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Influence of Red Lateritic Soils on the Geotechnical Properties of Expansive Dark Magnesium Clay

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Abstract **-** The focus of this research is an investigation of the geotechnical properties of Dark Magnesium Clay (DMC), an expansive soil occurring on the island of Mauritius, when mixed with non-swelling soils, used as additives. Index parameters, compaction characteristics and relevant engineering parameters of the expansive soil when blended with two identified additives were investigated separately. Dark Magnesium Clay (DMC) was sampled from Baie du Cap and La butte - two landslide prone areas and which have been a major aspect of concern during the last decade. The two additives, namely: red lateritic non-swelling soil was collected from Jin fei and the rock dust – from a local construction material supplier. Red soil and Rock dust were used for improving the engineering qualities of the expansive DMC. This study looks at the engineering behaviour of DMC when stabilised with varying percentage of the additives. The soil mixtures were prepared by adding different percentages of additives, ranging from 10% to 50% by weight at 10% intervals to the DMC. Experiments show that soil mixture from 30% to 40 % additive will improve the compaction properties of the expansive soil. The swelling pressure of the soil decreases down to 50% with addition of non-swelling soil as additive. Results clearly indicate interaction between the various components of DMC and additives, allowing to conclude that this all new concept of soil stabilisation by soil mixing may yield satisfactory composite material for civil engineering purposes.
Keywords**:** Expansive, Swelling characteristics, Additive, Dark Magnesium Clay, Non-swelling soil.

1. Introduction

The scholarly community is aware of the severe harm/distress caused to infrastructure when built on/in expansive soils [1, 2]. One of the preferred methods of dealing with these problematic soils is stabilization, which can be accomplished by using an appropriate additive or additives in appropriate optimum proportions. Over the years, many additives have been developed, and their effectiveness and usefulness have been convincingly proven by the earlier researches [3–11]. As a result, numerous additives are being used.to temporarily stabilize the expansive soils, may generally be divided into three primary groups, as shown in Table 1: cementitious, non-cementitious, and chemical additives.

Table 1: Categorization of various additives used for stabilisation of expansive soils

Additive	Category
Stone dust, quarry dust, aggregate waste, rock waste powder, crusher dust, granite saw dust, sand	Non-cementitious additives
Lime, fly ash, ground-granulated blast furnace slag (GGBS), cement kiln dust, lime kiln dust, silica fume	Supplementary cementitious additives
CaCl2, KCl, Na2SiO3, FeCl3, Mg (OH)2, Na (OH), NaCl, MgCl2, AlCl3	Chemical additives

The most widely utilized additive is lime, and expansive soil stabilization using this additive is a long-standing custom that is still followed today [12]. Despite being a cost-effective additive and being well suited for practically any form of expansive soil, lime stabilization is not always practical due to constructability concerns. Additionally, a higher temperature of at least 40 F is necessary for an efficient lime-soil reaction. Below this point, lime [1] typically remains dormant and does not start the reaction.

In an effort to get around these restrictions, researchers have been employing substitute materials such fly ash, stone dust, quarry dust, cement kiln dust, lime kiln dust, marble dust, granite saw dust, powdered granulated blast furnace slag, and others that are very affordable and easily accessible.

However, it must be recognised that all the above additives are not environmentally friendly and their production significantly increases the carbon footprint, negatively impacting on the climate change process, in an era where the world is engaged in reversing the actual trend.

In this study, attempts were made to evaluate the performance of two particular additives employed to stabilize residual Dark Magnesium Clay (DMC) of volcanic origin, occurring on the island of Mauritius and well for its expansive properties. Two types of additives, namely non-swelling residual Red lateritic soil and stone dust (categorized as non-cementitious additive), were used for investigation. The aim of this research is to establish an appropriate mix comprising two different clays, one belonging to the family of montmorillonite (DMC), well known for its expansive nature and another one, known for being very obedient non-swelling soil of kaolinite family, that will yield a composite soil with acceptable swelling and mechanical properties. This paper proposes an all new concept of stabilisation of problematic expansive residual soil, Dark Magnesium Clay (DMC) of volcanic origin, by soil mixing. DMC is a residual soil derived from eruption products of the old volcanic series, known for its disorderly geotechnical behaviour, mainly caused by the presence of montmorillonite clay component [12]. The proposed new concept of stabilisation by soil mixing will definitely reduce cost and it consists of partial replacement of the expansive raw material (DMC) by a non-expansive soil containing mainly kaolinitic clay, sampled from locations of the intermediate volcanic series, also occurring on the island of Mauritius.

The purpose of a parallel stabilisation with rock dust is for comparison purposes, as rock dust is an absolutely non swelling material.

Materials and Methods

The main physical and mechanical geotechnical properties of plain and formulated mixes, listed below, were investigated within the scope of this research. Liquid Limit,

- Atterberg limits
- Compaction properties
- Swelling pressure

Experiments are aimed at studying soil-mixtures with variable proportions of rock dust and red lateritic soil as additives. The dark magnesium clay is mixed with each additive separately. The soil mixtures are prepared by addition of red lateritic soil and rock dust in different percentages by mass of additives, varying from 0% - 50%, added to the dark magnesium clay and results are compared.

Experimental Investigation

Soil Sample Collection: DMC was collected from two locations, namely, La Butte region situated in south of Port Louis and Baie du Cap – south of the island. Red lateritic soil was sampled from Jin Fei - northern central part of Mauritius. All samples were collected in their disturbed state and from a depth below 1 m to avoid the vegetable layer. The samples were processed and then subjected to various experimental investigations to establish their physical, geotechnical, and swelling characteristics. The rock dust was collected from a local construction material supplier namely Gamma Materials Ltd

Additives Used and Mix Proportions: For stabilization of expansive soils, each additive separately and in varying proportions, was mixed with the expansive soil. Table 2 presents list of various additives and the corresponding proportions in percentages adopted for stabilization of expansive soil.

Table 2: Percentage additives used

Test	Percentage additive	Soil Type			
		DMC (g)	Red soil (g)	DMC (g)	Rock Dust (g)
Initial	0%	225		X	
Sample 1	10%	202.5	22.5	X-10%	10%
Sample 2	20%	180	45	X-20%	20%
Sample 3	30%	157.5	67.5	X-30%	30%
Sample 4	40%	135	90	X-40%	40%
Sample 5	50%	112.5	112.5	X-50%	50%
Total		1000	400		

Results and discussion

Liquid limit w_l: For the two dark magnesium clay samples w_l is in the range of 53.7% (Baie du Cap) and 75.6% (La Butte) respectively which is considered as highly plastic, 47% for red lateritic soil - moderately plastic and that of rock dust is 76% - also highly plastic, as read from the Casagrande plasticity chart. The dark magnesium clay is classified as a fat clay with high plasticity and red lateritic soil is classified as a lean clay of medium plasticity. Both materials are classified as clay.

Plastic limit: The variation of plastic limit with percentage red lateritic soil, as additive, is shown in Figure 1. The plastic limit changes from 39.1% to 37.48% with an addition of 10% non-swelling soil beyond which the decrease it quite constant from 10% to 40% non-swelling soil additive, with an acceleration up to 50%. The same trend is observed for rock dust as additive.

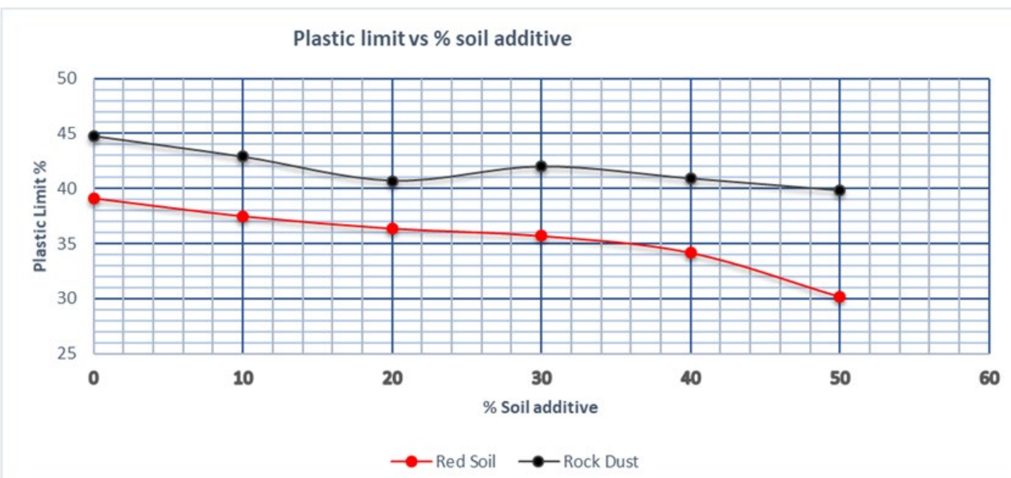

Figure 1: Variation of Plastic limit with percentage of soil additive

Figure 2 shows the variation of liquid limit with percentage of soil additive where it can be observed that the liquid limit decreases with addition of red soil from 10% to 40% and stabilised at 42% and increase again with a 50% DMC and red soil. It can be observed that the plasticity of the soil changes from highly plastic to medium plasticity after 30% additive and remains in the medium plasticity range till 50% additive.

When Rock dust is used as additive, the liquid limit values increase from 75.6% to 79.5%. respectively for plain expansive soil and 50% additive.

The above can be explained by the fact that the percentage of fines in rock dust is higher than that in the DMC, and contrary for red lateritic soil.

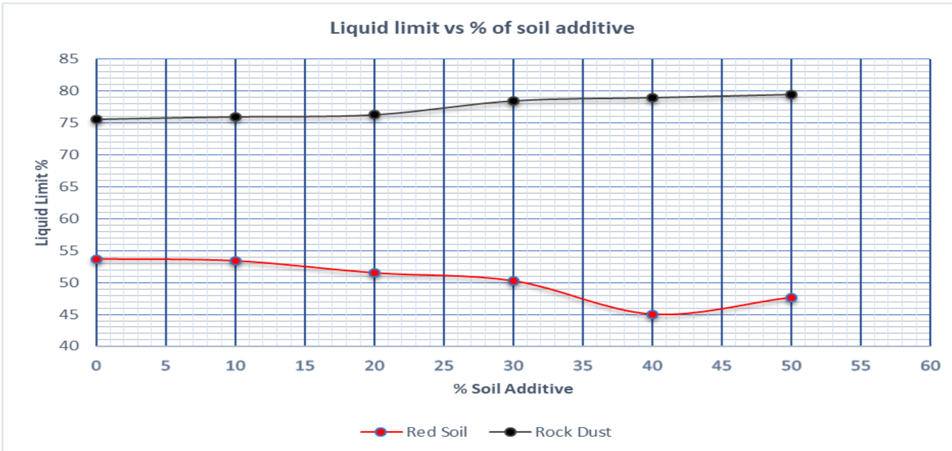

Figure 2: Variations of liquid limit with % of soil additive

Plasticity index Ip: Figure 3 shows the variation of plasticity index with percentage of soil additive.

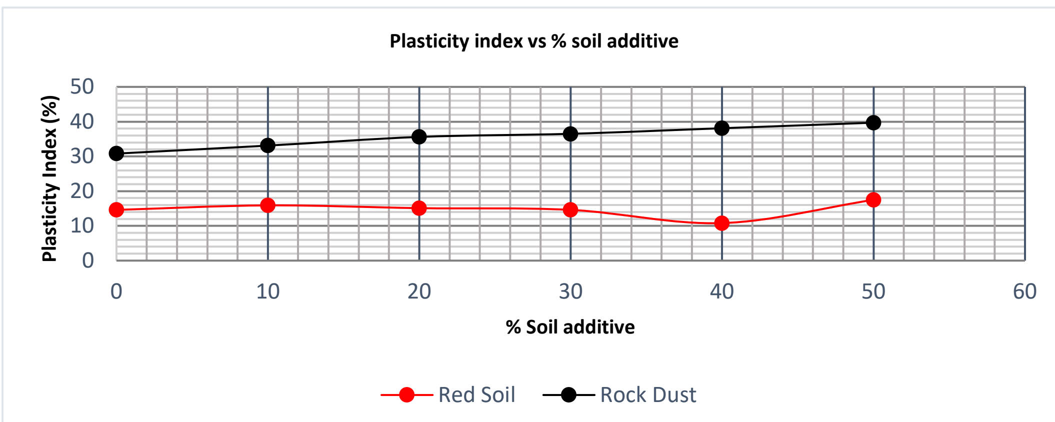

Figure 3: Variation of plasticity index with % of soil additive

The following classification is used: Ip = 0 - non-plastic; < 7 – Slightly plastic; 7 - 17 – Medium plastic; > 17 – Highly plastic.

It can be observed that the plasticity index varies differently for each of the two samples. For the one with the red soil it can be observed from the graph that the plasticity index varies from the initial soil sample where it is medium plastic and stays medium plastic till 40% soil additive and changes to highly plastic at 50% of soil mixtures whereas for the one with the rock dust it can be noted that there is an increased from 30.8% to 39.7%.

Proctor results

Figure 4 summarises the compaction properties of the various mixes.

For the Red soil it can be observed that the MDD is 1.309g/cm3 and for Dark magnesium clay it is 1.244g/cm3.The OMC is 33.30% for DMC and 29.50% for red soil whereas for the Rock dust as additives the maximum dry density value ɣdmax increases from 1.51 g/cm3 to 1.66 g/cm3 with variation in optimum moisture content from 25% to 27% for 0% to 50% additive respectively.

The graph above represents all the proctor graph where is can be seen graphically how the addition of percentage of soil change the MDD and OMC. It is observed for 30% additive of non-swelling soil additive the MDD is 1.348g/cm3 and the OMC is 22.1% which is an increase in maximum dry density and also a decreased optimum moisture content compares to initial soil.For the one with Rock Dust as additives the maximum dry density value ɣdmax increases from 1.51 g/cm3 to 1.66 g/cm3 with variation in optimum moisture content from 25% to 27% for 0% to 50% additive respectively. When comparing both sets of graphs it can be observed that both samples react the same.

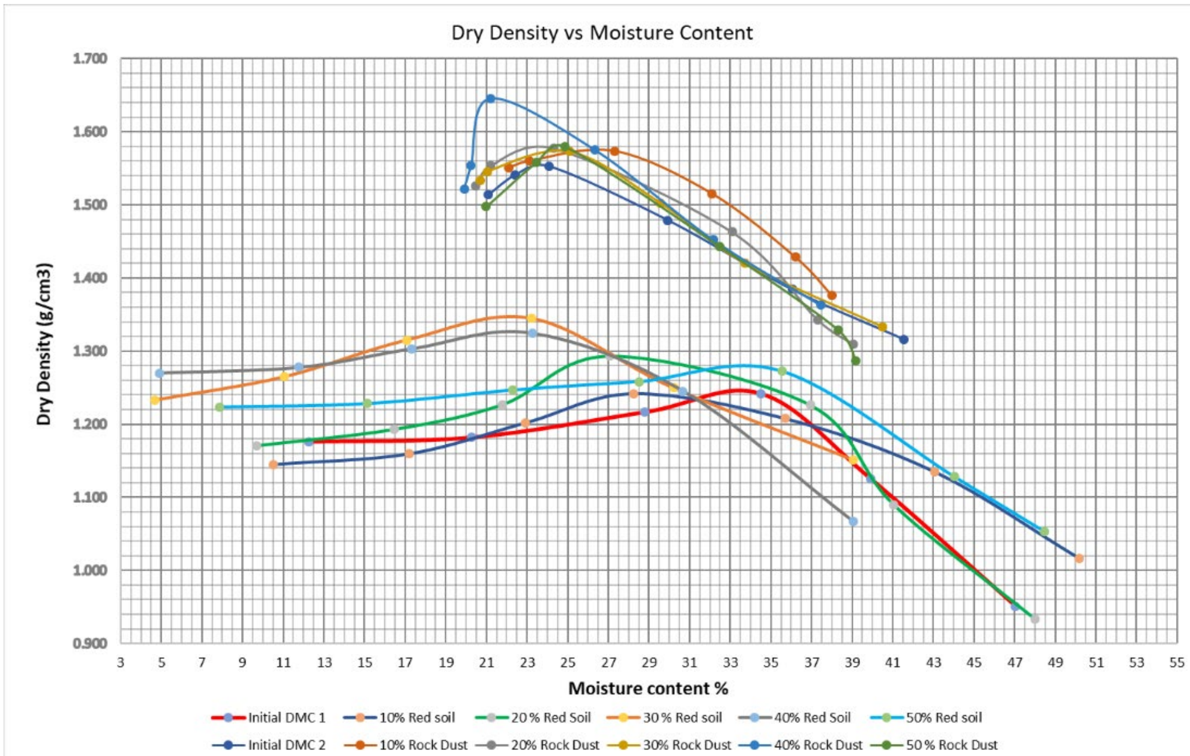

Figure 4: Graph of DD vs MC for all samples

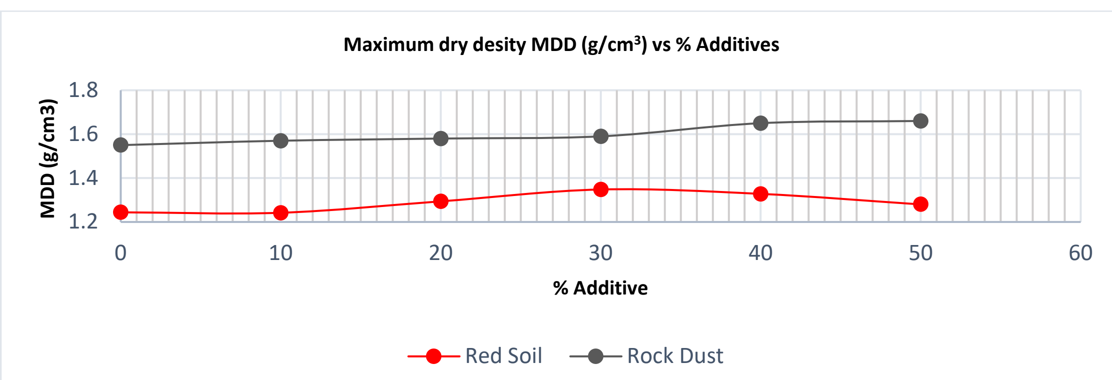

Figure 5: Trend of maximum dry density with increasing % of additives

Upon addition of red soil in increasing proportions to initial soil by weight, the maximum dry density (MDD) varies with the percentage of additive as seen in figures 4 and 5. With 10% of red soil additive the MDD is almost the same then increase with 20% to 30%. The maximum dry density stabilises at about 32% and 40% it decreases. At 50 % the maximum dry density value tends to return to the initial value. The maximum dry density value ɣdmax increases from 1.51 g/cm3 to

1.66 g/cm3 for 0% to 30% additive then between 30 % to 40 % of additives a major increase in the MDD is observed, then it starts to stabilise again between 40% to 50% of additives.

Optimum moisture content W_{opt} – defined as the water content at which a soil can be compacted to the maximum dry unit weight by a given compactive effort. For red soil as additive, a decrease in W_{opt} is observed. For 0% addition the W_{opt} is 33.3% and with addition the W_{opt} decreases to reach it minimum W_{opt} which can be read as 21.20% between 30% and 40% red soil additive and then increases to reach 33.75% at 50% red soil. In comparison with the red soil graph, for the rock dust it can be noted that the optimum moisture content increases from insignificantly for 25% to 27% for 0% to 50% additive respectively (Figure 6).

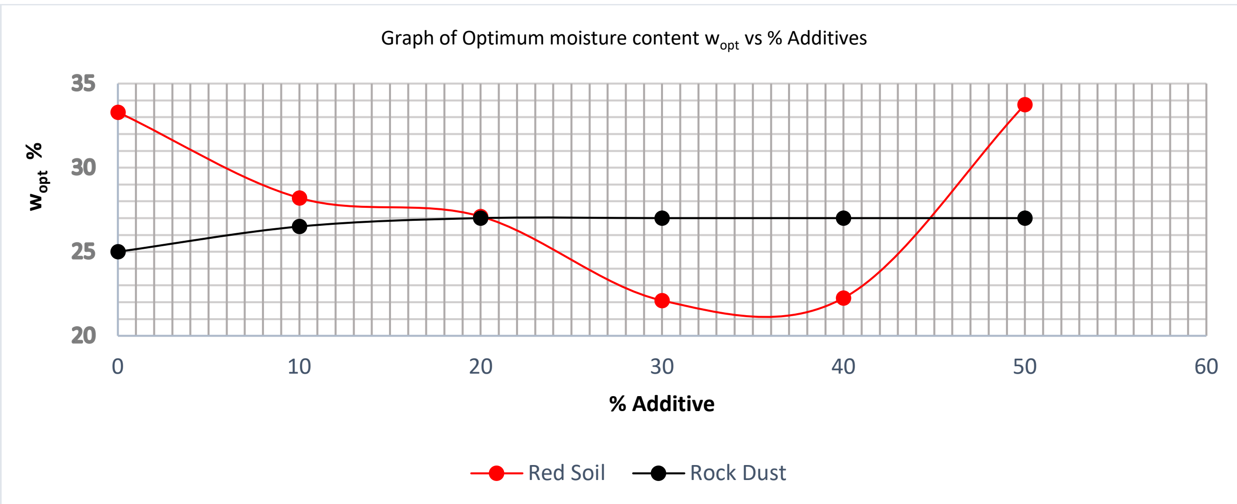

Figure 6: Trend optimum of moisture content with increasing % additives

Swelling pressure

The swelling pressure has been assessed from tests carried out on the 3 series of samples.

Results of each series of tests hare reported in Figure 7 below.

The swelling pressures decrease with the addition of percentage of non-swelling from 10% to 50% soil additive. The swelling properties are dependent upon the dry density of the soil and moisture content. The increase in dry density and the optimum moisture content has an impact on the swelling pressure.

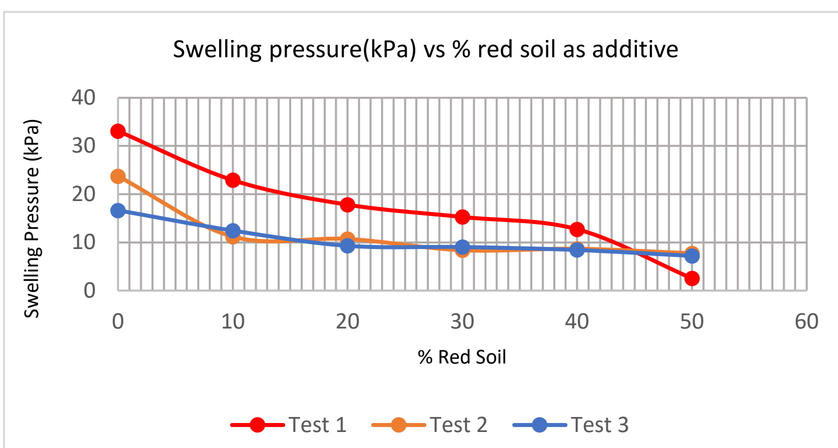

Figure7: Results of tests for swelling pressure

From the graph above it is observed that the swelling pressure of DMC decreases with the addition of non-swelling red soil. The swelling properties of the latter can be altered by controlling the dry density and moisture content.

Further testing may be required to identify the percentage of additive required to minimise the swelling pressure.

Conclusion

The soil-mixtures with red soil are designated as Initial and sample 1 to sample 5 throughout the work for reference Tests were conducted on the soil-mixtures. The Liquid limit decreases with addition of soil additive and stabilises with sample 4 at about 42% and start to increase till 50% soil additive. The Plastic limit decreases with the increase in percentage of red soil additive and Plasticity Index value decreases with 10% to 40% and increases with 50% addition of red soil. The Optimum Moisture Content (OMC) decreases with an increase in percentage of non-swelling soil from 10% to 30% and between 30% and 40% and start to increase when it reaches 50% addition. The maximum dry density (MDD) of the soil mixtures increases with addition in percentage of non-swelling soil from 10% to 30% then stabilised at about 32% and decrease from 40% to 50% soil mixtures.

Concerning the second soil mixture with Rock dust, it is clear from above experimental results that by increasing the amount of rock dust the value of plastic limit and swell potential were decreased and the properties like liquid limit, plasticity index, maximum dry density and optimum moisture content increased. The reason why rock dust improves soil properties is that it possesses pozzolanic nature and contains coarse particles that improves compaction characteristics and reduces the plasticity. Moreover, it has good interlocking strength with soil because of its angular shape.

The addition of rock dust has improved the strength property of the expansive soil and has given a skeleton to the soil which has reduced the swelling potential. Rock dust can be used for the treatment of expansive soils as it is readily available and cheap. Based on test results from the soil mixtures, it can be assumed that soil engineering properties is modified with addition of non-swelling soil to expansive soil in proper proportions. However, extensive experiments and deep analysis must be conducted to be more conclusive.

The addition of each of the additives in proper proportion improves the different characteristics of the swelling soils, but between the 2 soil mixtures tested it can be noted that mixing dark magnesium clay with rock dust yields more conclusive results.

Results also reveal that red lateritic soil may be used to reduce the swelling characteristics of expansive soils. In general, it has been observed that the swelling characteristics of expansive soils decrease with an increase in additive content.

Further, the performance of non-cementitious additives is observed to be superior over other categories of additives. Efforts were also made to study the influence of plasticity, compaction characteristics and swelling pressure.

The findings unequivocally demonstrate that a range of additives can be utilized to stabilize the expansive soils used in the study. However, while choosing a specific type of addition for the stabilization of expansive soils, considerations including cost, benefit, practicability, and availability must be made.

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