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Short-term Investigation to the Effectiveness of Cow Dung Powder on Lime Stabilized Tropical Soil in Road Construction

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Abstract:
Defects in properties of most soil samples encountered in construction industry call for search and research on different treatments measures to treat the available soils so as to meet up with the required standards. Cow Dung Powder (CDP) was used interchangeably with lime at ratios 4:0, 3:1, 1:1, and 0:4 (Lime: CDP) using the optimum lime contents derived from the plasticity of disturbed soil samples (granular material and silt-clay material)collected from two different locations (A and B) within Ado Ekiti, Ekiti state. The soil samples were subjected to laboratory tests such as particle density, particle size distribution, atterberg limits, compaction, California bearing ratio and unconfined compressive strength in accordance with British Standards (BS 1377: 1990 and BS 1924: 1990). Optimum lime contents of 8% and 6% by weight of soil samples as derived from the Plasticity index of soil samples A and B were used which serve as the basis for the quantity of lime and cow dung powder used at different ratio. Reasonable improvement was observed on the properties of the soil samples when stabilized with lime-cow dung powder. The investigation revealed that mix 1:1 and 3:1 of lime and cow dung powder are best suitable for granular and silt-clay soils respectively. Strength of the stabilized soils was monitored for fourteen days in this research. Further study to examine the long term performance of biodegradable material (CDP) in soil stabilization should be examined.
***Key Word**: Cow dung powder; Particle density; Lime; Biodegradable material; Tropical soil.*

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I. Introduction

Soil plays an important role in construction industry as it serve as fill materials and foundation on which civil engineering structures are built. Development in society and the process of laterization has made it difficult in most times to get completely perfect soil samples for construction purposes as findings on most of the available laterites used for construction of roads and as fill materials had shown that many of these soils are deficient either in terms of their particle size, strength and water retention capacity (Mustapha *et al.*, 2014).. Tropical soils are often found in very hot weather region with a lot of rainfall (soils.org). Strength properties of soil are influenced by so many factors of which are biological wastes, agricultural waste and industrial waste. Gupta *et al.*, (2016), defined Cow dung as the undigested residue of food material consumed by bovine animal species and excreted to the surface of the earth. While shifting the cowshed and in the movement of cattle from one location to another in search of food, they defecate on earth surfaces. The feces which dropped on soil stayed for period of time until it decomposed, rain fall on it and penetrate into the soil or packed by people who used it as either manure or as security on plant against attack from other animals.

Cattle manure is basically made up of digested grass and grain. Cow dung is high in organic materials and rich in nutrients. It contains about 3 percent nitrogen, 2 percent phosphorus, and 1 percent potassium (3-2-1 NPK). In addition, cow manure contains high levels of ammonia and potentially dangerous pathogens. For this reason, it's usually recommended that it be aged or composted prior to its use as cow manure fertilizer. Organic amendment such as crop residues, animal manure, logging and wood residue, various industrial organic wastes, food processing and fiber harvesting wastes are naturally occurring compound that are used as additives to improve soil physical condition and/or plant nutrition (Brady, 1990; Donahue *et.al*, 1990; Follet *et al.*, 1981; Chen and Avnimelech, 1986)

Organic residues from plants and animals, which are on or in the soil, are beneficial to soil and plant grown on it in various ways such as: (i) serving as the principal storehouse for anions essential for plant growth such as nitrogen, phosphates, sulphates, borates, molybdates and chlorides, (ii) increasing the cation exchange capacity of a soil by a factor of 5 to 10 times that of clay, (iii) buffering the soil against the rapid change due to acidity, alkalinity, salinity, pesticides and toxic heavy metals, (iv) reduces water and wind erosion by protecting soil peds against destruction especially by high intensity storms (Follet *et al*., 1981).

Organic amendments are known to have favourable effects on soil physical properties. Farm yard manure has been found to improve bulk density, resistance penetration, infiltration rate, pH, organic carbon, CEC and available N, P and K (Ganal and Singh, 1988). An interesting finding is given by Petterson and Von Vistinghausen (1979) reporting that the subsoil was compacted in plots receiving only inorganic fertilizer for a period of 20 years. The subsoil on the manure plots had a better structure and a lower bulk density. Such an effect on the deep subsoil layers would indicate that organic fraction migrate downward and are active below the plough layer in the soil. Such migration could be due to the movement of earthworms (Chen & Avnimelech, 1986).

The addition of organic manure to soils has been found to be effective method not only to increase total aggregation but also increase the preparation of water stable aggregates. Three years after a single application (50 kg/ha organic manure to a heavy clay soil, the soil percentage of water stable aggregates more than doubled (Vigerust, 1983). Crumble stability of arable soils can usually be increased if regular application of farm yard manure is done, though the amounts required may be very large. Annual application of 35 tonnes/ha for a century have made a measurable increase in the crumble stability of Rothamasted soil (Russell, 1988).Cow dung powder was used as replacement for cement in production of blended concrete by Ayeni *et al*. (2018). Samples of concrete was produced with 5%, 10%, 15%, 20%, 25% and 30% CDP in replacement of cement and tested for compressive strength. The study revealed that replacement of cement with up to 20% CDP met the strength requirement for the production of light concrete.

In quest of replacing the conventional binder in the production of concrete, many researchers (Sruthy et al., 2017; Venkatasubramanian et al., 2017; Arthika et al., 2018; Kumar and Anbuchezian, 2018) have tried using Cow dung ash as partial replacement of cement and lime. It was affirmed that 6% to 8% by weight replacement of cement with cow dung ash is effective in concrete production. This study is therefore aimed at investigating the short term performance of lime and cow dung powder as stabilize materials for tropical soil in road construction.

II. Materials and Methods

The major materials used for the study are lateritic soil, lime and cow dung. Samples of soil used were collected in disturbed state from two different burrow pits in Ado-Ekiti, Ekiti state, Nigeria. The soil samples collected from these pits which are located along Ado-Ilawe road and Ado-Ikere road are tagged as samples A and B respectively. Cow dung was obtained from cowshed located within the Federal polytechnic, Ado-Ekiti and hydrated lime used was purchased from chemical retailer shop in Ado-Ekiti. The study area has an annual mean temperature ranges between 25.5°C and 26.7°C while the annual rainfall varies between 1000mm and 1500mm.Cow dung obtained was sun dried, grinded to powder and sieved with mesh of 300µm aperture size before used.

The soil samples were stabilized with 0%, 2%, 4%, 6%, 8% and 10% lime by weight of dry soil and subjected to particle density and Atterberg limits test in other to obtain the lime content (in percentage) that will produce the lowest value of plasticity index (optimum lime content). Lime and Cow Dung Powder (CDP) were mixed interchangeably at proportions 1:3, 1:1, 3:1 and 4:0 (CDP: Lime) totaling the percentage of optimum lime content. The blended additives were used to stabilize the soil samples and were subjected to laboratory tests such as Atterberg limits, Compaction, California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS).

PARTICLE DENSITY

This test was carried out in accordance with the specification given in BS 1377:2:1990 for natural soil samples and in accordance with BS 1924: 1990 for stabilized soil samples 5 using density bottles and the value calculated using equation 1.

$$G_s = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)} \qquad \text{Eq. 1}$$

W_1 = Weight of empty density bottle, W_2 = Weight of bottle + dry soil, W_3 = Weight of bottle + soil + water and W_4 = Weight of bottle + water.

PARTICLE SIZE DISTRIBUTION

500grams of an air dried soil sample was weighed and soaked in water for 24 hours to allow for easy removal of fine particles from the lump of soil. The soaked samples were then washed through 0.075mm sieve. The residue was dried in the oven at a temperature of 105^0 C for 18 hours. The dried residue was poured into a set of sieves arranged in descending order of aperture size, placed on sieve shaker and agitated for 10 minutes. Percentage of soil retained and passing each of the sieves was calculated. The filtrate was allowed to settle and subjected to hydrometer test using 152H hydrometer bulb. The percentage passing each sieve is then plotted against the particle size.

ATTERBERG LIMITS

Some quantities of dry soil sample were pulverized using mortar and pestle and made to pass through 0.425mm sieve. 200grams of sieved soil samples were stabilized with lime from 0% to 10% in step of 2%. Lime and CDP blended together was used interchangeably in ratio of five trials (sum of which not exceeding the lime contents that produced the lowest values of plasticity index) to stabilize soil samples A and B which was tested to ascertain the plastic and liquid limits. The samples were tested in accordance with British Standards (BS 1377:2:1990) while the cone penetrometer method of determining liquid limit was adopted.

COMPACTION

The standard Proctor method test of compaction was employed. The method was in accordance with British Standards (BS 1377:4:1990). The test was conducted on the soil samples stabilized with lime-cow dung powder at varying proportions equivalent to the optimum lime contents for both soil samples. Graph of dry density against moisture content was plotted, from which the optimum moisture content and maximum dry density of the soils at different additive contents were obtained.

CALIFORNIA BEARING RATIO

The test was carried out in accordance with part four of British Standards (BS 1377:1990) in order to assess the suitability of soil samples to be used as fill material. The test was conducted on the soil samples stabilized with lime-cow dung powder at varying proportions equivalent to the optimum lime contents for both soil samples. Graph of penetration against load was plotted to show the behavior of the soil to loading different additive contents. The California Bearing Ratio (CBR) value was calculated using equation 2.

$$CBR = \frac{Test\ Load\ (kN)}{Standard\ Load\ (kN)} \times 100\% \qquad \text{Eq. 2}$$

UNCONFINED COMPRESSIVE STRENGTH

The test was carried out in accordance with part 7 of British Standards (BS 1377: 1990). Three different remolded soil samples were used as specimen for each proportions of lime-cow dung powder stabilized soil and tested using compressive machine of known proving ring factor. The unconfined compressive strength values of the soil were determined by dividing the maximum crushing force of the soil with the corrected area as shown in equation 3.

$$UCS = \frac{Maximum\ Crushing\ Force\ (kN)}{Corrected\ Area\ (m^2)} \qquad \text{Eq. 3}$$

III. Result and Discussion

Particle Density

The particle density of soil samples A and B as shown in Fig. 1 at natural state are 2.50 and 2.43 respectively. The values lesser than 2.60 shows an indication of organic materials in the soil (Wright, 1986). Density of the soil particles increased appreciably when lime and CDP were added to them. Lime was found to be optimal at 8% and 6% by weight of soil sample while optimal CDP was gotten at 4% and 6% for soil samples A and B respectively. Reduction observed in values of particle density beyond the observed optimal additives dosage in soil samples A and B respectively could be as a result of increase in void in the samples due to the increase in quantity of additives used.

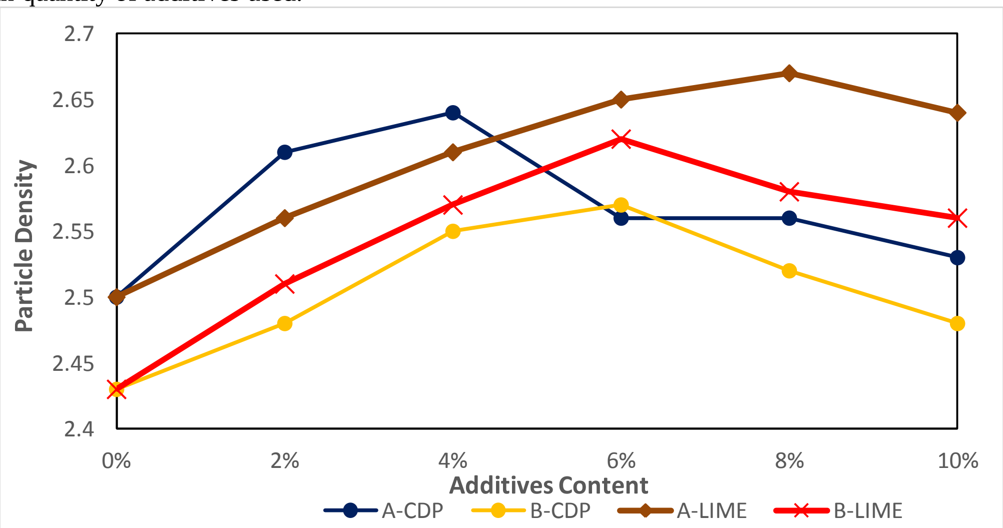


Fig. 1: Particle densities against CDP and lime contents for soil samples A and B

Particle Size Distribution

Particle distribution in percentage weight of soil samples A and B are as shown in Fig. 2. The quantities of soil (29.5% and 37.4%) passing 0.075µm sieve for soil samples A and B shows that the samples are respectively granular and silt-clay materials (AASTHO, 1986). The samples are further classified as well graded material.

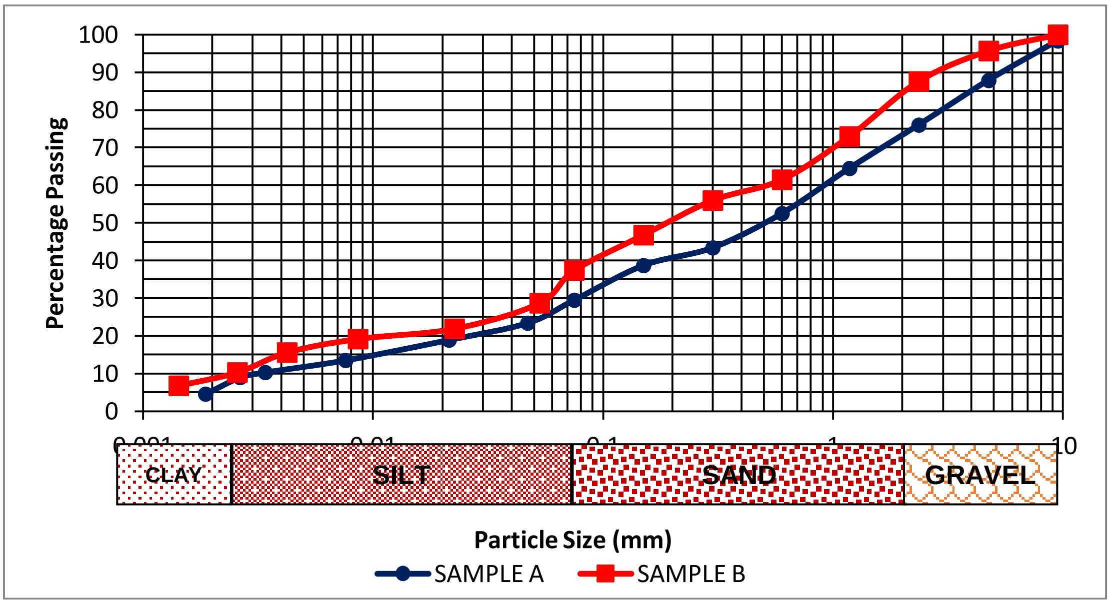
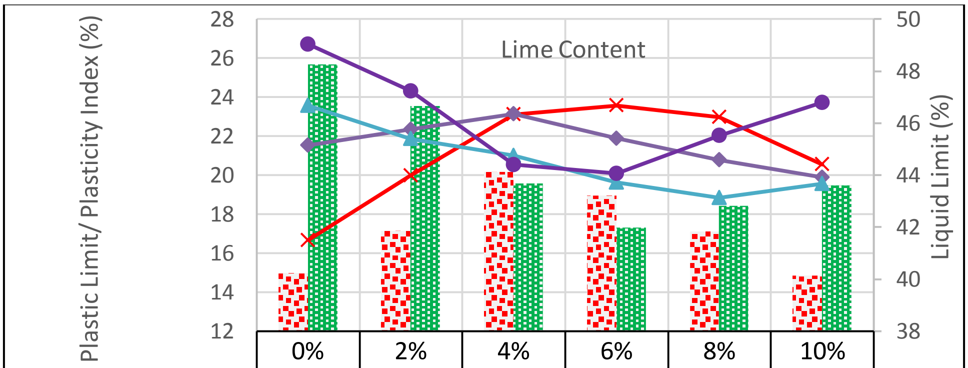


Fig. 2: Particle Size Distribution Curve

Atterberg Limits

The effect of lime on the Atterberg limits behavior of soil samples A and B is presented in Fig. 3. The liquid and plastic limits of soil sample A increase with increase in lime to 4% and 6% dosage respectively. Soil sample B has its liquid limit reduced up to 6% lime and its plastic limit increased to 4% lime content. The plasticity indexes of both samples reduced as the lime contents increases until it reaches 8% and 6% dosage for soil samples A and B respectively.

The natural soil samples A and B having plasticity index value greater than 11% show the samples as clayey materials. Soil samples A and B were further classified according to AASHTO (1986) as A-2-6 and A-7-6 respectively.



	0%	2%	4%	6%	8%	10%
Sample A (LL)	40.23	41.85	44.12	43.21	41.82	40.12
Sample B (LL)	48.24	46.65	43.67	41.96	42.81	43.6
Sample A (PL)	16.66	19.98	23.12	23.58	22.98	20.56
Sample B (PL)	21.53	22.34	23.14	21.88	20.78	19.88
Sample A (PI)	23.57	21.87	21	19.63	18.84	19.56
Sample B (PI)	26.71	24.31	20.53	20.08	22.03	23.72

Fig. 3: Atterberg limits behavior of soil samples A and B stabilized with lime.

Generally speaking, liquid limit values for soil samples A and B increases with an increase in the percentage of CDP in the lime-CDP proportions used as presented in Fig. 4. This could be attributed to the looseness of CDP which could as well increase its affinity for water. Lime-CDP performed optimally on the plasticity indexes of soil samples A and B at ratios 3:1 and 1:1 respectively of the optimum lime contents of both soil samples.

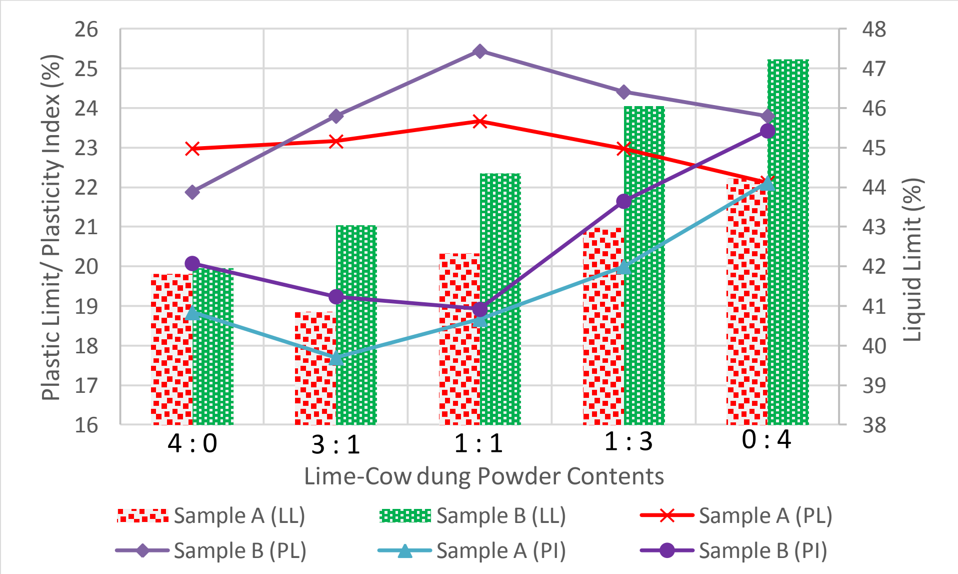


Fig. 4: Atterberg limit values against additives contents

Compaction

Compaction characteristics of both soil samples compacted with the energy of standard Proctor are as shown in Fig. 5. Maximum Dry Densities (MDD) of soil samples A and B at natural state were observed to be 1785Kg/m^3 and 1768Kg/m^3 and Optimum Moisture Contents (OMC) of 10.76% and 12.34% respectively. Values of MDDs for soil samples A and B greater than 1760Kg/m^3 make the samples suitable for use as subgrade or fill materials (FMWH, 1997).

As shown in Fig. 5, MDDs and OMCs of soil samples A and B increases beyond the natural samples with the addition of lime-cow dung powder irrespective of the additives proportions. Peak values of 1868Kg/m^3 and 1828Kg/m^3 for MDDs were observed for stabilized soil samples A and B at ratio 1:1 lime-cow dung powder. The increase in OMC of both soil samples could be as a result of the affinity of the powder (CDP) to water.

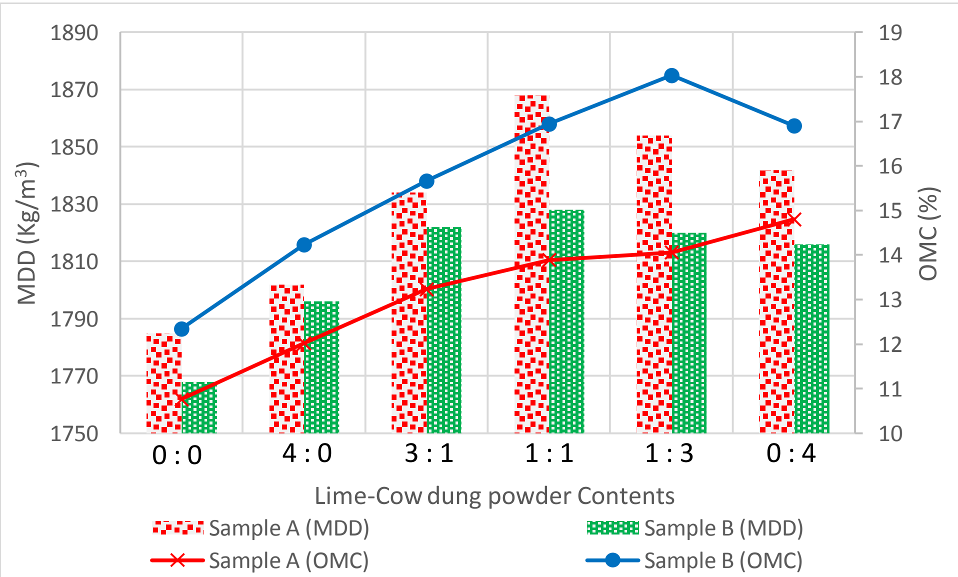


Fig. 5: Compaction Characteristics against Lime- Cow dung powder

California Bearing Ratio

Graph showing the California Bearing Ratio (CBR) results of soaked soil samples A and B at natural and stabilized states are as shown in Fig. 6. CBR values of soil samples A and B at natural state are 12.56% and 10.87% respectively. Addition of lime-cow dung powder at varying proportions increases the CBR values of both soil samples (though less than 30% recommended) with the optimum values 16.08% and 14.86% observed at ratios 1:1 and 3:1 lime-cow dung powder (FMWH, 1997).

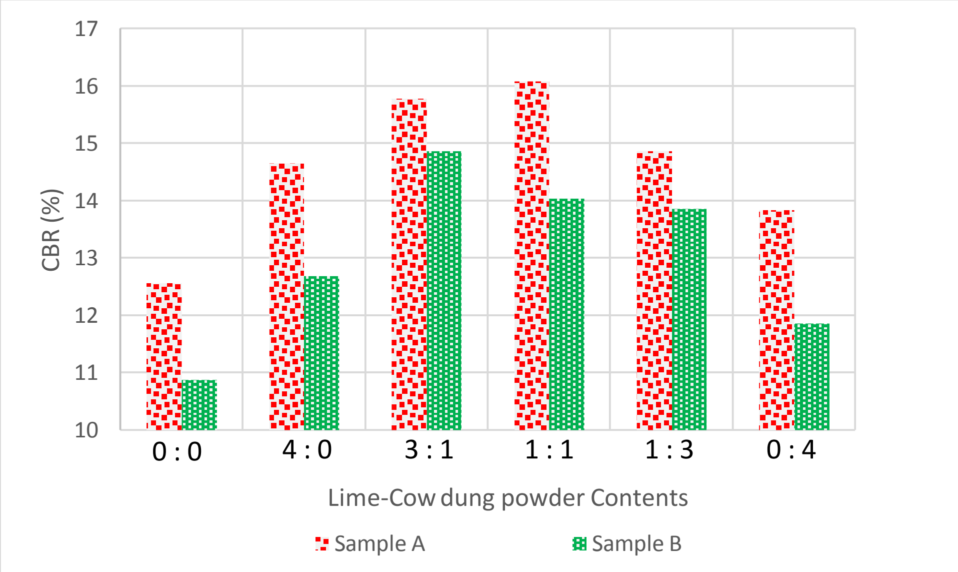


Fig. 6: California Bearing Ratio against Lime- Cow dung powder

Unconfined Compressive Strength

Unconfined Compressive Strength (UCS) of soil samples stabilized with lime-cow dung powder was examined at 7 and 14 days curing. The UCS values as shown in Fig. 7 improved with the addition of lime-cow dung powder and curing age. Cohesion of the soil samples increases with the addition of lime-cow dung powder as its clay consistency which were initially moderately stiff improved to very stiff consistency (engineeringcivil.com, 2020).

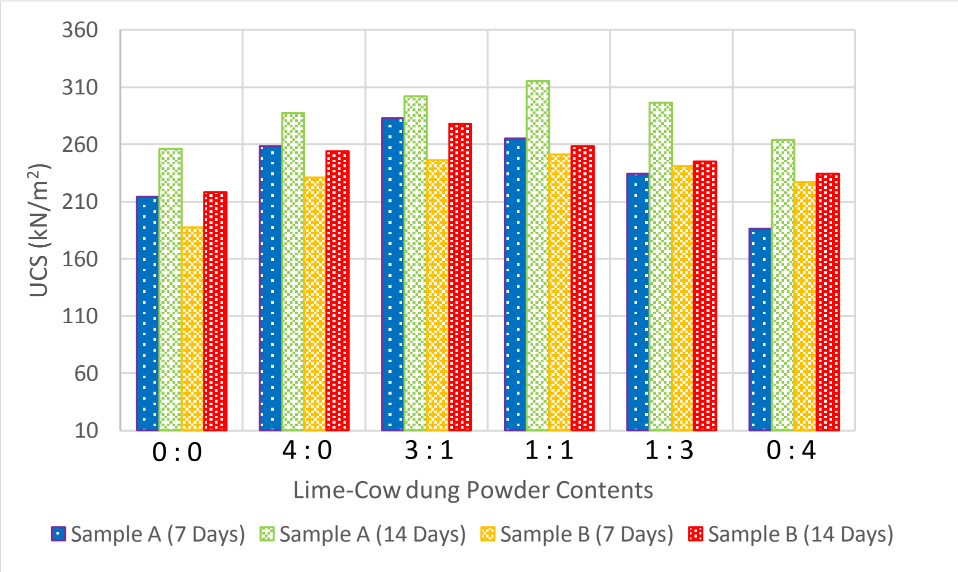


Fig. 7: Unconfined Compressive Strength values against Lime- Cow dung powder

IV. Conclusion

The soil samples were tested in natural and stabilized states in accordance with British standards BS 1377 and BS 1924 (1990) respectively. Results obtained revealed the effectiveness of the combination of lime and Cow dung powder on some geotechnical properties of A-2-6 and A-7-6 soils. The soils were stabilized with lime and Cow dung powder at different mix proportions, sum of which is equivalent to the optimum lime contents that gave the lowest plasticity index for the soil samples. The optimum lime contents by weight of soil, for soil samples A and B in terms of plasticity were observed to be 8% and 6% respectively. Combination of lime and Cow dung powder improves the examined geotechnical properties of soil considered. The additives mixed in proportions (lime: cow dung powder) were found to be at their optimum when mixed in ratio 1:1 and 3:1 for soil samples A and B respectively.

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