Effect of Lime and Stone Dust Admixtures on Geotechnical Properties of an Expansive Soil

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Abstract: ***Black cotton soils have the tendency to swell when their water content is increased and shrink when their water content is decreased. The water may come from rain flooding, leaking water or sewer lines or from reduction in surface evapotranspiration when an area is covered by a building or pavement. To achieve the economy and for proper performance of structures it is necessary to improve the geotechnical properties of expansive soil. Out of the different quarry wastes, quarry dust is one, which is produced in abundance. About 20–25% of the total production in each crusher unit is left out as the waste material-stone dust. Bulk utilization of this waste material is possible through geotechnical applications like embankments, back-fill material, sub-base material and the like. Lime treatment of soils is a proven method to save time and money on construction projects. Lime drying of wet soils minimizes weather-related construction delays and permits the return to work within hours. Lime modification chemically transforms clay soils into friable, workable, compactable material. Lime stabilization creates long-term chemical changes in unstable clay soils. For This project work we collected Black cotton soil sample from Pamarru in Krishna District (A.P). In this project the results of an experimental program undertaken to investigate the effect of stone dust & lime combined at different percentage with expansive soil, the test results such as index properties, Proctors compaction, differential free swelling test and unconfined compression strength, California bearing ratio obtained on expansive clays mixed at different proportions of lime and stone dust admixture are presented and discussed. From the results, it is observed that at optimum percentages, i.e., 6% lime +24 % stone dust, it is found that the swelling of expansive clay is almost controlled and also noticed that there is a marked improvement in the other properties of soil. The conclusion drawn from this investigation is that the combination of stone dust and lime is more effective than the addition of stone dust/lime alone to the expansive soil in controlling the swelling behaviour.***

Keywords: ***Block cotton soil, Lime, Stone Dust, Shrinking and Swelling, Compaction, Unconfined compression strength, California bearing ratio.***

I. INTRODUCTION

Soil improvement is of major concern in the construction activities due to rapid growth of urbanization and industrialization. The term soil improvement is used for the techniques which improve the index properties and other engineering characteristic of weak soils. In India expansive soil cover about 0.8x106 km2 area which is approximately one-sixth of its surface area. These soils contain montmorillonite mineral; due to this they swell and shrink excessively with change of water content. Such tendency of soils due to the presence of clay particles which swell, when they come in contact with water, resulting in alternate swelling and shrinking of soil due to which differential settlement of structure takes place. Expansive soils can be stabilised by the addition of a small percentage of lime and other admixtures. These techniques have been used for many construction purposes, notably in highway, railroad and airport construction to improve sub grades and sub-bases. The Quarry dust is a by-product produced in granite factories while cutting huge granite rocks to the desired shapes. About 3000 metric ton of granite dust/slurry is produced per day as a by-product during manufacturing of granite tiles and slabs from the raw blocks. The marble and granite industries are dumping these wastes in nearby pits or open lands. This leads to serious environmental pollution and occupation of vast area of land especially after the slurry dries up. This study investigate the Results of granite dust on the consistency limits and differential free swell (DFS) of Black Cotton Soil mixed with 2 to 6% lime and 6 to 30% granite dust by weight of soil.

Expansive Soils

Expansive soil deposits occur in the arid and semi-arid regions of the world and are problematic to engineering structures because of their tendency to heave during wet season and shrink during dry season. It swells and shrinks excessively with change of water content. Such tendency of soil is due to the presence of fine clay particles which swell, when they come in contact with water, resulting in alternate swelling and shrinking of soil due to which differential settlement of structure takes place. Stabilization of black cotton soil has been done in this project work by using lime and stone dust as admixture.

Black Cotton Soil

Expansive soils are soils or soft bedrock that increases in volume or expand as they get wet and shrink as they dried out. In India this Expansive soil is called ‘black cotton soil’. Colour of this soil reddish brown to black and this helps for cultivation of cotton, so is called black cotton soil. This swelling soil covers about 30% of the land area in India. They are also commonly known as expansive or Black Cotton soil. In India Black Cotton soil also known as ‘regurs’ are found in extensive regions of Deccan Trap. Black Cotton soil is one which when associated with as engineering structure and in presence of water will show a tendency to swell or shrink causing the structure to experience moments which are largely unrelated to the direct effect of loading by the structure.

These clays are characterized by

- Having a particle size, below 2 micron.
- A large specific surface area (SSA) and
- A high Cat ion Exchange Capacity (CEC).
- High liquid limit and plasticity index.

Problems Associated With Black Cotton Soil

Black Cotton soils are problematic for engineers everywhere in the world, and more so in tropical countries like India because of wide temperature variations and because of distinct dry and wet seasons, leading to wide variations in moisture content of soils. The following problems generally occur in black cotton soil.

(a) High compressibility

Black Cotton soils are highly plastic and compressible, when they are saturated. Footing, resting on such soils under goes consolidation settlements of high magnitude.

(b) Swelling

A structure built in a dry season, when the natural water content is low shows differential movement as result of soils during subsequent wet season. This causes structures supported by such swelling soils to lift up and crack. Restriction on heaving developed due to swelling pressures making the structure suitable.

(c) Shrinkage

A structure built at the end of the wet season when the natural water content is high, shows settlement and shrinkage cracks during subsequent dry season.

II. MATERIALS USED

a. Soil

The soil used for this investigation is obtained from Pamarru near Vijayawada, Krishna (District). The dried and pulverized material passing through I.S.4.75 mm sieve is taken for the study. The properties of the soil are given in Table 2.1. The soil is classified as "CH" as per I.S. Classification (IS 1498:1970) indicating that it is highly compressible clay. It is highly expansive in nature as the Differential Free Swell Index (DFSI) is about 55%.

Table 2.1: Properties of Untreated Soil

Sl.No.	Property	Value
1	Grain size distribution (a).Gravel (%) (b).Sand (%) (c).Silt&Clay (%)	 0.5 12.2 87.3
2	Atterberg Limits (a).Liquid Limit (%) (b).Plastic Limit (%) (c).Plasticity Index (%)	 57.5 26 31.5
3	Differential Free Swell Index (%)	55
4	Specific Gravity	2.69
5	Shrinkage limit (%)	13.33
6	Compaction Characteristics (a).Maximum Dry Unit Weight (kN/m^3) (b).Optimum Moisture Content (%)	 16.9 23.2
7	California Bearing Ratio Value (a) @ 2.5mm Penetration (b) @ 5.0mm Penetration	 2.8 2.53
8	Unconfined Compressive Strength (kN/m^2)	161.2
9	Direct shear parameters (a).Cohesion(kg/cm2) (b).Angle of internal friction(degrees)	 0.08 20

b. Lime

Lime is a White coloured powder and soluble in water. Addition of lime to clay causes several phenomenon's in soil like; plasticity index, rising of efficiency, resistance on survival in soil. Lime will show some chemical reaction with clay that causes some cemented minerals like: calcium silicate and calcium aluminates came to existence. The quantity or ratio of those minerals increases during time; and also the resistance of soil rises.

When adequate quantities of lime and water are added, the pH of the soil quickly increases to above 10.5, which enables the clay particles to break down. Silica and alumina are released and react with calcium from the lime to form calcium-silicate hydrates (CSH) and calcium-aluminate- hydrates (CAH). These compounds form the matrix that contributes to the strength of lime-stabilized soil layers. The chemical composition of the lime is shown in Table 2.2.

Table 2.2: Chemical Composition of Lime

S.No.	Basic Compounds (%)	Percentage
1	CaO	52.35
2	SiO_2	0.45
3	Al_2O_3	0.33
4	Fe_2O_3	0.14
5	MgO	1.05
6	Na_2O	0.06
7	K_2O	0.02
8	Loss on ignition	42.5
9	Insoluble Residue	0.2
10	Specific Surface (Kg/m^2)	538
11	Specific Gravity	2.65

c. Stone Dust

Stone dust is one, which is produced in abundance. About 20–25% of the total production in each crusher unit is left out as the waste material-stone dust. Bulk utilization of this waste material is possible through geotechnical applications like embankments, back-fill material, and sub-base material. The object of our present studies is to improve the various properties of black cotton soil by mixing locally available material, hence stone dust, which is locally and easily available material, selected to mix with black cotton soil in different proportions the admixture is collected from Chimakurthi in Prakasam (District), Andhra Pradesh. The raw material is Granite stone (Quarry Dust), which comes from leased open cast mines located nearby. The unit generally operates in one shift a day. The basic details are given below table 2.3 and geotechnical properties of stone dust are shown in the table 2.4.

Table 2.3: Product size analysis

Product size in mm	Local name
12 - 20	Aggregate
8 - 12	Grit
4 - 8	Dust

Table 2.4: Geotechnical Properties of Stone Dust

Sl.No.	Property	Value
1	Grain size distribution (a).Gravel (%) (b).Sand (%) (c).Silt&Clay (%)	 0.02 95.81 4.17
2	Atterberg Limits (a).Liquid Limit (%) (b).Plastic Limit (%) (c).Plasticity Index (%)	 - - -
4	Specific Gravity	2.7
6	Compaction Characteristics (a).Maximum Dry Unit Weight (kN/m^3) (b).Optimum Moisture Content (%)	 17.95 13.6

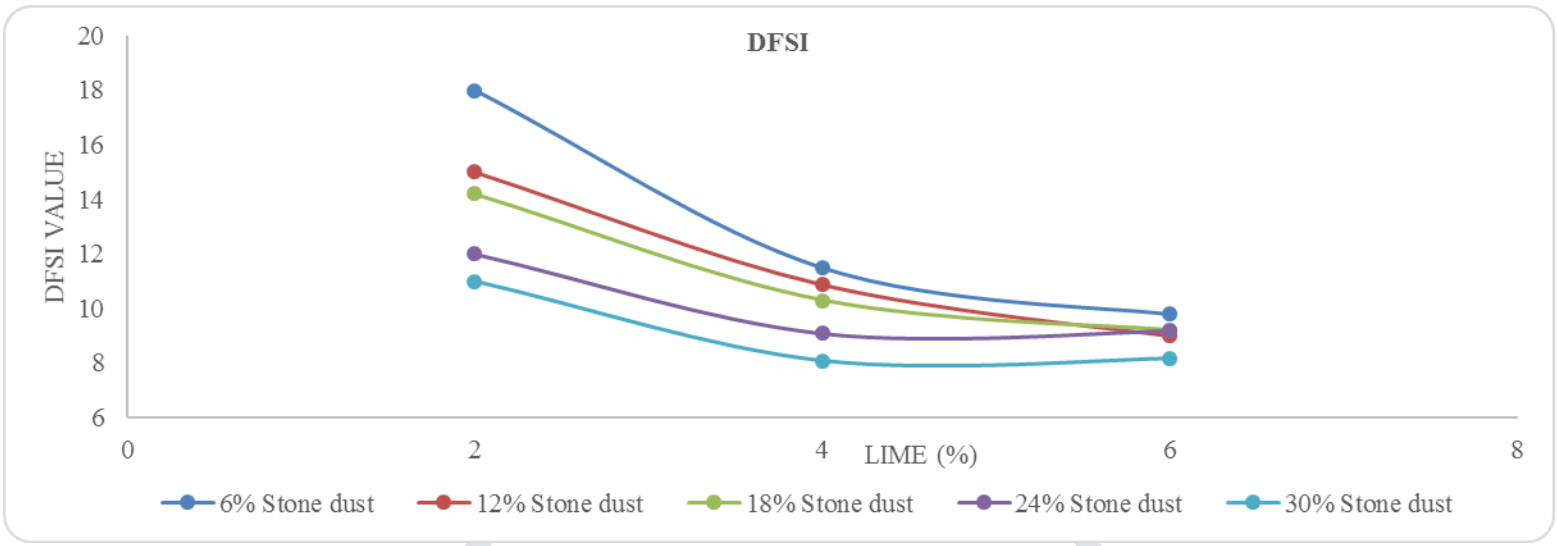
III. EXPERIMENTAL PROGRAMME

In this project the experimental program undertaken to investigate the index properties, Proctors compaction, differential free swell index and unconfined compression strength, California bearing ratio. The soil from the site is dried and hand sorted to remove the pebbles and vegetative matter if any. It is further dried and pulverized and sieved through a sieve of 4.75mm to eliminate gravel fraction if any. The dried and sieved soil is stored in air tight containers ready for use for mixing with Lime & Stone dust.

The soil sample so prepared is then mixed with various Proportions of Lime & Stone dust. The percent of Admixtures content is varied as 2% lime with 6% stone dust, 2% lime with 12% stone dust,4% lime with 6% stone dust,4% lime with 12% stone dust,4% lime with 18% stone dust,4% lime with 24% stone dust,4% lime with 30% stone dust,6% lime with 6% stone dust,6% lime with 12% stone dust,6% lime with 18% stone dust,6% lime with 24% stone dust,6% lime with 30% stone dust. The admixtures content is taken by weight of soil taken.

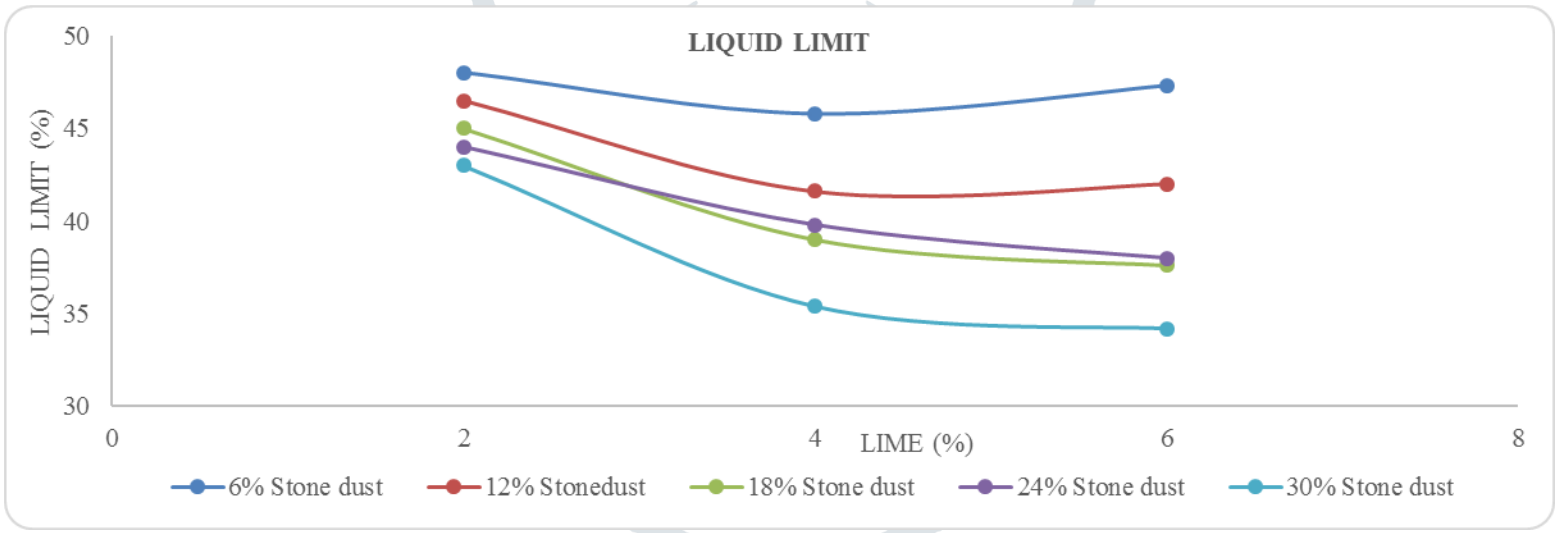
IV. COMPARISION OF RESULTS AND DISCUSSIONS

RESULTS:



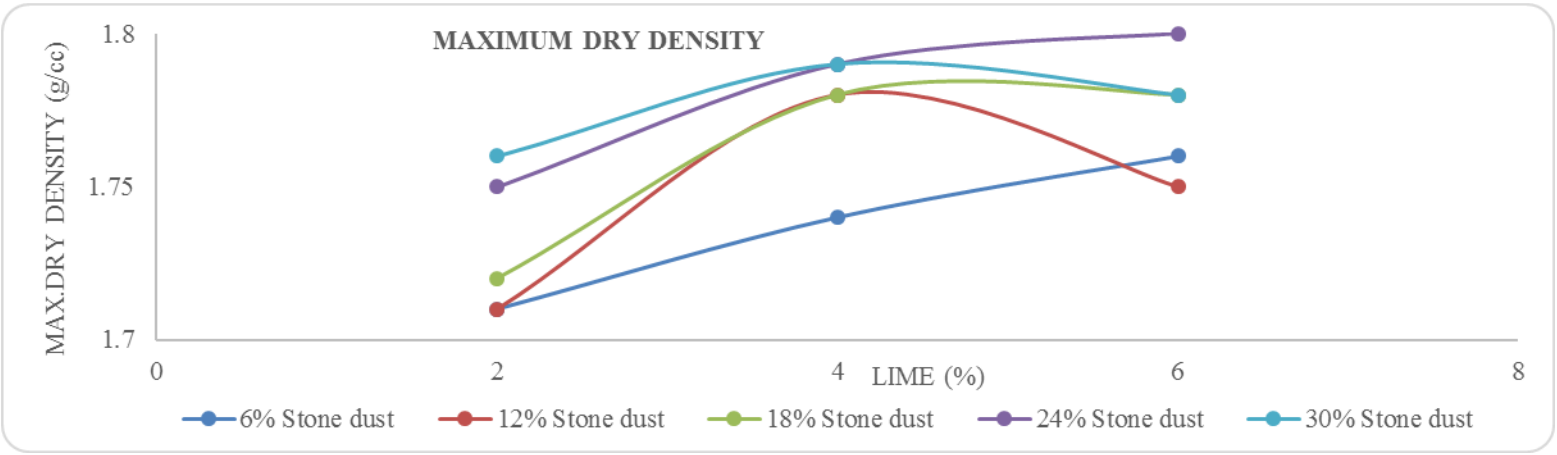
Graph: 4.1: Variation in Differential Free Swell Results.

Graph: 4.1 shows variation in differential free swelling value, it shows that maximum reduction in Differential Free Swelling was found at addition of 6% lime and 30% stone dust to black cotton soil.



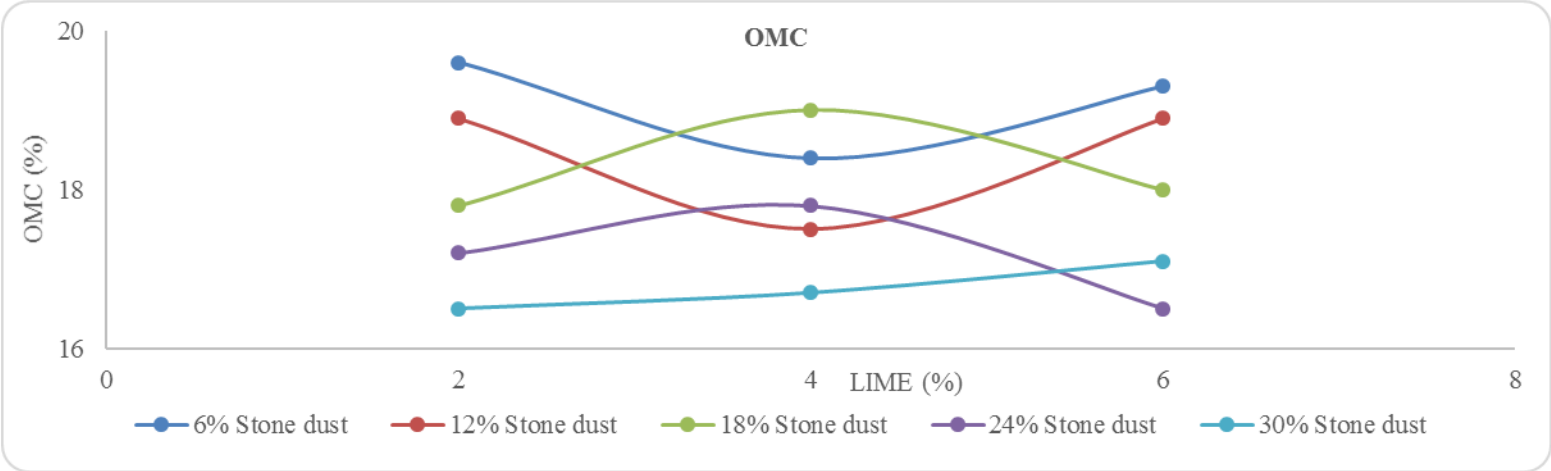
Graph 4.2: Variation in Liquid Limit

Graph: 4.2 shows variation in liquid limit of black cotton soil, it shows that maximum reduction in liquid limit was found with addition of 6% lime and 30% stone dust in black cotton soil.



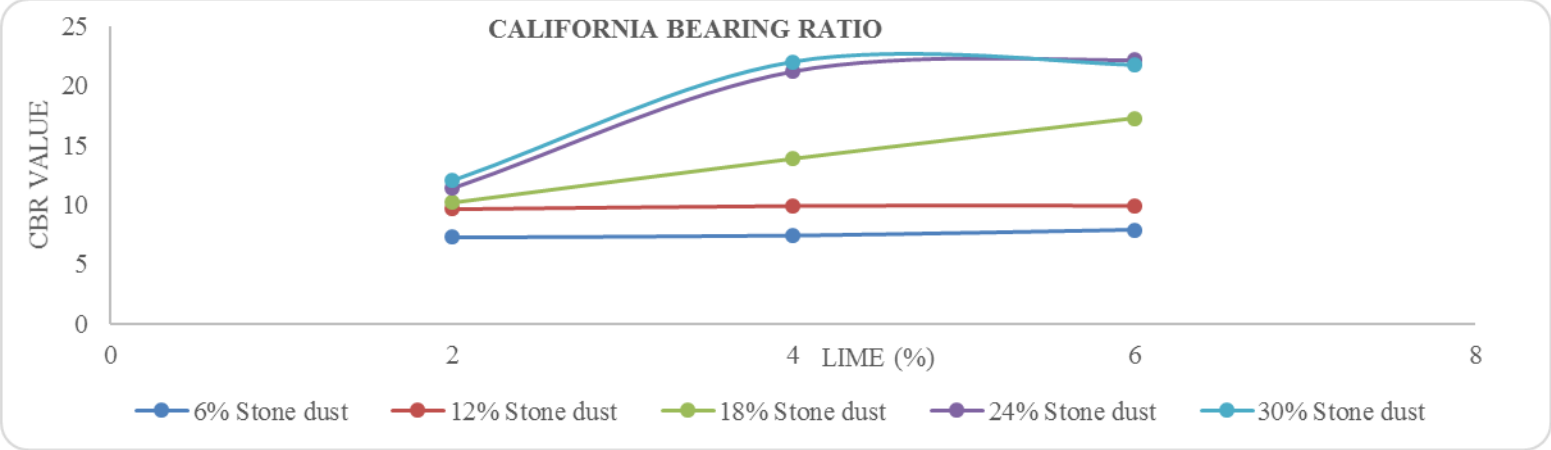
Graph: 4.3: Variation in Maximum dry density.

Graph: 4.3 shows variation in maximum dry density of black cotton soil, it shows that maximum dry density is increased with addition of 6% lime and 24% stone dust in black cotton soil.



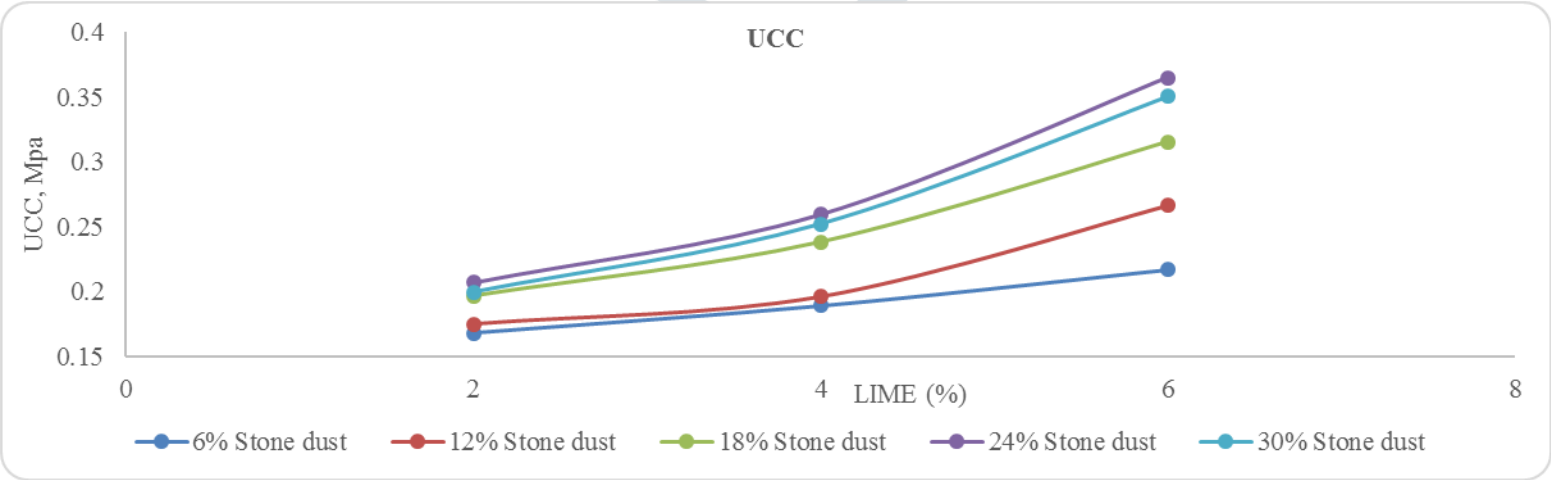
Graph: 4.4: Variation in Optimum Moisture Content.

Graph: 4.4 shows variation of optimum moisture content of black cotton soil, it shows that maximum reduction in OMC was found with addition of 6% lime and 24% stone dust in black cotton soil.



Graph: 4.5: Variation in CBR Values.

Graph: 4.5 shows variation in CBR of black cotton soil, it shows that maximum CBR value was found with addition of 6% lime and 24% stone dust in black cotton soil



Graph: 4.6: Variation in Unconfined Compression Strength of soil.

Graph: 4.6 shows variation in UCC of black cotton soil, it shows that maximum UCC value was found with addition of 6% lime and 24% stone dust in black cotton soil.

DISCUSSIONS:

1. The results of differential free swelling tests on lime and stone dust stabilized expansive soil treated with different percentages has been shown in above Figures. It is observed that by addition of lime and stone dust, the differential free swelling index of soil decreases to 8.2% at 6% lime+30% stone dust. The reason of which is the decrease in plasticity characteristics of soil due to reduction in clay content of soil because of replacement of clay with stone dust. This is because of the pozzolanic reaction of lime with the amorphous silica and Alumina present in soil and stone dust a strong inter particle bond develops, this cementing bond offers greater resistance to swelling and also does not allow the water to escape from soil to induce shrinkage.
2. Liquid limit of Black cotton soil was decreased by addition of lime and stone dust at different percentages. This is because when quicklime chemically combines with water, it can be used very effectively to dry any type of wet soil. Heat from this reaction further dries the wet soils. The reaction with water occurs even if the soils do not contain significant clay fractions. When clays are present, lime's chemical reactions with clays increase the moisture-holding capacity of the soil, which reduces free liquids and decreases in liquid limit because clay particles are reduces by addition of stone dust in black cotton soil.
3. It is observed that maximum dry density of Black cotton soil was increased upto addition of 6% lime and 24% stone dust. This is because of the frictional resistance from stone dust in addition to the cohesion from Black cotton soil and lime gives the binding property to soil.
4. The results of UCC tests on Black cotton soil treated with different percentages of lime and stone dust are shown in above figures. By increasing the percentages of lime and stone dust, UCC of soil increases upto a limit at addition of 6% lime and 24% stone dust, further addition of admixture decreases the UCC of the expansive soil. The UCC of Black cotton soil increases to 0.3644N/mm^2 from 0.1612 N/mm^2, when 6% lime and 24% stone dust was added. This is because of the additional frictional resistance. Reduction in UCC occurs due to reduction in cohesion because of the reduction in expansive soil content.
5. The results of CBR tests on black cotton soil with lime and stone dust are shown in above figures. It is observed that by addition of lime and stone dust at different percentages, rate of increases in the CBR of soil increases to 792% from 260% upto addition of 6% lime and 24% stone dust, further addition of admixtures slightly decreases the CBR of the soil. The CBR attains the highest value when the percentage of 6%lime and 24%stone dust was added. There is a 792% increase in CBR of the virgin soil by the combined effect of lime and stone dust. The reason of this effect is the pozzolanic reactions of lime with the amorphous silica and Alumina present in soil and stone dust. After addition of 6% lime and 24% stone dust the strength decreases because of the availability of extra admixtures to react with the insufficient amorphous silica and Alumina present in soil and stone dust which results in carbonation reaction and thus strength decreases.

V. CONCLUSIONS

The present study can serve as an effective method to utilize stone dust and lime in the stabilization of expansive soil. The conclusions are based on the tests carried out on various clay-stone dust and lime mixes selected for the same.

1. It has been seen that differential free swelling index and liquid limit decreases by adding lime and stone dust up to 4%lime & 30% stone dust, whereas further addition of admixtures increases it.
2. The optimum value of maximum dry density and unconfined compressive strength was found at 6% lime & 24 % stone dust.
3. Optimum moisture content was found gradually decreasing by adding admixtures and maximum reduction in OMC was found at 6% lime & 24 % stone dust.
4. Increase in plastic limit was very less up to addition of 2% lime & 6% stone dust further addition of admixtures plastic limit was gradually decreased up to 6% lime & 6%stone dust and after addition soil was found non plastic.
5. Maximum CBR value was found at addition of 6% lime & 24 stone dust.
6. It was found that there is a maximum improvement in strength properties for the combination of lime and stone dust as compared to lime/stone dust individually. This helps to find an application for industrial waste to improve the properties of expansive soil both in embankments and pavement constructions.

So the optimum percentages of lime and stone dust were observed at 6% lime and 24 % stone dust for improving the properties of expansive soil. Stone dust and lime has good potential for use in geotechnical application of soils is a proven method to save time and money on construction projects. Lime drying of wet soils minimizes weather-related construction delays and permits the return to work within hours. Lime modification chemically transforms clay soils into friable, workable, compactable material. Stone dust and lime stabilization creates long-term chemical changes in unstable clay.

VI. REFERENCES

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