles, and thus enables greater mobilization of friction between them with an increase in fibre content up to a certain limit. After that further increment in fibre content forms lumps and adheres to each other; thus, there may be deficiency in the contact between soil and fibre which is responsible for reduction of friction coefficient and hence reduces the UCS values. Because of the time-dependent pozzolanic reactions, the stabilization of the lime-treated soil is a long-term process (Rajasekaran and Rao, 1996). Thus, the strength of the stabilized soil increases as the curing time increases. The UCS values of the composite with different percentages of nylon fibres arranged in random and horizontal layers after 7 days of curing are given are given in Fig.8.

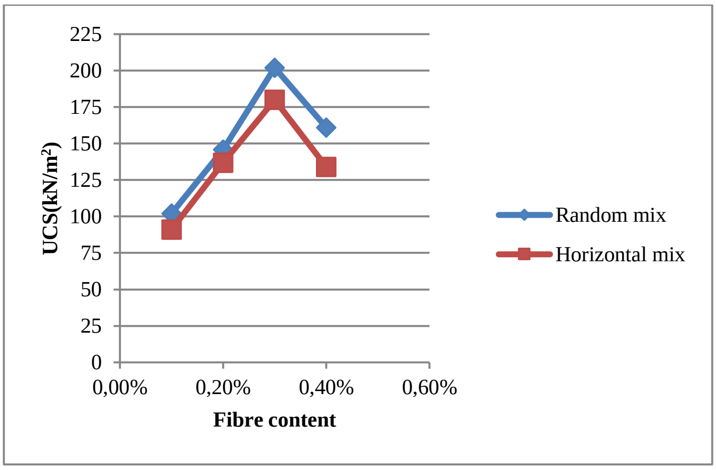


Fig. 8. UCS values of the composites with nylon fibres (random and horizontal arrangement) after 7 days of curing

On comparing UCS values of composites, it can see that both type of placing the nylon fibres are effective in improving the strength of the soil samples. The peak value of UCS shown by composites containing 0.3% nylon fibre placed randomly shows 7.1 times increase than the UCS values of the soil-lime mixture without nylon fibres. The peak value of UCS shown by composites containing 0.3% nylon fibre placed in horizontal layers shows only 6.32 times increase than the UCS values of the soil-lime mixture without nylon fibres. It seems that the difference shown by the composites containing nylon fibres whether randomly placed or horizontally placed is very small.

As conclusions it propose, 1) With the addition of lime optimum moisture content increases where as maximum dry density decreases which is due to the pozzolanic reaction between lime and clay. 2) The compressive strength of soil increases with increase in lime upto 10%. Above 10% lime content, it decreases. 3) With the addition of nylon fibres optimum moisture content increases where as maximum dry density decreases. 4) As the percentage of nylon fibre increases, compressive strength increases up to 0.3% nylon fibre inclusion. With further increase in nylon fibre content, compressive strength decreases. 5) Composites containing 0.3% nylon fibres arranged in a random manner showed 7.1 times increase in compressive strength than the soil-lime mixture without nylon fibres. Composites containing 0.3% nylon fibres arranged in horizontal layers showed 6.32 times increase in compressive strength than the soil-lime mixture without nylon fibres. 6) In the present study the difference in the increase in compressive strength shown by composites with random and horizontal layers of nylon fibres appears to be very small. 7) It seems that together with lime stabilisation, fibre reinforcement is adoptable and may be an economical method of ground improvement. Due to time constraints, curing period up to 7 days has been done. It may not be sufficient to make a conclusion regarding effect of time on compressive strength of soil sample. Hence curing period extending few months have to be evaluated to reach a conclusion.

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