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Stabilization of Expansive Soil By Using Lime and Quarry Dust

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ABSTRACT: Black cotton soils tend to expand as their water content increases and contract when it decreases. The water may originate from rain floods, leaking water or sewer lines, or decreased evapotranspiration when an area is covered by a structure or pavement. It is vital to modify the geotechnical qualities of expanding soil in order to achieve economic efficiency and optimal structural performance. One of the most abundant quarry wastes is quarry dust. Twenty to twenty-five percent of each crusher's entire output is discarded as stone dust. Through geotechnical uses such as embankments, back-fill material, and sub-base material, this waste material may be used in large quantities. Soil treatment with lime is a tried and true approach for saving time and money on building projects.

Lime drying of wet soils reduces weather-related construction delays and facilitates the resumption to work within hours. The alteration of clay soils with lime renders them friable, workable, and compact. Unstable clay soils undergo long-term chemical changes as a result of lime stabilisation. We obtained Black cotton soil samples from Shad-Nagar in MahbubNagar District for this investigation (Telangana). In this project, the results of an experiment designed to determine the influence of stone dust and lime on expansive soil are presented and discussed. These results include index properties, Proctors compaction, differential free swelling test, unconfined compression strength, and the California bearing ratio.

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

I. INTRODUCTION

Need for Stabilization of soil

It may be defined as the modification of soil done to improve their certain characteristics. It develops the shear capacity and shrinking, swelling of soil. It boosts the load carrying power to assist the construction works. In our project work we have undertaken clayey soil, substituted with stone dust by adding lime. Due to urbanisation and industrialization's fast expansion, soil improvement is a crucial problem for construction projects. Soil improvement refers to approaches that enhance the index characteristics and other engineering features of poor soils. In India, expansive soil covers around 0.8 x 106 km2, or almost one-sixth of its surface area. These soils include the mineral montmorillonite; as a result, they inflate and contract excessively with changes in water content. Due to the presence of clay particles that inflate when they come into touch with water, soils tend to alternately expand and contract, causing differential settling of structures. With the addition of a little amount of lime and other admixtures, expansive soils can be stabilised. These strategies have been utilised to enhance subgrades and subbases in a variety of construction applications, including highway, railroad, and airport building. Quarry dust is a byproduct created in granite companies during the shaping of enormous granite blocks. Approximately 3000 metric tonnes of granite dust/slurry are created daily as a byproduct of the production of granite tiles and slabs from raw blocks. These wastes are dumped in neighbouring pits or on open ground by the marble and granite industry. Especially as the slurry dries, this results in severe environmental damage and the occupancy of a huge amount of land. This study examines the effects of granite dust on the consistency limits and differential free swell (DFS) of Black Cotton Soil mixed with 2 to 6 percent lime and 6 to 30 percent granite dust by weight of soil.

Expansive Soils

Expansive soil deposits are found in arid and semi-arid parts of the world, and their inclination to heave during the rainy season and contract during the dry season is troublesome for engineering buildings. It expands and contracts excessively with changes in its water content. This is due to the presence of small clay particles that expand when they come into touch with water, causing the soil to alternately swell and contract, resulting in differential structural settling. Using lime and stone dust as an additive, the black cotton soil was stabilised in this experiment.

Black Cotton Soil

Expansive soils are soils or soft bedrock that grow in volume when wet and contract when dry. In India, this Extensive soil is known as "black cotton soil." This soil's colour ranges from reddish brown to black, which facilitates the growing of cotton, hence the name black cotton soil. This expanding soil covers around 30 percent of India's geographical area. They are also known as expanding or Black Cotton soil. Extensive sections of the Deccan Trap in India contain Black Cotton soil, commonly known as "regurs." Black Cotton soil is one that, when coupled with an engineering structure and in the presence of water, causes the structure to experience moments that are entirely unrelated to the direct action 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 Shad-Nagar in MahbubNagar 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 (%)	0.5
	(b).Sand (%)	12.2
	(c).Silt&Clay (%)	87.3
2	Atterberg Limits	
	(a).Liquid Limit (%)	57.5
	(b).Plastic Limit (%)	26
	(c).Plasticity Index (%)	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**

Quicklime is calcium oxide (CaO), which has variable particle size depending on the end use and high available calcium content. After mixing initially, the calcium ions (Ca++) from hydrated lime drift to the surface of the clay materials and displace water and other types of ions. The soil becomes friable and granular, makes it easier to work and compact. The overall procedure, which is called “flocculation and agglomeration," normally occurs in a few hours. Using certain amounts of CaO and water, acidity decreases rapidly and pH becomes more than 10.5 eventually breaking down the clay matters. Products released that are Silica and alumina combine with Ca to produce calcium-silicate-hydrates (CSH) and calcium-aluminates-hydrates (CAH). These are the cementitious by-products. The matrix that is formedby the products improves the strength of the layers of the lime-modified soil. After formation of the matrix, transformation of the soil happens from a void less material to a relatively firm impervious layer with a massive load bearing power. Within the first few hours, initial stage of the procedure begins for a lengthy period of time which may last for years in a properly designed setup. At the end, the whole mix becomes impervious, firm and long lasting structurally.

Table 2.2: Product size analysis

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

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 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 2.2 and geotechnical properties of stone dust are shown in the table 2.3

Table 2.3 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	Specific Gravity	2.7
3	Compaction Characteristics (a).Maximum Dry Unit Weight (kN/m^3) (b).Optimum Moisture Content (%)	 17.95 13.6

III. EXPERIMENTAL PROGRAMME

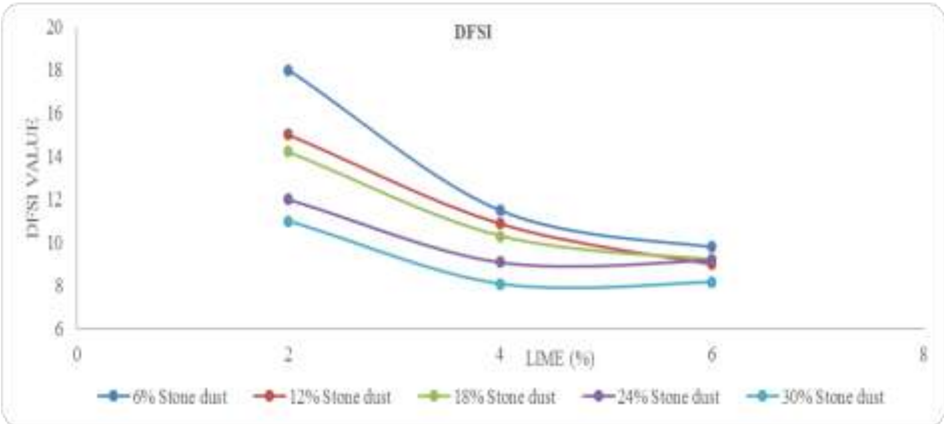
This study experimental programme investigates the index characteristics, Proctors compaction, differential free swell index and unconfined compression strength, and California bearing ratio. The site's soil is dried and manually sifted to eliminate any stones and plant material. It is then dried, ground, and sieved through a 4.75mm mesh to remove any gravel portion. The dried and sieved soil is kept in airtight containers until it is ready to be mixed 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**.**

The experiments were conducted as per following IS codal provision:

- IS 2720 (Part 5) –1985 - Liquid limit & Plastic limit test
- IS: 2720 (Part 7) – 1980 - Standard proctor test (SPT)
- IS: 2720 (Part 10) – 1991 - Unconfined compressive strength (UCS) test
- IS: 2720 (Part 16) – 1987 - California bearing ratio (CBR) test

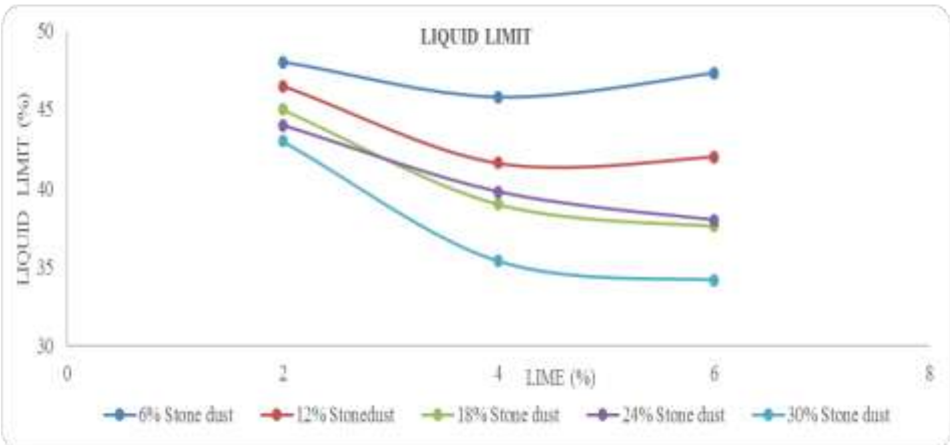
IV. COMPARISION OF RESULTS AND DISCUSSIONS

RESULTS:



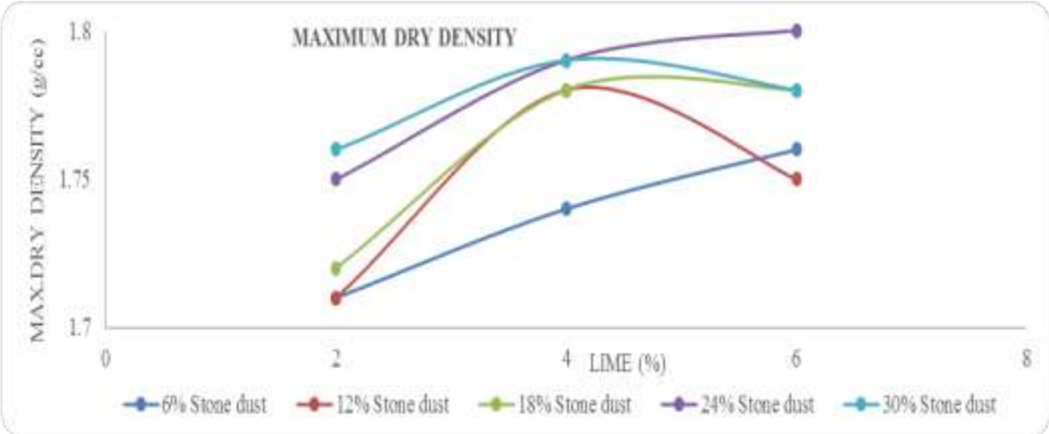
Graph: 4.1: Variation in Differential Free Swell Results.

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



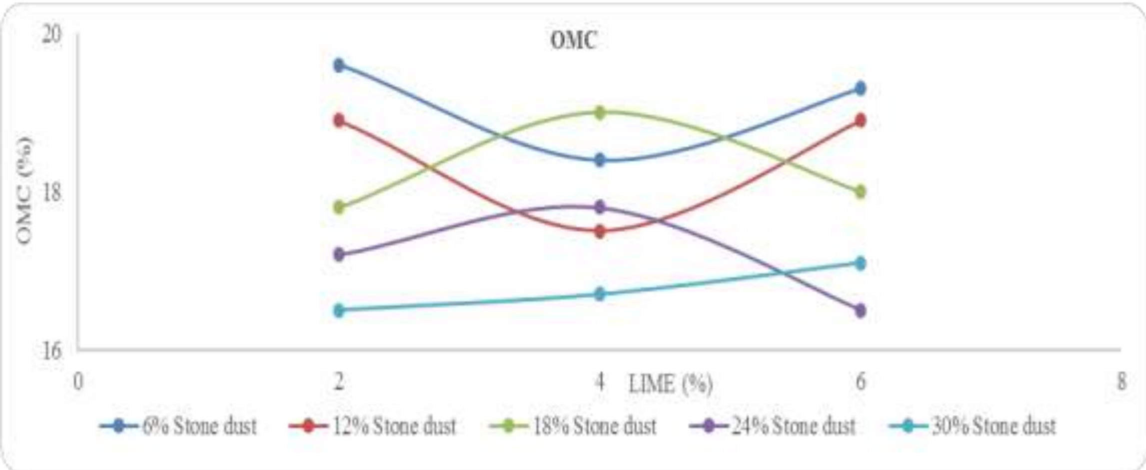
Graph 4.2: Variation in Liquid Limit

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.



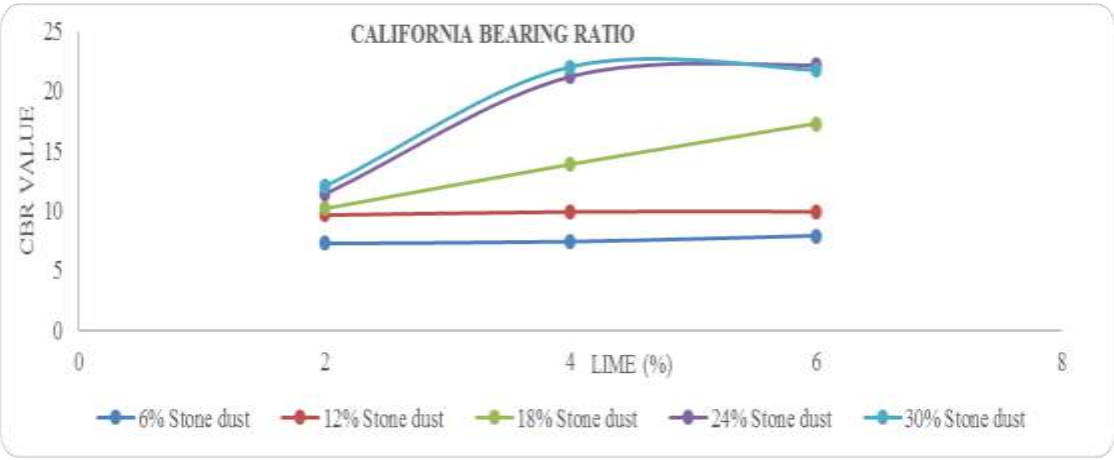
Graph: 4.3: Variation in Maximum dry density.

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.



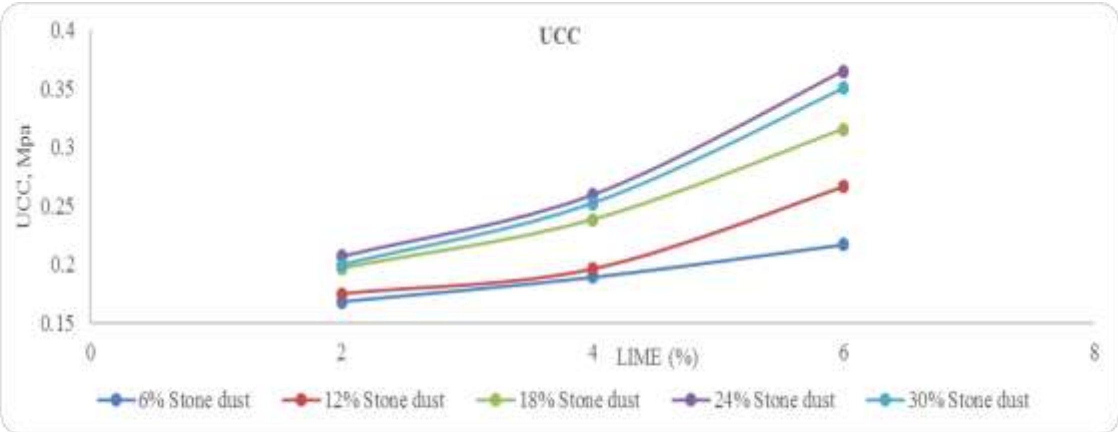
Graph: 4.4: Variation in Optimum Moisture Content.

Graph: 4.4 shows variation of optimum moisture content of black cotton soil, it shows that maximum reduction in OMC was found with additionof 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% stonedust 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% stonedust in black cotton soil.

V. 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 notallow 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.

VI. 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 tolime/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.

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