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Load – Penetration Behaviour of Composite Soil with Nano – Alumina Material under Soaked and Unsoaked Condition

Sivapriya S.V[1][0000-0002-9818-1393], Madhu T. R[2] and Sajid Ali[2]

[1] Associate Professor, Department of Civil Engineering, Sri Sivasubramaniya Nadar College of Engineering, Chennai – 603110, India.
[2] Undergraduate Students, Department of Civil Engineering, Sri Sivasubramaniya Nadar College of Engineering, Chennai – 603110, India.
sivapriyavijay@gmail.com

Abstract. The load – penetration behaviour of virgin soil is compared with initial lime consumption of the soil as Lime column and Lime column with 0.5 % of Nano Alumina in column form. Tests were conducted in CBR mould with a consistency index of 0.42 under soaked and unsoaked condition. Unsoaked condition tests were conducted after two hours of preparation of soil sample and for soaked condition, the sample is immersed in the water for four days. Tests results from unsoaked condition show with inclusion of lime, the load-bearing increases by about 40% and with the addition of Nano – Alumina into the lime column, it increases by 105%. Whereas under soaked conditions, the increase in percentage is 20 % for both soaked and unsoaked condition.

Keywords: Load-penetration, Lime column, Alumina, Soaked condition, Unsoaked condition

1 Introduction

Stabilisation of soft soil ground through chemical treatment is a traditional method. For structures such as runway, the time allotted for stabilization (renovation) will be diminutive and to increase the rate of stabilization within the stipulated time; innovative additional admixture should be required. Considering this scenario, the nano-material came in utilisation to increase the strength of a material i.e concrete or soil [1].

The usage of nanoparticles in concrete is to increase its compressive strength[2]. Nano metakaolin along with carbon nanotubes improves the interaction and increases the compressive strength by 18%[3]. Also, Carbon nanotube is widely used in the crack – bridging, filling the hole, modification of soil's microstructure and nucleation effects([4],[5]).

The main problem in road system is the formation of crack which may be due to inadequate strength found in the subgrade soil which can be assessed from the CBR value. However, the usage of nanomaterials can mitigates cracks formation due to its functional characteristics ([6],[7]). For sandy soil, with the inclusion of nano silicate

and artificial pozzolan, the maximum dry density increases and strength increases (9) with the increase in cement content [8]. However, for a clayey soil, addition of nano-Alumina reduces the swelling index of the soil in addition to strength improvement[10].

Considering the advantages of nano in increasing the strength of the soil, nano – Alumina is added to the soil with lime as an activator as a column. The influence of water content and admixture influence ratio is studied in the laboratory and discussed in this paper.

2 Materials

The clay needed for experimenting is obtained from Thaiyur, Chennai. The soil was then pulverized and the properties of the same are listed in Table 1.

Table 1. Properties of Soil

Properties	Indian Standard Code	Value
Specific Gravity	IS 2720 (Part III/I) Determination of Specific Gravity of Fine grained Soil[11]	2.76
Particle Percentage, %		
Sand	IS 2720 (Part IV) Methods of test for soil - Grain size analysis[12]	2.88
Silt		28.41
Clay		68.71
Liquid Limit, %	IS 2720 (Part V) Determination of Liquid and Plastic Limit [13]	75.8
Plastic Limit, %		23.49
Differential Free Swell Index, %	Determination of free swell index of soils[14]	76.48
Soil Classification	IS 1498-1970 (Reaffirmed 2002) : Classification and identification of soil[15]	CH

Hydrated lime which is used as an activator was obtained from M/s. Shiyal Chemicals and the Nano-sized particle Alumina chosen for the test series was obtained from M/s. Astraa Chemicals, India.

3 Methodology

The Load – Penetration characteristics of soil is evaluated by conducting unit cell study with lime and lime + nano - Alumina and then compared with virgin soil (Fig.1). The unit cell model comprises a single column and its equivalent circular influence zone. It is used to represent a column located on the interior of an infinitely large group of columns. A similar concept is used for the penetration analysis on lime and lime + Nano-Alumina columns. The soil is prepared at a soft consistency of 0.42

under soft consistency. Specimens are prepared and tested after soaked and unsoaked curing conditions [16].

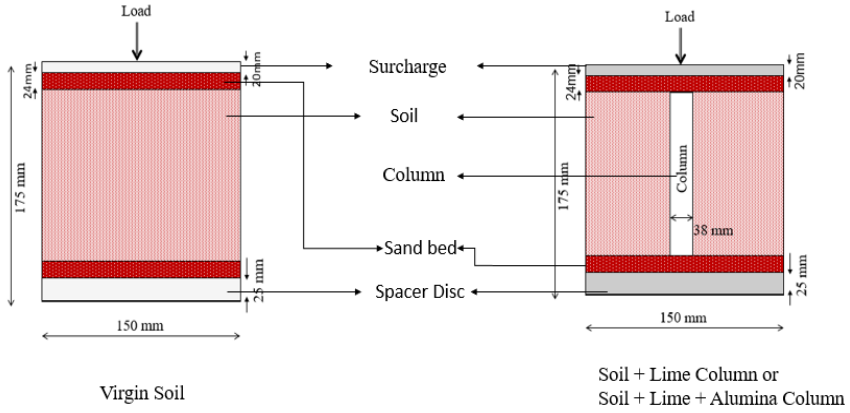


Fig. 1. Schematic representation of Test sample

Lime used as an activator is mixed at Initial Consumption Limit (ICL) as suggested by Eades and Grim [17] and the value was found as 4.5%. The sample preparation for untreated ground involves pouring of soil mixture having consistency index of 0.42 into the CBR mould layer by layer for achieving uniformity in sample preparation. For the treated ground, the column was prepared by mixing water and lime at a proportion of 1:2 and poured into a predrilled hole inside the soil using a pipe of inner diameter 38 mm. The pipe was first placed in the centre of the mould, the soil is then placed at various layers. Once the soil is filled, the lime + water is poured into the column and then the pipe is removed and allowed for two days for column formation and tested for unsoaked condition (Fig. 2). The preparation of the untreated and treated soil sample is the same for the soaked condition, but the sample was immersed in a bucket of water for 4 days.

a. Sample with Column

b. Under Soaked Condition

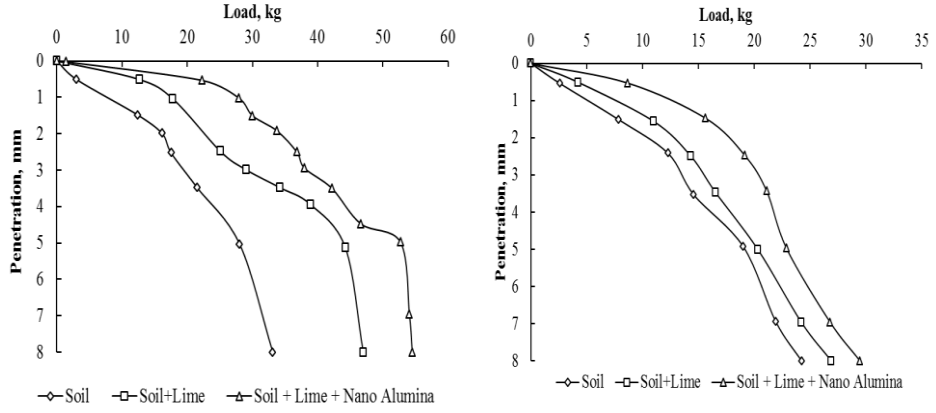
Fig. 2. Prepared Sample

An arbitrary amount of 0.5% of Nano is added to a lime column for studying its influence on load- penetration behaviour. Upon preparation of the sample, the soil specimen is placed on compression testing machine and a 50 mm diameter plunger is kept on the top surface of the specimen. The load was applied into the prepared soil at a rate of 1.25 mm per minute. The load was applied through a plunger to penetrate the specimen and the load which causes 2.5 mm and 5 mm penetration was recorded.

4 Results and Discussion

4.1 Effect of water content vs load

The soil is mixed with water at a consistency index of 0.42 for all the three conditions. With the known Atterberg's limit of the soil, the water content for the virgin soil is 44.38%. The liquid limit of soil + ICL and soil + ICL + Nano were 54 and 53 % respectively with non – plastic nature. The water required to possess a consistency of 0.42 were 31.74 and 31.16%. The reduction in water content is due to the replacement of ions present in the material/ water with calcium ions, which reduces the plasticity index and shrinkage properties called flocculation and agglomeration[18]. The load at 5 mm penetration is used for interpretation of data (Fig. 3).



a. Unsoaked Condition b. Soaked Condition

Fig. 3. Load- penetration characteristics

For unsoaked condition, there is an increase in load by 58.01 and 88.25% for 5 mm penetration; whereas for soaked condition, the increase is by 6.89 and 20.47 % for soil +ICL and soil +ICL +Nano conditions respectively (Fig. 4). With a reduction in water content due to emission of heat by the addition of admixtures, due to agglomeration of Nano Alumina, weak zones were formed with a decrease in density and increase in load in case of unsoaked conditions. Load Intensity Vs Penetration

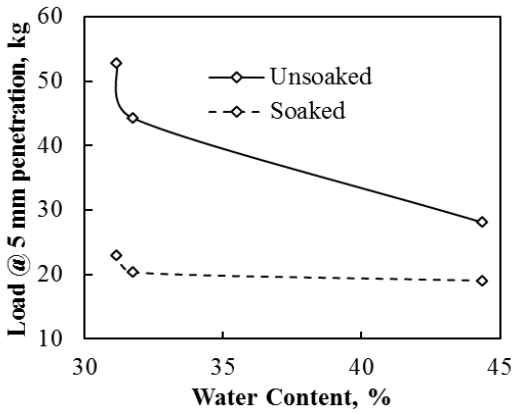


Fig. 4. Water content Vs load

Table 2 shows the CBR values for different proportions. It is observed that CBR value increases with increase in admixture. The chemical reaction occurs due to hydrated lime reduces water holding capacity thereby inducing an increase in CBR value. From the test results, it clearly shows that under unoaked condition, the CBR value increases by 42. 89% and 108.59% for Soil + ICL and soil + ICL+Nano combination; the same is observed for the soaked condition with an increase in CBR value by 18.48 and 54.35%.

Table 2. CBR values

Combinations	Unsoaked	Soaked
Soil	1.28	0.92
Soil + Lime	1.83	1.09
Soil +Lime+ Nano	2.67	1.42

Addition of nano Alumina enhances the bonding between the soil particles; leading to an increase in CBR value in case of lime stabilised soil. Calcium from the hydrated lime combine with the silica and alumina produces calcium – aluminate a-hydrate, a compound leading to cementitious action which helps in increasing the strength. Weak soil stabilised with nanoparticles enrich the impermeable and load-bearing characteristics of soil, making an unsuitable land into a suitable ground.

Admixture Influencing Factor (AIF) [19], a ratio of CBR (2.5 mm penetration) value of treated soil to untreated soil is referred for further understanding. Soil stabilised with lime increases the CBR value, because of the bonding created through their chemical reaction. From Fig. 5, the ratio increases almost linearly and shows a greater increase with the addition of nano- alumina. To speed up the rate of increase in strength, nano is added. With the addition of nano, the ratio increases about double the time than the initial condition.

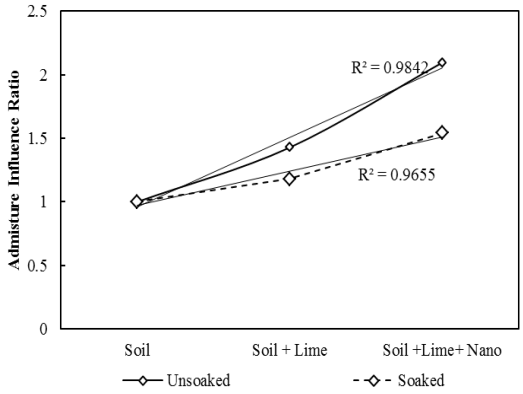


Fig. 5. Influence of admixtures in *AIF*

4.2 Limitations

Tests were conducted till 8 mm penetration. The soil sample was removed and the condition of the column was observed. Small bulging was observed near the top of the column due to its load distribution mechanism. Due to damage in the ground during sample ejection, the depth of location of bulging was not estimated. In addition to that, the dial gauge fixed in the set-up in soaked condition remained constant suggesting that the addition of chemical additives inhibit the swelling potential of the soil.

5 Conclusions

Laboratory tests were conducted to understand the influence of nano – Alumina with lime in weak soil in this study. A set of three combinations was used; i. soil, ii. Soil + ICL and 3.soil +ICL + nano- Alumina. The lime (ICL) and lime (ICL) + nanomaterial were injected into the soil as a column with an inner diameter as 38 mm. The following observations were inferred,

1. The water content reduces with the inclusion of lime and nano into the soil and also contributed to improving the load-bearing strength of the soil. .
2. The CBR value increases drastically with the addition of admixture, the increase is about 42. 89% and 108.59% for Soil + ICL and soil + ICL+Nano combination respectively. The similar increment is also observed for the soaked condition. The increment is about 18.48 and 54.35% respectively.
3. The AIF increases linearly with the addition of admixtures.

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