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Effects of Lime Stabilization on the pH Scales of Soils in Parts of KwaZulu Natal, South Africa

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ABSTRACT

In South Africa, the use of stabilizing agents in road construction has been in practice for some years. The province of KwaZulu Natal, in South Africa is currently undergoing some road rehabilitation projects with the investigation of properties of lime stabilized soil-the pH value being one of the necessities to understand the behavior of the soil. In this study, six selected soil samples of different pH scales were used and the effects of the lime stabilizer on the pH values were determined in the laboratory. The percentage of lime used in the samples varied from 2%, 4%, 6%, 8% to 10% by weight method of the soil samples that were tested. From the analysis carried out, it was found that the treatment of the samples with lime content changed the pH of the samples from acidic to alkaline and the value increased with increasing lime content for all the samples. For examples the pH value for sample one changed from 3.94 to 4.02, sample two changed from 4.54 at 4.92, Sample three changed from 4.50 at 5.22, sample four changed from 8.95 to 9.20, sample five changed from 8.05 at 8.27 and sample six from 8.34 at 8.68 on average lime. The changes were as a result of the changes in the chemical properties and the composition of the samples due to their chemical reactions with lime additive.

Keywords: Hydrated lime, soil stabilization, soil pH, properties of the soil

INTRODUCTION

Majority of natural occurring soils in the province of KwaZulu Natal are of acidic nature [3], and this is due to pH below scale of seven (7) and due to high percentage rainfall the province receives annually. Some of the soil in other parts of the province is of alkaline nature. Alkaline soils are mostly found in the Northern part of the KwaZulu Natal Province, in places like Mkuze and Nkwalini. For the province, the farming community at all times relies on good quality soil to produce crops, with acidic soil causing a major problem in in the adequate growth of crops. The latter is a major cause of poor yields of crops and vegetables, limiting plant growth by stunting root development and thereby the uptake of water and nutrients due to pH [5, 10 & 13]. Soil pH can be managed by measures such as applying the proper amount of nitrogen fertilizer (for agricultural purposes). This (i.e. nitrogen fertilizer) affects crop yields, crop suitability, plant nutrient availability, and soil micro-organism activity which influence key soil processes thus improving the soil organic matter and overall soil health. Alternatively, mixing lime into the topsoil is one effective way of dealing with soil pH problems. In most of the civil engineering works, the use of lime to soil is associated with weak, unstable or unsuitable soils so as to increase the soil properties capabilities. The application of lime to soil in trying to increase its strength reduces the acidity of the soil by promoting an increase in its pH, thus enhancing many properties of the soil [1-2 & 6-9].

Among the above mentioned properties are index, engineering and micro structural properties of the lime stabilised soil to mention a few. The soil pH mentioned above is an important indicator of soil health which relates to the degree of soil acidity and alkalinity. For soil that is acidic, it is said to have pH scale below 7 while for a soil which is said to be alkaline, its pH scale is above 7, with factors affecting soil pH such as climate, mineral content and soil texture playing a key role as contributory factors. From an engineering and agricultural standpoint, particularly the earlier mentioned (engineering), the use of lime for liming can be used to manage the pH of the soil. Acidic soils are said to be having base cations ranging from Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Potassium (K^+), to Sodium (Na^+) to name a few, with alkaline soils having minor elements such a Zinc (Zn), Copper (Cu), Baron (B), Magnesium (Mn) and Iron (Fe). [4] states that a high alkaline environment, probably greater than 12.4, needs to be maintained to enable the pozzolanic reaction to occur. The pozzolanic reaction referred to above enables the soils silica and or alumina and lime to form various types of cementing agents [13]. The minimum amount of lime required to achieve the above (i.e. high alkaline environment (greater than 12.4) in the soil is called lime demand, which is the quantity of lime required to satisfy cation exchange and short term reactions [12].

MATERIALS AND METHODS OF TESTING

Sample Preparations

Bags of naturally occurring acidic and alkaline soil samples were collected from Umlazi, a township on the east coast of KwaZulu-Natal, South Africa, located south-west of Durban (29°58′S 30°53′E), Scottburgh is a coastal town situated on the mouth of the Mpambanyoni river (30°17′S 30°45′E), Amanzimtoti, (26.2 km South of Durban in South Africa, Mkuze area (27°37′S 32°02′E), located approximately 350 km from the city of Durban as well as Nkwalini (28°53′18″S 31°26′54″E). Soil samples for laboratory analyses were typically air dried and pulverized to provide a stable homogeneous mixture.

Tests Conducted on Soils and Testing Procedures

Tests such as sieve analysis, consistency limits (Atterberg tests), Maximum Dry Density and Optimum Moisture Content determination, Curing Soaking- for CBR penetration, CBR Penetration were performed. These tests were conducted in relation to South African Technical Methods of Highway 1 (TMH1) under subsections, method A2, A3, and A4 with the prime purpose being to quantify different properties of the soils prior to treating it with lime, with complimentary information from other documents such as SANRAL's materials testing manuals.

RESULTS AND DISCUSSION

Consistency Limits

From the analysis carried out, it can be seen that the treatment of the samples with lime content changed the pH of the samples from acidic to alkaline and the value increased with increasing lime content for all the samples. For examples the pH value for sample one changed from 3.94 to 4.02, sample two changed from 4.54 at 4.92, Sample three changed from 4.50 at 5.22, sample four changed from 8.95 to 9.20, sample five changed from 8.05 at 8.27 and sample six from 8.34 at 8.68 on average lime. The above referred changes were as a result of the changes in the chemical properties (chemical property: A property or characteristic of a substance that is observed during a reaction in which the chemical composition or identity of the substance is changed) and the composition of the samples due to their chemical reactions with lime additive.

Grading Envelope for the Six Soil Samples

Soil gradation/classification ranks the soil based on the different particle sizes contained in the soil for the six soil samples. Fig. 1, shows the grading curves for sample 1 to 6 respectively of acidic nature. Based on the grading analysis on the three soil samples indicated that sample one (well graded) is a well graded soil containing particles of a wide range of sizes and has a good representation of all sizes. Soil gradation/classification ranks the soil based on the different particle sizes contained in the soil for the three soil samples. Fig. 1, shows the grading curves for sample 1 to 6 of acidic and alkaline nature. Based on the grading analysis on the three soil samples indicated that sample one (well graded) is a well graded soil containing particles of a wide range of sizes and has a good representation of all sizes.

Density vs Moisture Content Test Results

The addition of lime contributed to the increase in the optimum moisture content and the decrease in dry density. Generally, all soils exhibited a similar correlation between moisture content and dry density when subjected to a given comp active effort (Table -2). For each soil, a maximum dry density develops at an OMC for the comp active effort used. The OMC at which maximum density is obtained is the moisture content at which the soil becomes sufficiently workable under a given comp active effort to cause the soil particles to become so closely packed that most of the air is expelled. An analysis on the maximum dry density and the optimum moisture content of the lime treated six soil samples at different contents of lime was performed to determine the relationship between the moisture content and the dry density. The result are series of tests conducted to examine the impact of different lime contents at 2%, 4%, 6%, 8% and 10% on the AASSTHO Maximum Dry Density (MDD) and the Optimum Moisture Content (OMC) of soil at specified comp active efforts. The results of the compaction tests conducted on the soil samples showed that the addition of lime resulted in the improvement in the characteristics of the natural six soil samples.

Table -1 Consistency Limits

Properties	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Liquid Limit (%)	32	23.43	22	31	41	33
Plastic Limit (%)	21.25	10.61	11.31	21.94	32.82	22.31
Plasticity Index (%)	10.98	12.82	10.68	9.05	8.17	10.69
Plasticity Index (%)	8.42	10.72	7.61	8.11	7.12	9.52
Linear Shrinkage (mm)	4.210	4.24	3.89	5.57	3.37	1.76
pH (prior treatment)	3.94	4.54	4.50	8.95	8.05	8.34
pH (post treatment)	4.02	4.92	5.22	9.20	8.27	8.68

Table -2 Density vs Moisture Content Test Results

Sample number	2% lime MDD & OMC	4% lime MDD & OMC	6% lime MDD & OMC	8% lime MDD & OMC	10% lime MDD & OMC
1	1703 kg/m³ 20%	1703 kg/m³ 20%	1741 kg/m³ 20%	1749kg/m³ 19%	1672 kg/m³ 19%
2	1666kg/m³ 22%	1643kg/m³ 20%	1670.1 kg/m³ 20%	1677.35 20%	1645.59kg/m³ 20%
3	1834.4kg/m³ 15%	1937.3kg/m³ 14%	1811.3 kg/m³ 21%	1899.9 kg/m³ 14%	1792.7kg/m³ 17%
4	1752.2kg/m³ 17.33%	1731.4kg/m³ 19.5%	1663.93kg/m³ 18.23%	1674.9kg/m³ 18.16%	1591.53kg/m³ 28.19%
5	1867.6kg/m³ 23.95%	1786.4kg/m³ 17.58%	1657.1kg/m³ 23.85%	1673.6kg/m³ 23.9%	1672kg/m³ 24.83%
6	1721kg/m³ 2.41%	2075kg/m³ 22.01%	1835.3 kg/m³ 22.19%	1778.1kg/m³ 33.76%	1597.4kg/m³ 29.17%

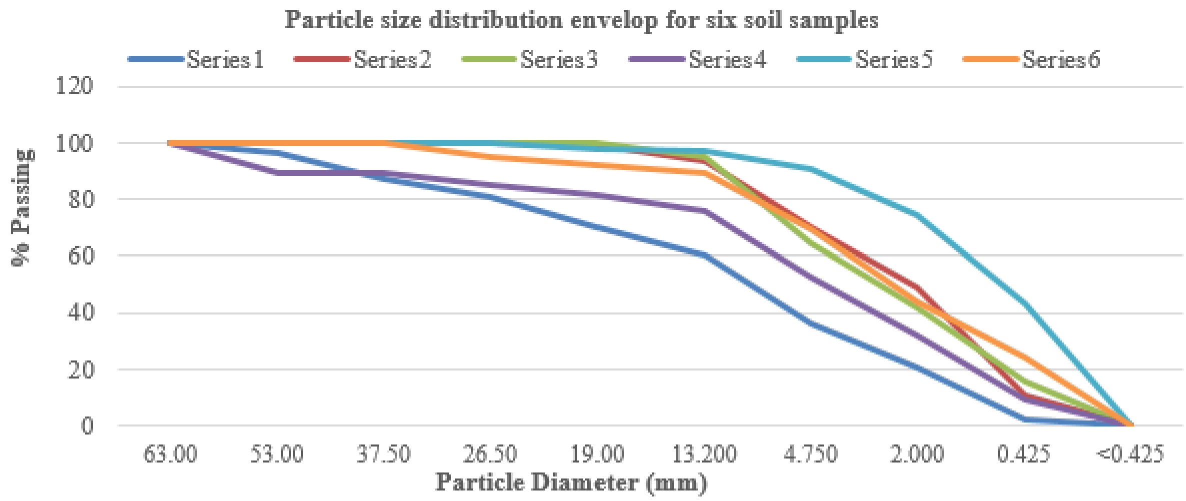

Fig. 1 Consistency index properties of the soil

EDS/EDX Micrographs

Acidic soil

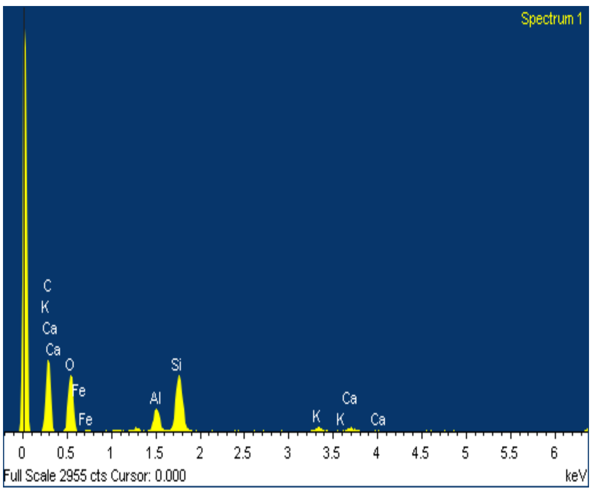

Fig. 2 Sample 1 EDS/EDX

Acidic soil

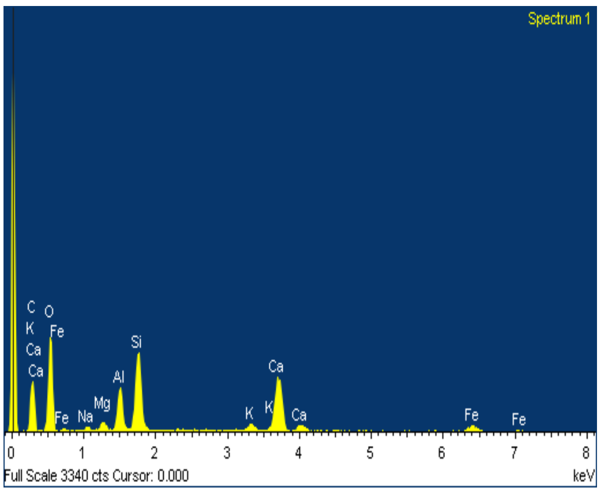

Fig. 3 Sample 2 EDS/EDX

Acidic soil

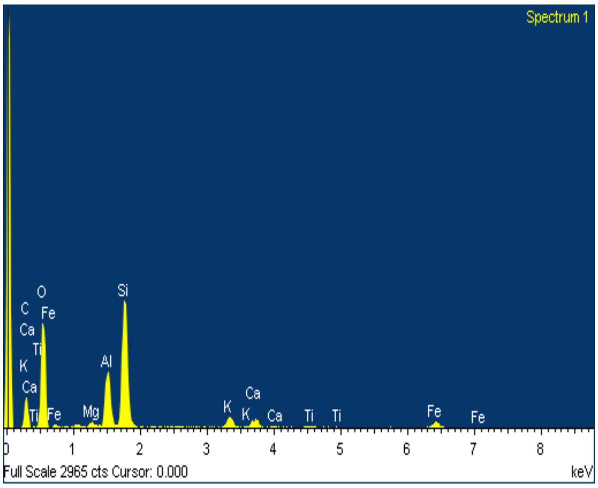

Fig. 4 Sample 3 EDS/EDX

Alkaline soil

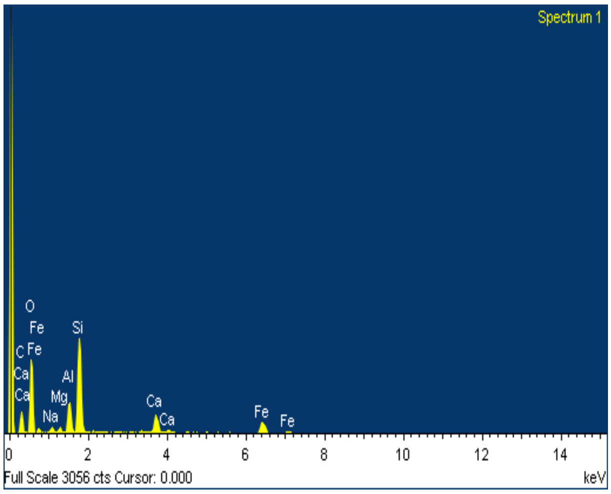

Fig. 5 Sample 4 EDS/EDX

Alkaline soil

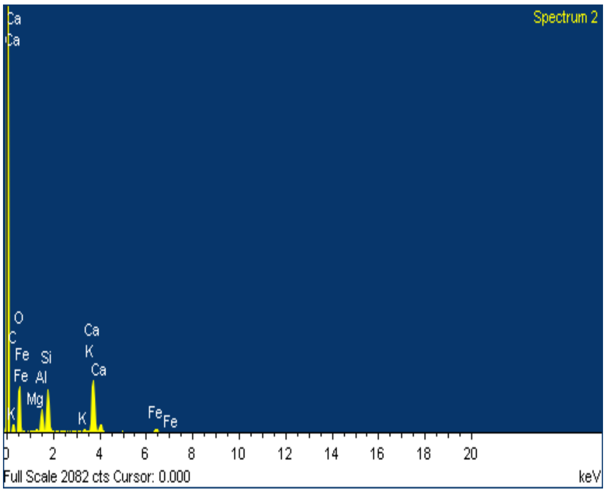

Fig. 6 Sample 5 EDS/EDX

Alkaline soil

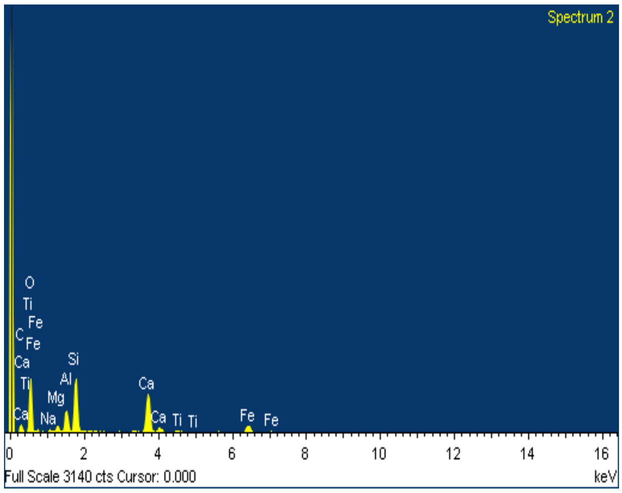

Fig. 7 Sample 6 EDS/EDX

pH of Soil

Test results showed that lime had an impact on the soil samples in terms of significantly affecting the pH of the soil. Hydrated lime used for this experiment in the presence of water sets up an alkaline environment (pH above 7) in which lime reacts with any pozzolans that are present in the soil material. The degree of acidity or alkalinity of a soil is a very relevant property affecting many other physicochemical and biological properties as can be observed in the below Figures Soil pH increased with the rate of lime applied, with particular noticeable manifestation of the increase being with soil sample three at pH difference of 0.72. On the other side, basic or alkaline soils are the consequence of the buffering of soil pH by base elements or by the presence of buffering compounds such as carbonates as can be seen in Fig. 2 to 7. Some of the soil features affected by soil pH include the following but not limited to;

- Availability of mineral elements (Fig. 2 to 7) in the soil. At low pH, the risks of deficiency of base nutrients (Ca, Mg, and K) increases due to their low content; also the solubility of P compounds is decreased, thus decreasing its availability.
- Physical properties: Low Ca concentration in acidic soil samples relating to an increased dispersion of colloids if Al is not present at high concentration. Thus, acidic soils can have poor soil physical properties, including poor structural stability or low permeability.

CONCLUSION

In addition to the above, the use of lime contributed to the increase in the optimum moisture content and a decrease in dry density, with all soils exhibiting a similar correlation between moisture content and dry density when subjected to a given comp active effort. On consistency limits, it is observed that the treatment of the samples with lime content changed the pH of the samples from acidic to alkaline and the value increased with increasing lime content for all the samples. Generally, the test results showed that lime had an impact on the soil samples in terms of significantly affecting the pH of the soil. Hydrated lime used for this experiment in the presence of water sets up an alkaline environment (pH above 7) in which lime reacts with any pozzolans that are present in the soil material. Soil pH increased with the rate of lime applied, with particular noticeable manifestation of the increase being with soil sample three at pH difference of 0.72. On the other side, basic or alkaline soils are the consequence of the buffering of soil pH by base elements or by the presence of buffering compounds such as carbonates as can be seen on the EDX micrographs with other additional soil features affected by soil pH including the availability of mineral elements in the soil as well as the physical properties of the soil.

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