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Improving the Geotechnical Property of Expansive Soil through Marble Dust and Lime for Road Construction Projects

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Abstract - *Expansive soil is one of the most problematic grounds which cause extensive damage in civil engineering structure; mainly on the building, shallow foundation or other lightly loaded structure including roads, airport pavement, and pipelines. This type of soil occurs in many parts of the world, Ethiopia is one of those countries. In the Wolaita Sodo areas there is a large coverage of the expansive soil. Soil stabilization is one of the techniques to improve the physical and mechanical behavior of poor soil. The study conducted field investigation to identify the expansive soil and experimental work. Free swell test was carried out to identify the level of expansiveness. The stabilization occurred fixing the lime percent in (1-3) % increasing the percentage of marble dust with 0%, 5%, 10%, 15%, 20%, 25%, and 30%. The laboratory tests carried out to evaluate Atterberg limits, free swell, and compaction and CBR tests. The result indicated that the addition of marble dust with small percentage dosage of lime showed significant improvement on the geotechnical properties of both selected expansive soil samples. It reduces plasticity index, swelling, and OMC with an increase in MDD and CBR values with all combinations. Therefore, using lime and marble dust in a combined way further improved the geotechnical property of soil and the materials can be used as stabilizing agent for expansive soils.*

Key Words: Expansive soil, lime, marble dust, soil stabilization, CBR, MDD, OMC

1. INTRODUCTION

Expansive soils are a worldwide problem that poses several challenges for civil engineering structures. They are considered a potential natural hazard, which can cause extensive damage to structures if not adequately treated [1]. Expansive soils causes more damage to structures, particularly light buildings and pavements, than any other natural hazard, including earthquakes and floods [2].

Expansive soils pose a significant hazard to foundations of buildings founded in them. Such soils can exert uplift pressures which cause considerable damage to lightly loaded structures. The annual cycle of wetting and drying causes the soil to swell and shrink. Thus, the arid and semi-arid regions are much susceptible to damage from expansive soils throughout the year [3].

In expansive soil because of change in moisture conditions, there could be a significant volume change problem at different seasons. This could affect the stability of lightweight structures as a result of cyclic swell-shrink process [4] .The improvement of problematic soil at a site is indispensable due to rising cost of the land, and there is a huge demand for road construction. There is a need to concentrate on improving properties of soils using cost-effective practices like treating it with low cost and readily available material.

There are several treatment methods for improving properties of problematic soil; among this Stabilization is one of the most common ways. Soil stabilization is the process of altering the properties of soil by applying some modifiers to meet specified Engineering requirements of road pavement layers. It was carried out by various methods, and one of them is mixing with the Stabilizing Additives such as lime and cement. The demand of lime and cement has been increasing in the construction industry which causes increasing their cost. In this study, industrial wastes like marble dust had been used with small percentage of lime to improve geotechnical properties of a soil. Waste marble dust is obtained by different methods of cutting marble in manufacturing companies.

2. OBJECTIVE

2.1General Objective

The general objective of the study is to improve the geotechnical property of expansive soil through marble dust and lime for road construction projects

2.2 Specific Objective

- ✓ To identify their level of expansiveness.
- ✓ To study the influence of lime and marble dust effect on the geotechnical properties of the expansive soil.

3. Literature Review

Expansive soil is the term referred to any soil or rock that has potential for shrinking or swelling under changing moisture condition. The primary problem that arises with regard to expansive soil is that the deformations are significantly greater than elastic deformations and they cannot be predicted by classical elastic or plastic theories. There are several techniques for improving the engineering properties of soils for use in construction. One of the extensively used techniques for the improvement of problematic soil through stabilizing agents. Recently, a number of waste materials have been used in the stabilization of soils in order to reduce both environmental problems.

Stabilization of lateritic soil with marble-dust, crushed stone aggregate, lime, crushed stone aggregate lime mix and cement improves some of the geotechnical properties. Stabilization of expansive soil with potassium chloride, sugarcane molasses- cement mix, lime, cement, molasses, anyway Natural Soil Stabilizer (ANSS), natural and crushed sand, bagasse ash-lime mix, marble dust and Rice Husk Ash improves some of the geotechnical properties [5]. According to the study conducted by [6] stabilization of soil conducted by using marble dust with 3, 6,9,12, and 15%. Marble dust addition showed improved performance in problematic soils. The addition of marble dust increased the California bearing ratio.

[7] Investigated the geotechnical properties of lateric soil stabilized with banana leaf ash. Engineering tests such as compaction, California bearing ratio and unconfined compressive strength tests were also carried out on the lateritic soil at their natural states and at when the banana leaves ashes were added to the soil at varying proportions of 2, 4, 6, 8 and 10% by weight of soil. The unsoaked CBR value of the soil at its natural state was 10.42 % and it got to optimum value of 28.10% by addition of 4% banana leaves ash by weight of soil. The unconfined compressive strength improved from 209.18 KN/m2 at natural state to 233.77 KN/m2 at 4% banana leaves ashes. Therefore the study concluded that the banana leaves ash satisfactorily act as cheap stabilizing agents for subgrade purposes.

[8] Concluded on combination of Quarry dust and Egg Shell Powder is more effective than the addition of Quarry dust or Egg Shell Powder alone for the improvement of the properties of clay soil. According to the study conducted by [9], the geotechnical properties of soil examined using stabilization of soil with Terrasil solution. The stabilization of lateric soil with Terrasil solution with the percentage ranging from 0% to 16% at 2% interval. The result showed that the increment on unsoaked CBR value. Therefore the authors concluded that the Terrasil solution serves as a cheap and effective stabilizing agent for poor soil.

The addition of marble powder to clay reduces the liquid limit (LL), raises the plastic limit (PL) and shrinkage limit (SL) and reduce the plasticity index (PI) of soil, and hence swelling potential. The reduction of plasticity index was an indication of improvement of soil property [10]. Marble dust addition showed improved performance in problematic soils with the help of cation exchange reaction and hence 9% marble dust addition can be regarded as the optimum percentage for stabilizing the soil sample [11].

[12] Investigated the geotechnical properties of black clay soil in stabilized with pumice in stepped concentration of 10%, 20%, 30%, 40%, 50%, and 60% by dry weight of the soil. Analysis of the results shows slight improvement on the geotechnical properties of pumice stabilized soil. Pumice slightly reduces the index properties of the black clay soil as well as the heaving tendency of the soil. Pumice is known to its light weight property due to that the MDD of the soil decreases as the ratio of the pumice increased in the clay soil. Moreover, the CBR-Swell, free swell and one dimensional swelling pressure shows a decrease as the pumice ratio increases in the clay soil.

4. MATERIALS AND RESEARCH METHODOLOGY

4.1 study area

The study conducted on from Wolaita Sodo town to Gununo town from B/sore woreda. The average monthly temperature in the area ranges between 11.9°c (august) and 26.2°c (January) with a mean annual temperature of 18.9°c. Rainfall averages 1100 mm a year and is bimodal, with the short rains from February or March until April and the long rains from June until September or October.

4.2 Study design

To meet the objective of this research, field identification, Sampling and data collection, laboratories tests and analyzing the result from tests and conclusion and recommendation from the laboratory result is made. Field identification were conducted on the study area to identify the properties of expansive soils that are good indicator of their extensive potential, these was done for sampling during the time of highly dry season where expansive soils can be identified.

The samples were collected by following purposive soil sample, five test pits having expansive soil from different location have been selected, among this test pits a representative soil sample from two test pits were taken depending upon the value of their free swell tests. Disturbed soil samples were taken at a depth of 1.5m. After careful sampling, samples are transported to the laboratory and then the tests were performed on natural and stabilized sample soil to investigate; the engineering parameters of natural soil sample and the effect of proposed stabilizing agent on their properties by fixing different percentage of lime 1% up to 3%and blending it with varying percentage of marble dust from 5% up to 30%. The laboratory test conducted on selected natural subgrade soil and stabilized subgrade soil are; natural moisture content, grain size analysis, hydrometer, free swell tests, Atterberg limit, standard Proctor test and California bearing ratio (CBR).

4.3 Sample Technique

Purposive sampling technique was used for the study

4.4 Sample size

Five soil samples from a different location, (Sodo post office, waraza lasho, Kuto Sorpela, kebele 02(gununo), Boloso Sore which can be well represented expansive soils found in Sodo town to Gununo (Boloso sore) are purposively selected.

4.5 Material source

4.5.1 Expansive Soil

The soil used in this study was collected from Sodo town to Gununo. The soil sample with represents an expansive soil of Wolaita Sodo town to Gununo was obtained from two pits, kuto sorpela and Gununo where expansive soils highly occur. A disturbed sample is collected from the hole at a depth of 1.5 m from ground level to avoid the inclusion of organic matter. The Index & Engineering properties of expansive soil are going to be determined as per AASHTO and ASTM standard.

Table 1: Classification of expansive soil in the study area according to U.S.B.R

No.	Sample code	Color	Free Swell (%)	U.S.B.R Classification
1	S-1	Black	90	Medium expansive
2	S-2	Black	100	Medium expansive
3	S-3	Black	110	Highly expansive
4	S-4	Black	100	Medium expansive
5	S-5	Black	150	Very highly expansive

Based on their free swell value, S-1, S-2 and S-4 expansive soil were classified under Medium expansive soil; S-3& S-5 were classified under highly expansive and very highly expansive respectively. From the five expansive soil samples S-3 & S-5 were selected and the laboratory test was conducted for both this soil samples on natural soils and on stabilized conditions.

4.5.2 Marble Dust

Marble dust used in this research was obtained from Ethiopian marble industry which is located in the Hawassa Ceramic Factory. Marble dust from the sector is appropriately packed in sacks and transported to the laboratory.

Fig 1: Sample marble dust

Table 2: Physical properties of marble dust from Hawassa industry

Physical properties of marble dust	
Liquid limits	21.8
Plastic limits	18.68
Plastic index	3.32
Specific gravity	2.83

4.5.3 Limes

Table 3: Chemical composition of Senkelle hydrated lime [13]

Constituent	Percentage (%)
SiO2	6.21
AL2O3	2.18
Fe2O3	3.57
CaO	59.47
MgO	3.91
Na_2O	0.61
K_2O	0.79
Ti_{O2}	0.3286
P_2O5	0.208
MnO	0.2785
SO_3	0.58

5. Laboratory results

5.1 The laboratory test result of natural soil

Parameter	Sample 3	Sample 5
Percentage passing through sieve No 200	98.3% and	97.0 %
Liquid limit	106.5	98.5
Plastic limit	40.2	38.45
Plastic index	65.84	59.55
AASHTO specification	A-7-5	A-7-5
Specific gravity	2.64	2.70
Free Swell	110	150
Natural Moisture content	44	62
Maximum dry density g/cm3	1.230	1.245
Optimum moisture content	37.2	36.45
CBR value	1.1%	0.93%
CBR-swell	10.4	10.8
ERA subgrade class	S1	S1
Color	Black	Black

5.2 Effect of marble and lime on LL(S-3)

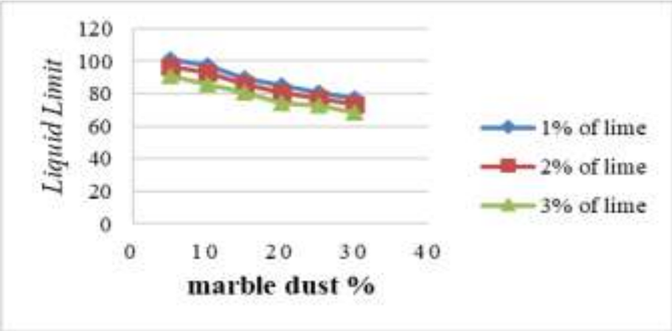

Fig 2: Effect of lime and marble dust on LL

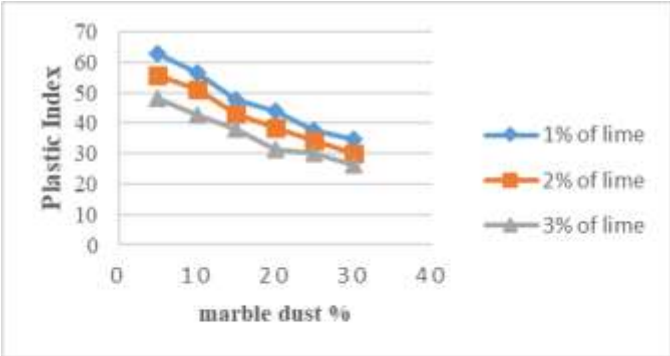

Fig 3: Effect of lime and marble on plastic index

5.3 Effect of marble and lime on LL(S-5)

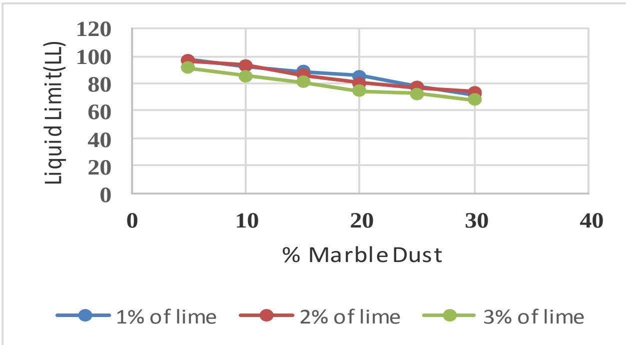

Fig 4: Effect of lime and marble dust on LL

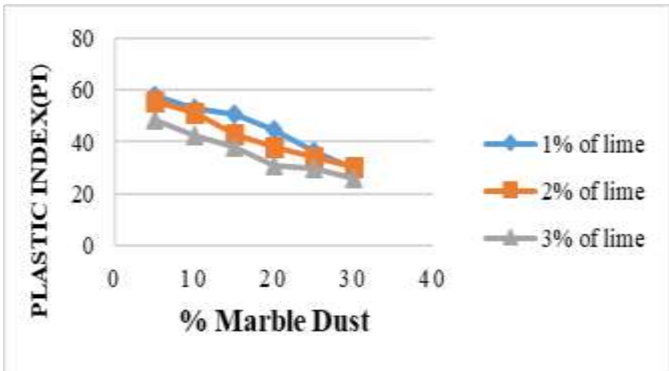

Fig 5: Effect of lime and marble dust on PI

As shown in the above chart, the combination of lime and marble dusts effectively improve the plasticity of expansive soil. This is shown by the fact that plasticity index of treated soil decreased with increasing additive content. These effects probably due to the partial replacement of plastic soil particles with both non-plastic materials(lime and marble dust)and flocculation and agglomeration of clay particles caused by cation exchange. However, plastic limit diagrams of both sample 3 and sample 5 treated with combinations of different percentage of lime and marble dust results unusual variations from which it was difficult to decide whether increment or decrement on plastic limit values.

5.4 Effect of lime and marble dust on free swell

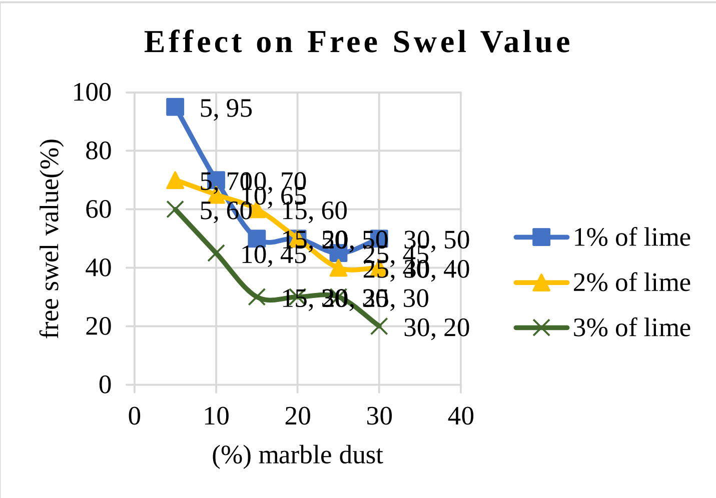

Fig 6: Effect on lime and marble dust on free swell (S-3)

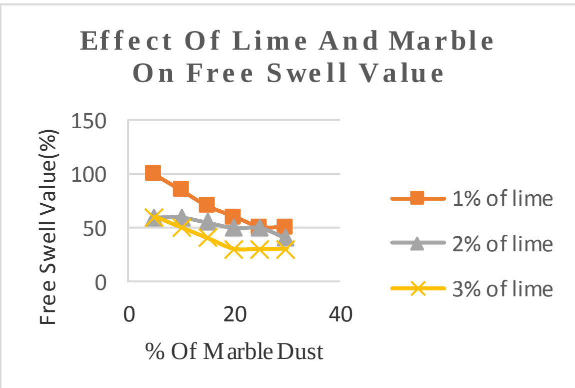

Fig 7: Effect on lime and marble dust on free swell (S-5)

As is shown in the above figure, the reduction in free swell value is directly proportional to the quantity of admixture (lime and marble dust). The highest reduction in free swell value is attained when the expansive soil is treated with 3% lime and 30% marble dust which is 75% and 70% reduction when compared to the untreated soil for sample three and sample five respectively. The decline in percentage is mainly due to the reason may be due to cation exchange in the combination of lime and marble with soil mix.

5.5 Effect on Maximum dry density (kutosorpela)

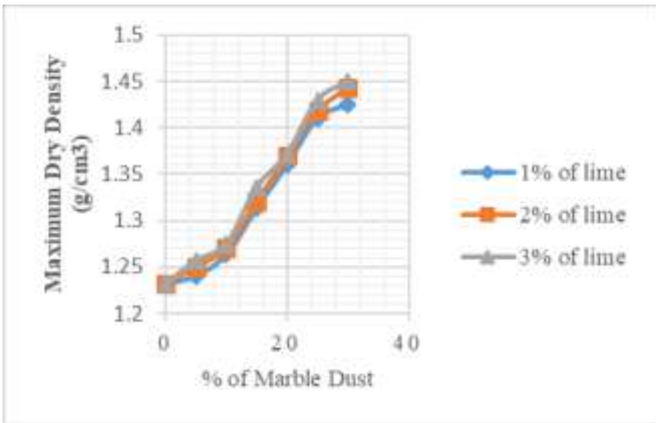

Fig 8: Effect on dry density(S-3)

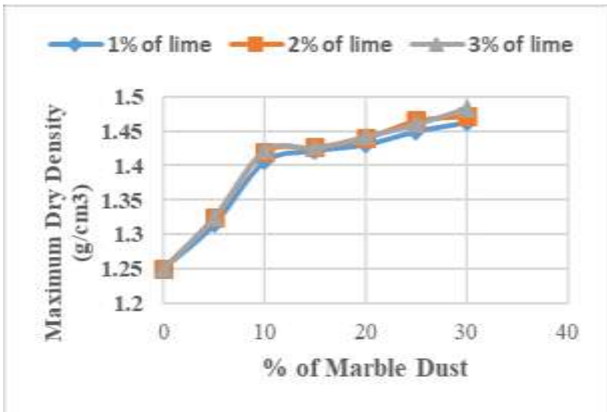

Fig 9: Effect on dry density(S-3)

The combined effect of marble dust and lime on the maximum dry density of both samples calculated by fixing percentage lime from 1%-3% and blending it with different percentage of marble dust from (5%-30%) shows that maximum dry density increase with increasing percentage of both lime and marble dust. The result showed that maximum dry density increase with increasing percentage of both lime and marble dust.

5.6 The effect of marble dust and lime on the moisture content

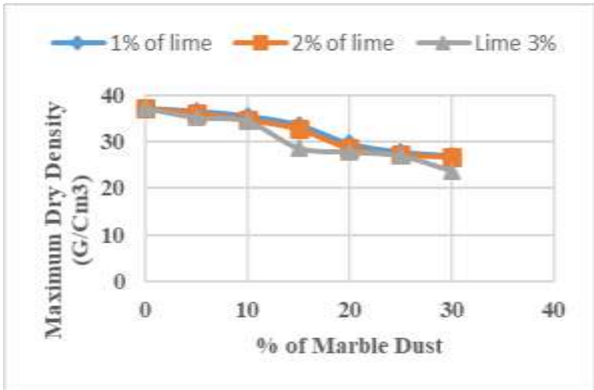

Fig 10: Effect on Moisture content(S-3)

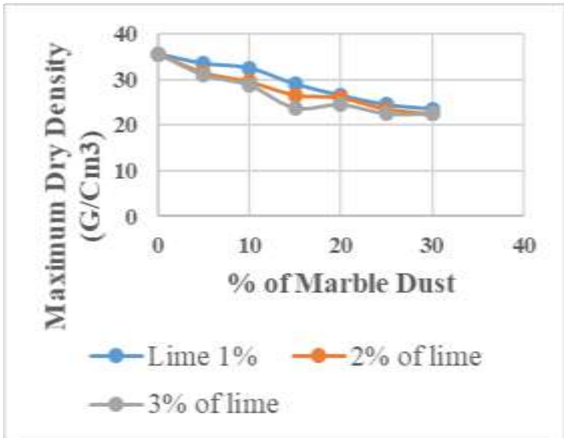

Fig 10: Effect on Moisture content(S-5)

It was observed that optimum moisture content of both sample soils is decreasing with increasing percentage lime and marble dust. For the maximum percentage of lime used in this study (3%) and combined with maximum percentage marble dust (30%), the optimum moisture content of natural soil(sample 3 and sample 5) was decreased because both lime and marble are non-plastic material.

5.7 Effect on CBR value

Two samples are usually prepared for CBR tests; one is tested directly after sample preparation (unsoaked CBR), and the other one is after soaking in water for 96hr (soaked CBR). Fixed percentage of lime that blended with different percentage marble dusts are increased, It can be seen that the CBR values of the soil samples are significantly increased, almost above the minimum recommended amounts that specified by ERA manual for subgrade soils, when different percentage of Marble dust with both natural soil samples are blended with 2% and 3% of lime. When compared untreated soil sample with the sample treated with lime (1-3%) blended with marble dust (5-30%), 18%-420% increases in CBR values on sample 1, and 30%-650% increases on sample 2. On the other hand, 45%-200% and 9%-265% increases on CBR values on sample 3 and sample 5 respectively, when compared with the sample soil treated with maximum percentage of marble dust (30%).

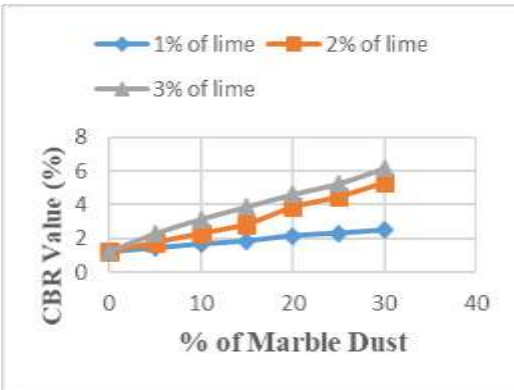

Fig 11: Effect of lime and marble on CBR value (S3)

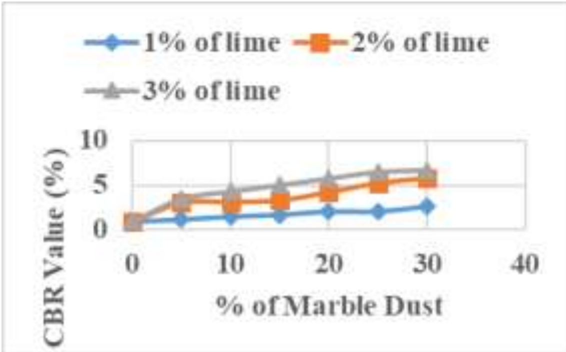

Fig 12: Effect of lime and marble on CBR value (S-5)

From the above chart the CBR values of both soil samples have been increasing as fixed percentage lime that added to the different percentage of marble dust increased. This increment may be attributed to the chemical and cementitious effects of lime on structural composition of soils is more significant than to that of marble dust, since both lime and marble dust have cementitious material which bonding between clay particles, lime and marble dust becomes strong, and the load bearing capacity has been increased.

6. CONCLUSIONS

- ✓ Laboratory test result indicates that the natural subgrade soil of the subject area was classified as a material of deficient engineering property to be used as a sub-grade material. It requires first modification and stabilization to improve its workability and engineering property.

- ✓ With the addition of lime and marble dust, the liquid limit and plasticity index decreased, maximum decrement on liquid limit and plastic index value is achieved when both soil samples were mixed with 3% of lime and 30% marble dust combined.
- ✓ The addition of marble dust and lime on both natural soil sample resulted in a remarkable increased in the maximum dry density and a decreased in optimum moisture content.
- ✓ Free swell values of both soil sample goes decreasing as combined percentage of lime, and marble dust increased, maximum decrement on free swell value is achieved at combinations of 3% lime and 30% marble dust, it decreased from105% and 110% to 30% and 20% respectively for sample 3 and sample5. With this combination, both soil samples are shifted from highly expansive to low expansive soil. Hence, it will not create any problem with the structures to be founded on it.
- ✓ Soaked CBR values of both soil sample increases with increase in combined percentage of lime, and marble dust, maximum increment in CBR value is achieved a combination of 3% lime and 30% marble dust.
- ✓ Combinations of 3% of lime and 30% of marble dust were found to be a percentage proportion of admixtures which yielded maximum strength as well as minimum swelling potential and plasticity in the soil sample.
- ✓ Combining two local materials (lime and marble dust) can efficiently improve the poor geotechnical properties of this soil and help in increase land resources available for construction projects.

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