Effects of Lime on Sub-Base of Flexible Pavement

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Abstract
Lime Stabilization is the modern method of Improving physical and chemical properties of soil, this method expected to improve the Performance of Flexible Pavement by treating the Sub-base Materials locally available in the Construction corridor by Lime. The objective of this paper is to evaluate the performance of Flexible Pavement by treating the sub-base materials by Lime and was meant to analyse the CBR and UCS as the measure of the Performance of Flexible Pavement. Materials was classified as Clayey Gravel contained 61.9% Gravel and 28.5% Clay, either material were having a PI of 25% and Liquid Limit of 40.8% wand classified as Clay with low Plasticity. Investigation showed that as the increase in Lime content the CBR values increased by 20.9% at 10% Lime content which gave a CBR value of 22.4% while at 0% was 4.7% but beyond 10% Lime Soil exhibits decrease in CBR. Either as the increase in Lime content the UCS has shown an increase by 24% where at 2% UCS value was 0.8Mpa and at 10% UCS value was 3.2Mpa after seven days curing and submerged into water for four hours as per standards. From the discussion of results as the study jointly analysing the associated factors for the Performance of Flexible Pavements which were CBR and UCS, therefore it was established the optimum Lime content of 10% gives the maximum strength as such Locally available soil along the construction corridor can be used as the Sub-base materials with high Performance of Flexible Pavement.

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1. INTRODUCTION.

In developing Countries like Tanzania massive construction is going on day after day which led to the scarcity of Construction materials and the volume of Traffic are accumulated day after day which distresses the Structural layers of pavements and results into Premature failures of the Pavement. Therefore, Agencies are looking for low quality materials locally available to be used in Road Construction [1]**.** ***Cement/Lime*** Treatment has become an accepted technique for Increasing the strength and durability of soils.

This paper aimed to investigate the Native Granular Materials locally available in the vicinity of Construction corridor as such to find the Optimum Lime Content which will be used in the Design of Soil – Lime Design in order to reduce cost of borrowing materials from far distance purposely to be used for Sub-base Structural Layers. It has been a common method to borrow materials from Borrow pit which increases the cost of Construction instead of modifying the native materials by Lime and then being used as the Sub-base Layer materials.

[2] Stated that in order the Granular materials to perform as the Structural layer (Sub-base Layer) on the flexible pavement investigation should be done since the behaviour and performance of those materials have the impact on the Structural layers of the Flexible Pavements. Therefore, Standard and Regulations have established minimum quality requirements that these materials must meet [3]. The minimum requirements for Sub-base materials to be used for heavily Traffic loaded should have a **UCS>1Mpa** (C1) as such the Flexible Pavement can perform well. As per **IRC 37:2018** [4] the stabilized materials should have a strength of **0.75Mpa to 1.5Mpa** for Traffic less than 10 Million Standard Axels (Msa) purposely for the design and analysis of Flexible pavement. Furthermore, the guideline elaborated that the strength parameters for treated sub-base is **UCS.**

The present research paper investigated the Impact of stabilizing the sub-base layer with lime on the Performance of Flexible Pavement. The Performance of Flexible Pavements was evaluated by checking the CBR before and after stabilization, also the UCS of stabilized materials if met the specifications and analysing the stresses, strains and deformation of the materials by fixing other parameters in the analysis.

In order to evaluate the Performance of Flexible Pavement, Soil was stabilized by adding the percentage of lime as 2%, 4%, 6%, 8% and 10%, by adding the percentage of lime stated the CBR values of Soil increased until when started decreasing and where we established the percent of lime to be used for the Performance of Flexible Pavement, as well as Unconfined Compressive Strength (UCS) of soil.

[5] **,**[2]**,** [6]**,** did a study on stabilized gravel for road sub-base, it was resulted that in CBR there is an increase of CBR after adding a lime of 6% and RHA 8% under unsoaked condition where CBR values increased up to 28.25, either a combination of 6% lime and 6% RHA CBR values increased by 28.825 under soaked condition and also UCS were increased up to a certain point after that no any increment of UCS.

From previous studies, ***Avinashi et_al March, 2021***[7]**,** concluded that Stabilization is the best Techniques in Improving the Engineering properties and Index Properties of low-quality materials and reported that the CBR and UCS values improved after stabilization after adding 40% of Waste Foundry Sand to the Clay soil. ***Fadamoro et_al May 2019*** concluded that after the addition of ***20% Forage Ash***, there were increase in Maximum Dry Density (MDD) and reduction of Moisture Content, either strength i.e., CBR and UCS values were slightly increased as the forage Ash increased.

It has been observed that there is limited research which has been done on the Clayey Gravel, so for the current research Stabilization of Clayey Gravel were made and their effect on the use of Treated Clayey Materials in Sub-base to the Performance of Flexible Pavement is checked. The objectives of this study are presented below

- To evaluate the Properties of Stabilized Granular Materials
- To Curtail (determine) the Optimum Lime Content which will provide high CBR and UCS
- To Stabilize the native Granular Materials and modify to be used for sub-base materials

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2. Materials and Methodology

2.1. Materials

2.1.1. Soil

Materials (Soil) used in this research was sampled from the Borrow pit locally available in the Construction Corridor with low quality as such to evaluate the workability and to reduce the cost of Borrowing quality materials from far away from the site. Sampling was made after the removal of overburden materials which includes grass roots to a depth of 0.15m according to British standards and specifications world-wide.

The Sample collected was in the state of disturbed from a sufficient depth range from 1.5m to 1.8m after the removal of the overburden materials and debris and brought to the laboratory where the soil sample was air dried for 12hours in order to remove the unwanted moisture and take sample for determination of Natural Moisture Content. Either the sample was sealed with plastic bags in order to avoid the entry of moisture to the sample.

2.1.2. Lime

Lime is the by-product of the decomposed lime stone at elevated temperature composed of calcium carbonate **($CaCo_3$)** of 51% of all chemical composition [8]. Lime used world-wide to stabilize the low-quality material as such to improve the Properties, Lime exhibits the cementitious property. Lime used in this study was Hydrated Lime which was collected for local markets and the sample was sealed with plastic bags and secured tied in order to preserve carbonation.

2.2. Methodology

Sub-base materials were sampled from Borrow-pit locally available along the Construction Corridor, before sampling started Overburden materials was removed at a depth of 0.15m, the overburden materials include grass roots, debris and unwanted materials thereafter the samples to be investigated was excavated to a depth range from 1.5m to 1.8m and it was in disturbed state and sample was parked into plastic bags as such to preserve moisture and transported to laboratory.

Sample was air dried on sunlight and different mixes of clayey Gravel were prepared at different percent of Lime Content ranges from 0% to 10% of weight of soil in steps of **2 percent** [8].

The completion of the research involved the following tests to be done i.e., Atterberg Limit tests, Standard Proctor Compaction test, CBR and UCS tests. For the sake of CBR test each sample was soaked into water within four days and UCS samples was cured for 7 days and submerged into water for four hours prior testing.

3. Results and Discussion

3.1. Physical and Index Properties of Soil

In Atterberg Limit test was performed according to relevant codes ***IS-2720 (Part 5)-1985*** and for Particle Size distribution was conducted according to ***AASHTO*** and relevant codes of Indians.

It has shown that as the increase in Lime Concentration to the Soil, the Liquid Limit of Soil decreases [9][5], [10][6]**,** At 0% lime Concentration Liquid Limit was 40.8% but at 10% of Lime the Liquid Limit decreased to 24.0% which is equivalent to 58.8% due to the addition of lime as results the fines are increasing and the surface area also increased as such more water is increase.

Plastic Limit increases with the increase in Lime concentration because of the cementitious property present in the lime as such the Plasticity index properties of Clayey Gravel Soil decreases, The

Plastic Limit increased from ***15.90% to 21.6%*** and plasticity Index decreases from ***25% to 7.10% at 10%*** Lime content. In line of the above the Lime content plays a vital role in the increase in strength of the Gravel materials in this study and reflect the Performance of Flexible Pavements under Traffic Loading. Figure No 1 represents the variations of Liquid Limit, Plastic Limit, Linear shrinkage and Plasticity Index of Gravel materials.

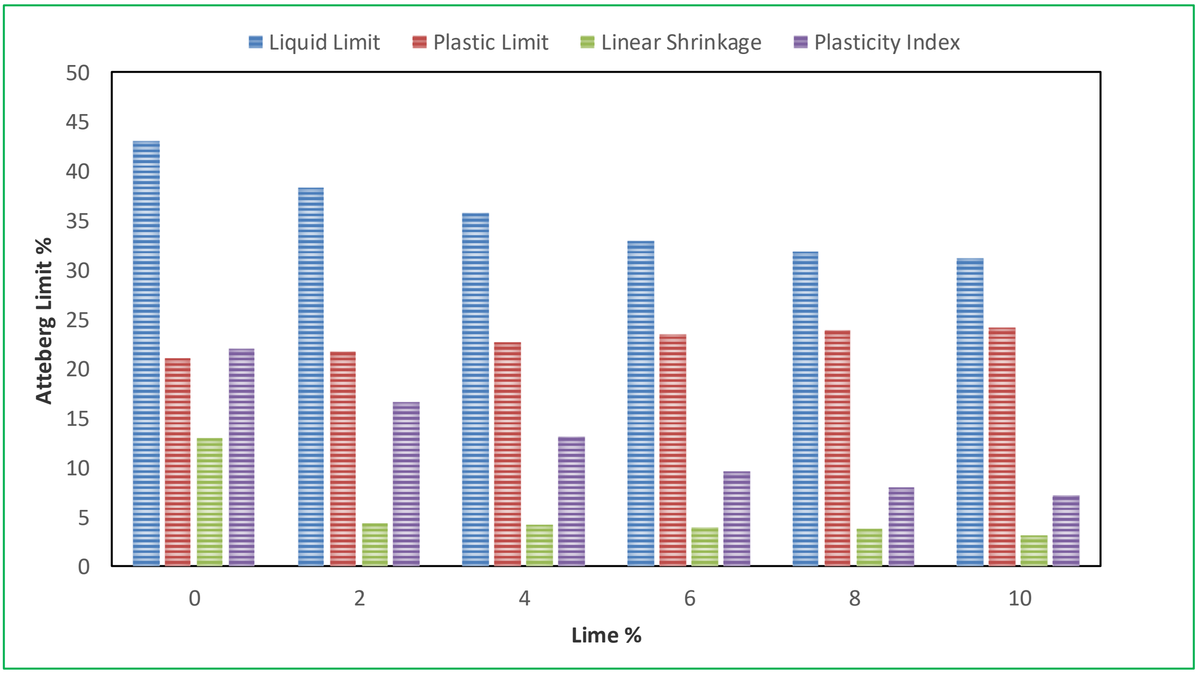

Fig: 1 Variations in Liquid Limit, Plastic Limit, Linear Shrinkage and Plasticity Index

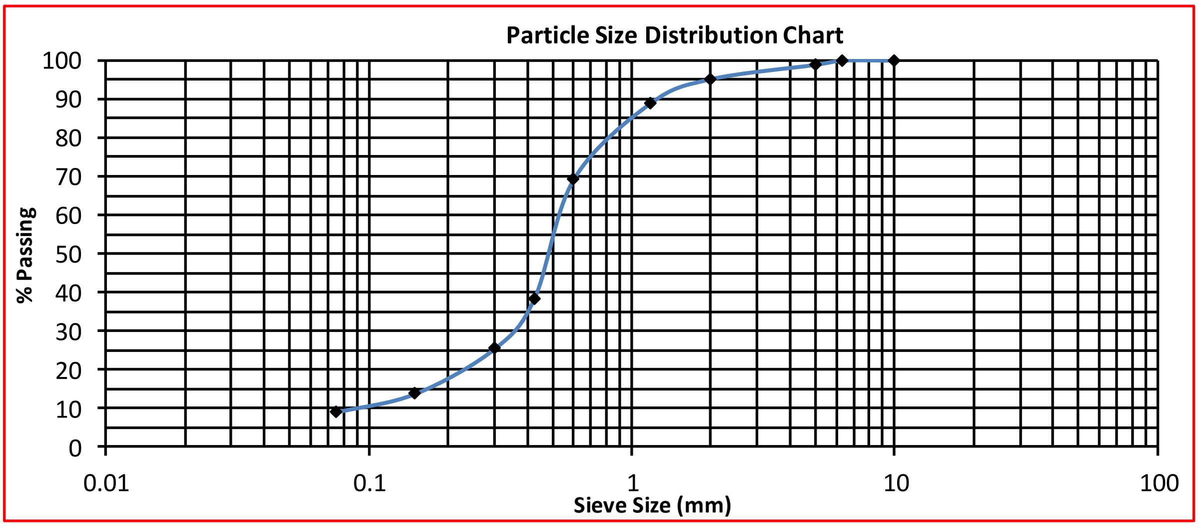

Fig: 2 Particle Size Distribution Curve (Sieve Analysis).

3.2. Compaction Tests

As the increase in Lime Concentrations the maximum Dry Density decreases which is due to the addition of fines which results in less compactive efforts and led to the decrease in Maximum Dry

Density as the lime content is increased. Maximum Dry density decreased from 1857Kg/m^3 to 1814Kg/m^3 as shown on **Figure 3** below.[12]**.**

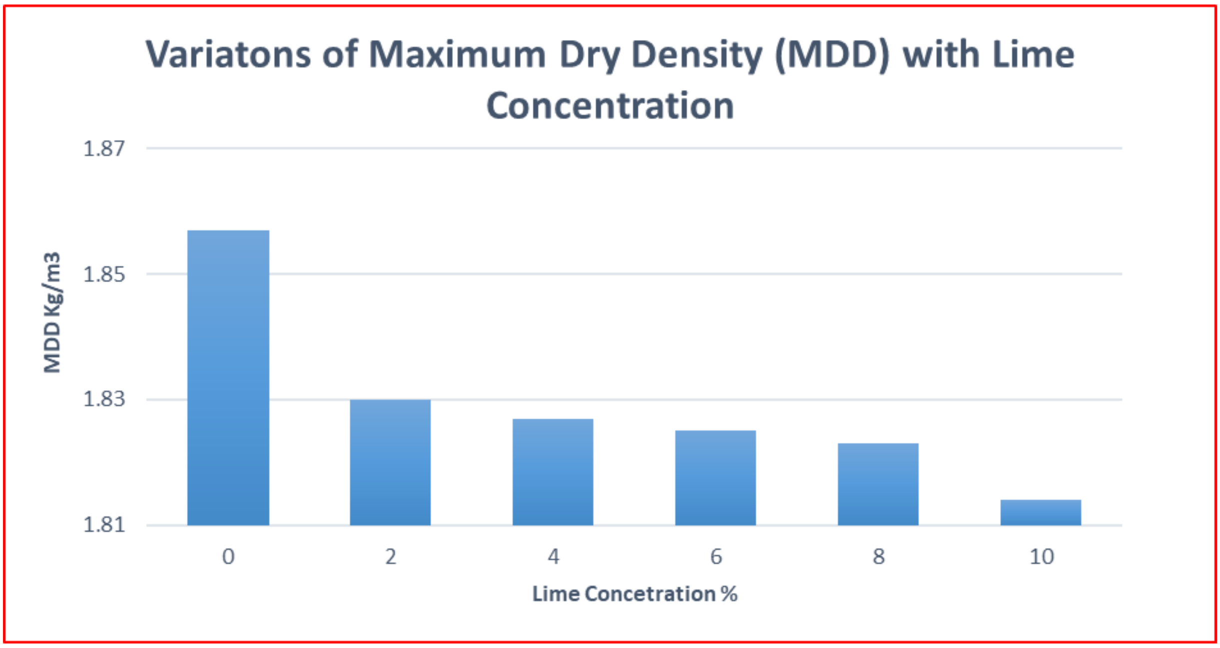

Fig 3: Variations of Maximum Dry density with Lime Concentration.

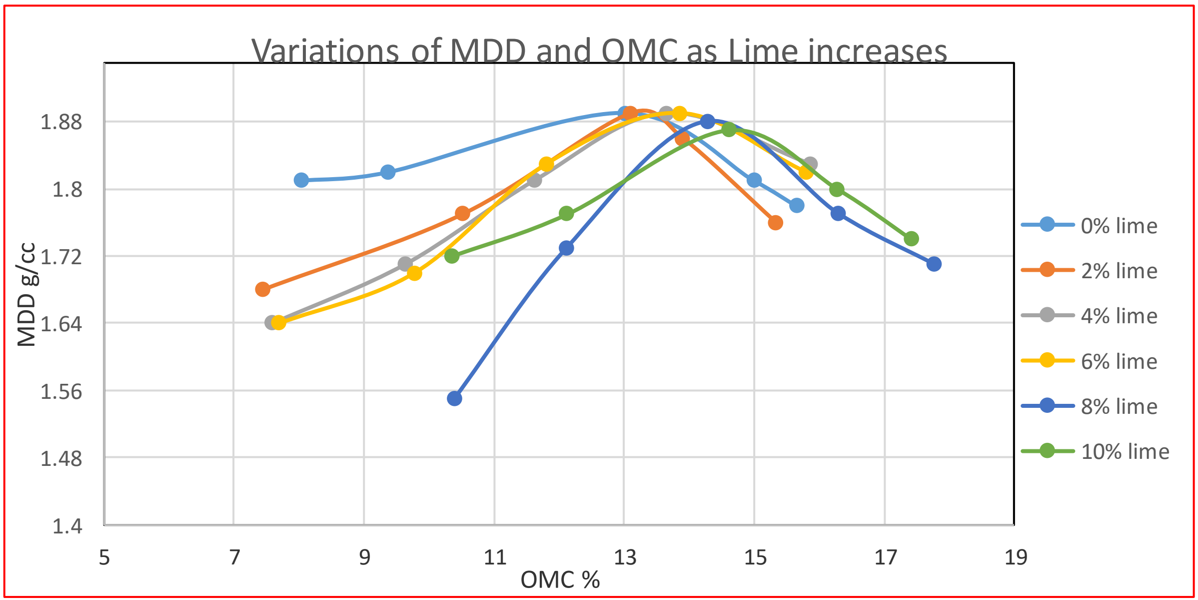

Fig 4: Variations of Maximum Dry Density and Optimum Moisture Content with the Increase in Lime Concentration.

As lime content increased in the mixture of soil and lime the fines content increase and there will be in increased in moisture content as the fines increased in the mixture also the demand of moisture content increased. Optimum Moisture Content was increased from 11.4% to 14.6% as shown in **figure 5** below. Previous researchers and most of them have studied the stabilization of Granular materials with Lime and results revealed that as the Lime increases Optimum Moisture Content increases and this is due to the presence of clay materials within the Granular materials sampled, Clay materials have the tendency to react with the lime once added where Ions and Cations takes place and makes some Soil characteristics to be modified, either as the lime increases fines content also increased which in turn there were increase in surface area and more demand of moisture content increase as much as possible [13],[14]. The increase in Optimum Moisture Content it may be attributed due to the presence of Hydrogen Bond in the materials especially the presence of Clay particles, where during Flocculation process (the exchange of Cations and ions) immediately after the addition of Lime content, Cations tends to absorb more water and led the increase in moisture.

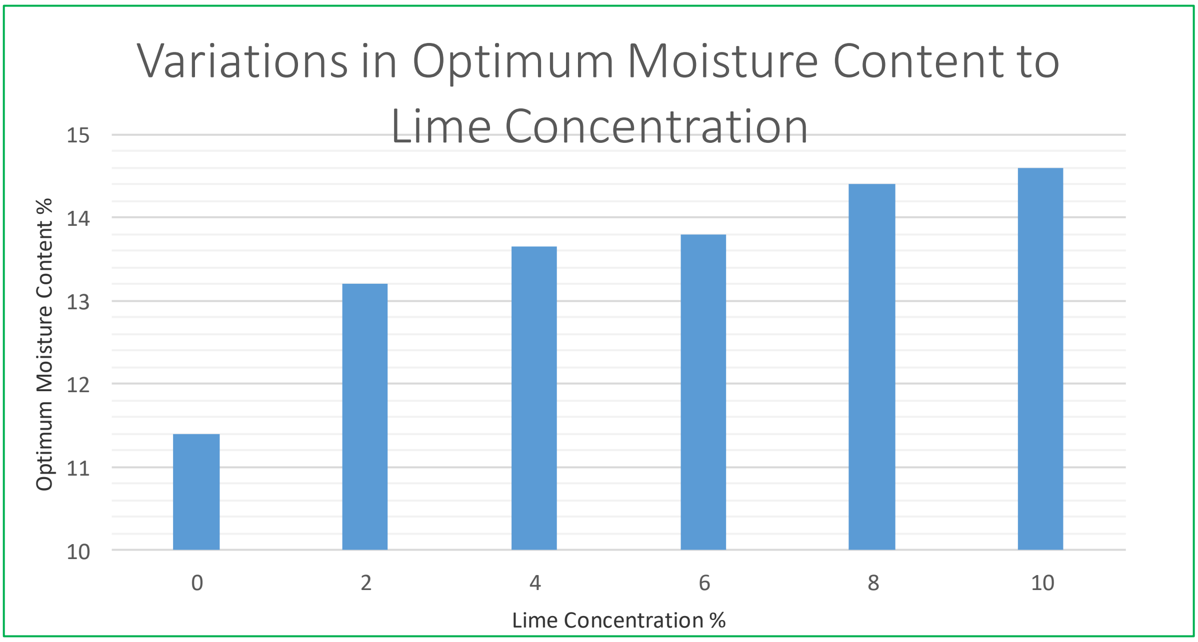

Fig 5: Variation in Moisture Content with the increase in Lime Content

*3.4. **California Bearing Ratio (CBR)***

CBR test was conducted on materials samples passing on sieve sizes 19mm IS sieve and if the soil contains particles larger than 19mm were removed otherwise fraction greater than 25% the test was ignored as not applicable. It has been shown that s the Lime content is increased also the CBR values increased. CBR values was increased by 20.98% at 10% Lime Content compared to 0% lime content, as CBR values at 0% was 4.7% and gradually increased up to 22.4% at 10% Lime Content.
It has been concluded that with the increase in Lime Content CBR values also increased, in the Current study it has shown that CBR values increased up to 10% lime content addition and there after no increase in CBR values has shown which in turn at 10% showed a significance effect on the Performance of Flexible Pavements. **In figure 6** below showed that after reaching a fixation point which is 10% the CBR values started to decrease, Lime Stabilization undergo three important stages which ***Soil drying***, ***Soil Modification*** and ***Soil Cementitious***, Soil Modification were taken place as such soil properties (soil Characteristics) modified to be used as the Sub-base materials in Structural Flexible Pavements. Modification of soil was like reduction in Plasticity Index, Increase in Moisture Content, decrease in Maximum Dry Density, Increase in CBR values up to the fixation point and starts to decrease, Improved capability, Reduction in soil's capability of swelling and

shrink, improved strength and stability after compaction. As per Soil particles distribution analysis it showed that Soil contained clay with low plasticity, when Soil contains clays starts to be modified the particle size decreased where particles bring together and shear strength of materials increased where flocculation takes place. Once Lime added to Soil Modification process starts where Ions and Cations take place and there was a rapid increase in CBR values as lime increased lime fixation reached where Cations and Ions no longer exists in the modification process and lime remained attracted and starts absorbing water and CBR values starts to decrease.

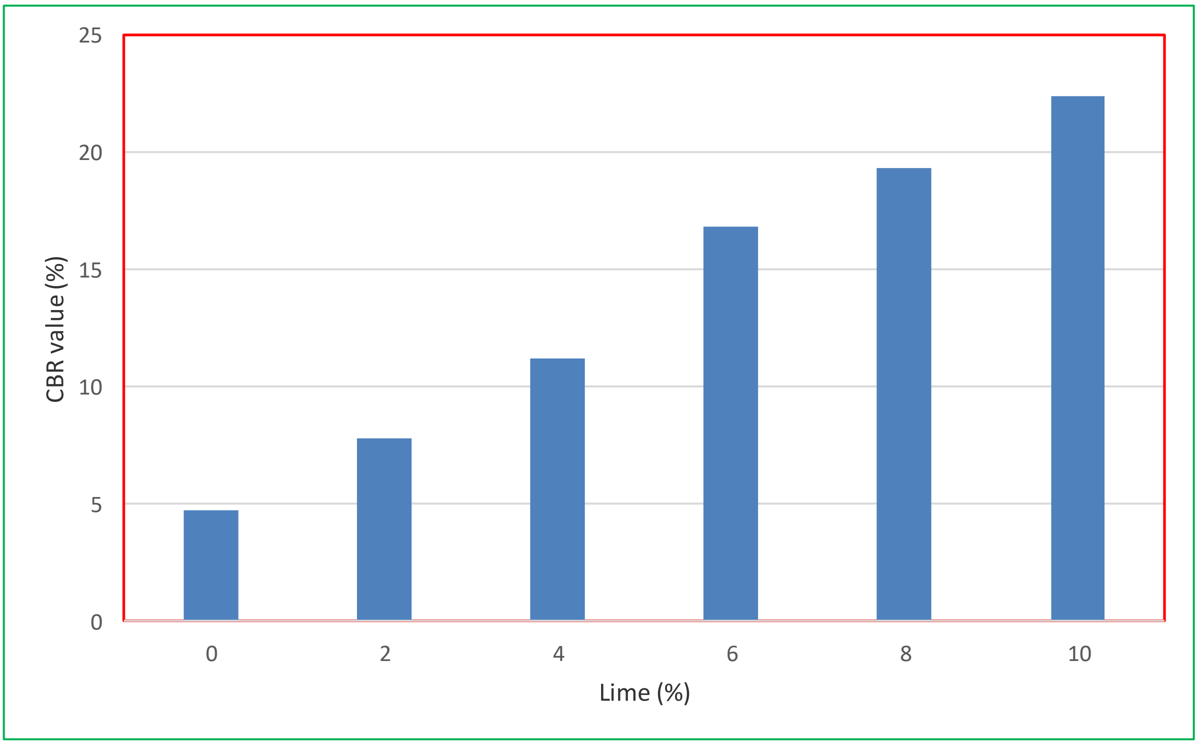

Fig 6: Variations of CBR with the increase in Lime Content

*3.5 **Unconfined Compressive Strength (UCS)***

A total number of 15 samples were prepared according to standards mentioned above and were cured for seven (7) days, after curing for seven days specimen were removed from plastic bags and specimens submerged into water for 4 hours [16]***[10],*** [17]***[11]*** at a temperature of 25 degree centigrade prior to testing, based on specifications curing for seven days is enough for ***sub-base materials*** to gain strength and sustain Traffic loading which results into Performance of Flexible Pavements [18].

It has been shown that as the increase in Lime content makes the Unconfined Compressive Strength to increase, from test results obtained in investigations it showed that the UCS increased by 24.2% at 10% Lime content compared to 2% Lime, at 2% lime UCS value was 0.8Mpa while at 10% Lime UCS value increased up to 3.3Mpa after seven days curing and 4 hours soaking.

[19]**[12]** in their study they investigated the effects of curing and soaking of the specimens, it was stated that as the increase in curing period also the UCS values increases either as the increase in soaking period of specimens after curing the UCS increases.

[20]**[13]** did an investigation on the effects of soaking on a lime stabilized clay and implications for pavement design. A high plasticity clay was used in their research which resulted that the Unconfined Compressive strength were affected by soaking the specimen into water for 3 and 7 days, but those tested after curing were revealed a superior value of UCS.
From ***fig 6*** below results showed that there is an increase of Unconfined Compressive Strength with the increase in Lime Content. The increase in UCS as lime content is attributed with the presence of chemical properties of soil when mixed with Lime which contains alumina, either the test methods for UCS is the crushing value of specimen to failure which is cohesive crushing and particles bonding which is called cementitious, as the lime increases the bond between soil particles and lime is increased and also the crushing value of specimen is increased. Also, the curing process of UCS specimen made the UCS specimen increase

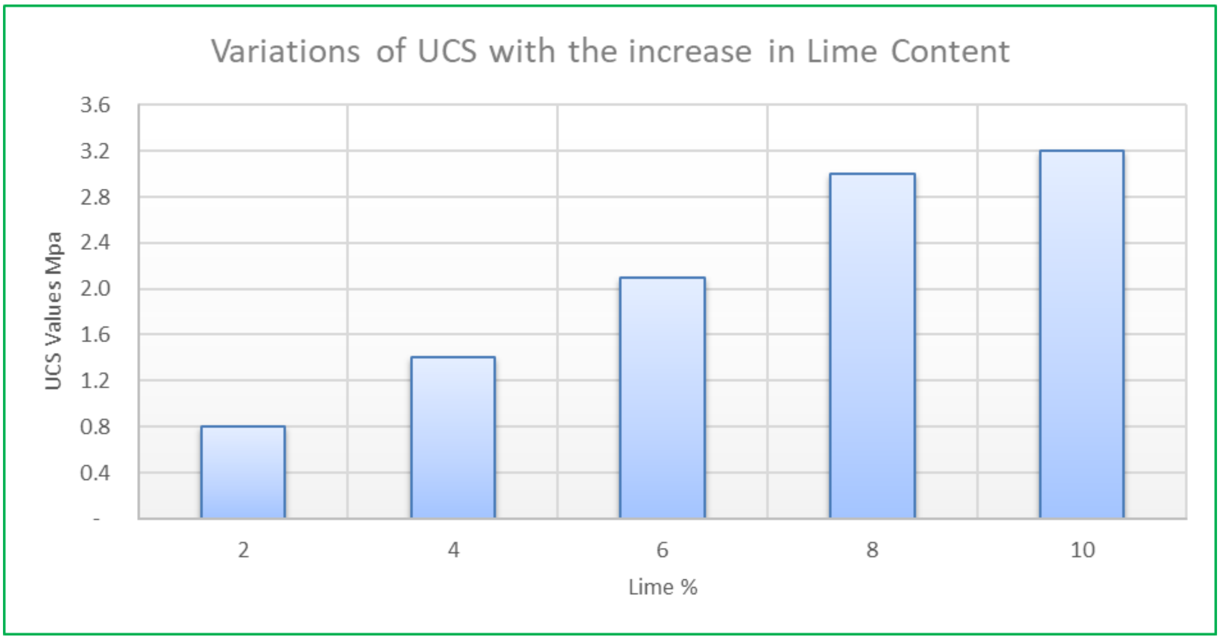

Fig 7: Variations of UCS with the increase in Lime Content.

According to Tanzanian specifications for Road Works 2000 and from Design Manual 1999, It was established that UCS Specimen to be cured for seven days and soaked for 4 hrs prior subjected to compressive force to failure. Based on the Specifications the materials to qualify for sub-base should be more than ***1Mpa*** (C1), and in this investigation the UCS values is more than 1Mpa which is ***3.3Mpa*** in line of the above materials locally available can be used for ***sub-base layer*** and Flexible Pavement will perform as a pavement.

4.0. CONCLUSION

- The study on the stabilization of ***sub-base materials by lime*** was meant to analyse the variations in CBR values and UCS values as the measure of the Performance of Flexible Pavements. The aim was to evaluate and provide information for adequate and economic design during stabilization procedure, either to provide the Optimum Lime Content. The following conclusion has drawn from the Current investigation done.

- As it has been seen on the investigation of locally available granular materials along the construction corridor, after the addition of Lime Plasticity index of Soil decreased, CBR and UCS values increased significantly which reflects the improvement of Strength to the Soil.

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