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# Improvement in Geo Technical Characteristics of Expansive Soil Using Lime and Quarry Dust

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**ABSTRACT:** Nearly 51.8 million hectares of land area in India are covered with Expansive soil (mainly Black Cotton soil). The property of these expansive soils, in general, is that they are very hard when in dry state, but they lose all of their strength when in wet state. In light of this property of expansive soils, these soils pose problems worldwide that serve as challenge to overcome for the Geotechnical engineers. One of the most important aspects for construction purposes is soil stabilization, which is used widely in foundation and road pavement constructions; this is because such a stabilization regime improves engineering properties of the soil, such as volume stability, strength and durability. In this process, removal or replacing of the problematic soil is done; replacement is done by a better quality material, or the soil is treated with an additive. In the present study, using Stone/quarry dust obtained from Haldwani, stabilization of black cotton soil obtained from Jhansi and lime from local market is attempted. With various proportions of this additive i.e. 10%, 20%, 30%, 40% & 50%, expansive soils is stabilized. Owing to the fact that Quarry Dust possess no plastic property, plasticity index (P.I.) of clay-Quarry Dust mixes show a decrease in value with increasing Quarry Dust content. In conclusion, addition of Quarry Dust results in decrease in plasticity of the expansive soil, and increase in workability by changing its grain size and colloidal reaction. Tested under both soaked and un-soaked conditions, the CBR values of clay with Quarry Dust mixes were observed. Analysis of the formerly found result exposes the potential of Quarry Dust as an additive that could be used for improving the engineering properties of expansive soils.

**KEYWORDS:** Expansive oil, Quarry Dust.,

## I. INTRODUCTION

### 1.1 Expansive soil

Expansive soils, which are also called as swell-shrink soil, have the tendency to shrink and swell with variation in moisture content. As a result of this variation in the soil, significant distress occurs in the soil, which is subsequently followed by damage to the overlying structures. During periods of greater moisture, like monsoons, these soils imbibe the water, and swell; subsequently, they become soft and their water holding capacity diminishes. As opposed to this, in drier seasons, like summers, these soils lose the moisture held in them due to evaporation, resulting in their becoming harder. Generally found in semi-arid and arid regions of the globe, these type of soils are regarded as potential natural hazard – if not treated, these can cause extensive damage to the structures built upon them, as well causing loss in human life. Soils whose composition includes presence of montmorillonite, in general, display these kind of properties. Tallied in billions of dollars annually worldwide, these soils have caused extensive damage to civil engineering structures.

Also called as Black Cotton soils or Regur soils, expansive soils in the Indian subcontinent are mainly found over the Deccan trap (Deccan lava tract), which includes Maharashtra, Andhra Pradesh, Gujarat, Madhya Pradesh, and some scattered places in Odisha. These soils are also found in the river valley of Narmada, Tapi, Godavari and Krishna. The depth of black cotton soil is very large in the upper parts of Godavari and Krishna, and the north-western part of Deccan Plateau. Basically, after the chemical decomposition of rocks such as basalt by various decomposing agents,



these are the residual soils left behind at the place of such an event. Cooling of volcanic eruption (lava) and weathering another kind of rock – igneous rocks – are also processes of formation of soils. Rich in lime, alumina, magnesia, and iron, these soils lack in nitrogen, phosphorus and organic content.

Consisting of high percentage of clay sized particles, the colour of this soil varies from black to chestnut brown. 20% of the total land area, on an average, of this country is roofed by expansive soils. These soils are suitable for dry farming and for the growth of crops like cotton, rice, jowar, wheat, cereal, tobacco, sugarcane, oilseeds, citrus fruits and vegetables; the reason behind it is owed to the moisture retentive capacity of expansive soils, which is high.

In the semi-arid regions, just in the last couple of decades, damages due to the swelling- shrinking action of expansive soils have been observed prominently in form of cracking and break-up of roadways, channel and reservoir linings, pavements, building foundations, water lines, irrigation systems, sewer lines, and slab-on-grade members, lines, irrigation systems, sewer lines, and slab-on-grade members.

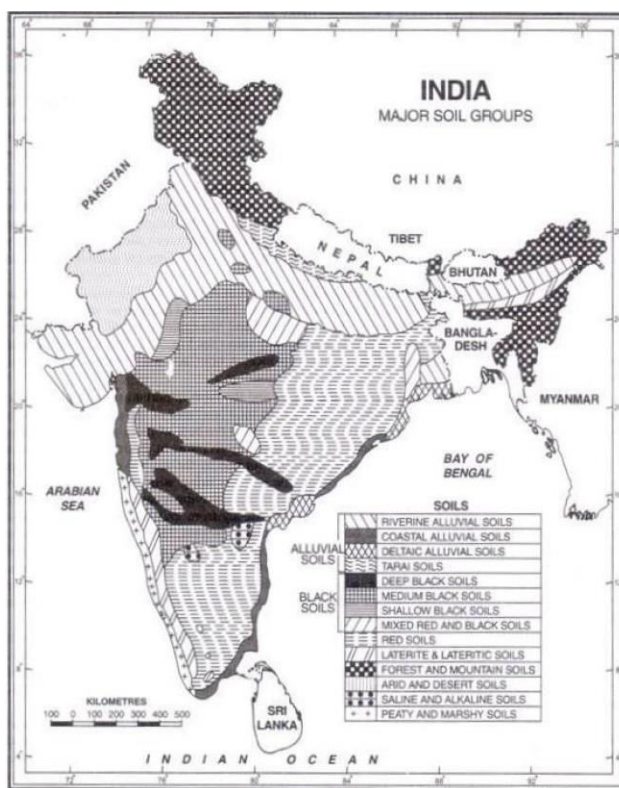


Figure 1: Major Soil Types in India

### 1.2 Quarry Dust

A waste material extracted from the gases emanating from coal fired furnaces, generally of a thermal power plant, is called Quarry Dust. One of the chief usages of volcanic ashes in the ancient ages were the use of it as hydraulic cements, and Quarry Dust bears close resemblance to these volcanic ashes. These ashes were believed to be one of the best pozzolans (binding agent) used in and around the globe.

The demand of power supply has exponentially heightened these days due to increasing urbanization and industrialization phenomena. Subsequently, this growth has resulted in the increase in number of power supplying thermal power plants that use coal as a burning fuel to produce electricity. The mineral residue that is left behind after the burning of coal is the Quarry Dust. The Electro Static Precipitator (ESP) of the power plants collect these Quarry Dust.



Production of Quarry Dust comes with two major concerns – safe disposal and management of Quarry Dust. Because of the possession of complex characteristics of wastes which are generated from the industries, and their hazardous nature, these wastes pose a necessity of being disposed in a safe and effective way, so as to not disturb the ecological system, and not causing any sort of catastrophe to human life and nature. Environmental pollution is imminent unless these industrial wastes are pre-treated before their disposal or storage.

Essentially consisting of alumina, silica and iron, Quarry Dust are micro-sized particles. Quarry Dust particles are generally spherical in size, and this property makes it easy for them to blend and flow, to make a suitable concoction. Both amorphous and crystalline nature of minerals are the content of Quarry Dust generated. Its content varies with the change in nature of the coal used for the burning process, but it basically is a non-plastic silt. For waste liners, Quarry Dust is a potential material that can be employed; and in combination with certain minerals (lime and bentonite), Quarry Dust can be used as a barrier material. In present scenario, the generation of this waste material in picture (Quarry Dust) is far more than its current utilization. In other words, we are producing more of Quarry Dust than we can spend.

Almost 20% of land in India is roofed by expansive soils. With the rapid growth in industrialization and urbanization, land scarcity appears to be an imminent threat. Construction of civil engineering structures on expansive soils, however, pose a major risk to the structure in itself, because of the greater degree of instability in these kinds of soil. Tallied in billions of dollars per year is the loss in property every year globally owing to the instability in the expansive soils. On the other hand, disposal of Quarry Dust has become a growing issue. India, as a developing country, is highly dependent on coal based thermal power plants for production energy, and this dependency isn't going to falter anytime soon. Pulverization of coal in these power plants produces many waste materials, including Quarry Dust. As of 2012, the generation of Quarry Dust rose to 130 MT/year. However, only 56% of this generated Quarry Dust waste were only utilized. The residual Quarry Dust is disposed off in places, and this poses threat to health, and also the reduction in land area that can be otherwise utilized for purposes other than the disposal of Quarry Dust.

Keeping both the issues in mind, this research of stabilizing expansive soil using Quarry Dust is justified.

### 1.3 Objective of Research

- To check the ambit of reducing expansiveness and improving bearing capacity value by adding additives.
- Also to establish the usage of Quarry Dust as an additive, thereby helping utilize it which otherwise always lays as fine waste product from Quarry Crushers.

## II. LITERATURE SURVEY

Sharma et al. (1992), using mixtures of Quarry Dust, blast furnace slag and gypsum, studied stabilization. He found that when Quarry Dust, gypsum and blast furnace slag are used in proportions of 6:12:18, the swelling pressure decreases from 248 KN/m<sup>2</sup> to 17 KN/m<sup>2</sup>, whereas an increase by 300% was observed in case of unconfined compressive strength.

Srivastava et al. (1997) studied the microscopic changes in the fabric and micro-structure of the expansive soil due to the addition of lime sludge and Quarry Dust using SEM photography. He found that there were changes in the micro-structure and fabric of the expansive soil when 16% lime sludge and 16% Quarry Dust were both added.

Srivastava et al. (1999) have also stated that the best stabilizing effect of the swelling and consolidation behaviour in an expansive soil mixed with Quarry Dust and lime sludge was obtained when 16% lime sludge and 16% Quarry Dust were added.





Cokca (2001) found out that swelling pressure decreased by 75% after 7 day curing, and 79% after 28 day curing when soil specimens were treated with 25% Class C Quarry Dust (18.98% of CaO).

Pandian et al. (2001) made an effort towards stabilization of expansive soil by using Class F Quarry Dust. He found that Quarry Dust can make for an effective additive when he saw that with 20% Quarry Dust content, the CBR value of Black cotton soil improved (about 200%) significantly.

Turker et al. (2004) employed sand along with Class C & Class F Quarry Dust for stabilization of expansive soil. Without any contradiction of belief, Class C Quarry Dust was more effective in stabilization, and decrease in free swell with curing period was observed. The percentage content of soil, Class C Quarry Dust and sand that gave the best result was 75%, 15% and 10% respectively.

Satyanarayana et al. (2004) aimed to study the mutual effect of addition of lime and Quarry Dust on the engineering properties of the expansive soil. He found out that 70%, 26% and 4% were the optimum percent mixture of the ingredients for the construction of roads and embankments.

Phani Kumar et al. (2004) saw that the hydraulic conductivity, swelling properties and plasticity of expansive soil-Quarry Dust mixture decreased, whereas the strength and dry unit weight increased with the increase of Quarry Dust content in the mix. For a given water content, the resistance to penetration also increased with the increase in Quarry Dust content.

Baytar (2005) contemplated the stabilization of expansive soils using desulphogypsum and Quarry Dust acquired from a thermal power plant by 0 to 30%. A variable percentage of lime (0 to 8%) was appended into the expansive soil-desulphogypsum-Quarry Dust mixture. The samples, thus formed, were cure for a period of 7 days and 28 days. It was observed that swelling percentage decrease, and there was an increase in rate of swell with increasing percentage of the stabilizer in the mixture. The curing process reduced the swelling percentage further; and with the addition of 30% desulphogypsum and 25% Quarry Dust, reduction in swelling percentage were to such levels that stood comparable with the one where lime was only used as stabilizing compound for the expansive soil.

Amu et al. utilized Quarry Dust and cement mixture for the stabilization purposes of expansive soil. Three distinct classes of samples: (i) 12% cement, (ii) 9% cement + 3% Quarry Dust, and (iii) natural clay soil, were taken to be tested for Maximum Dry Densities (MDD), Unconfined Compressive Strength (UCS), Optimum Moisture Contents (OMC), California Bearing Ratios (CBR), and the Undrained Triaxial tests. The results of this test indicated that the sample with 9% cement and 3% Quarry Dust showed better results with respect to CBR, OMC, MDD, and shearing resistance, in comparison to the other two samples. This indicated the value of Quarry Dust as a stabilizing agent.

Sabat et al. (2005) studied the stabilization of expansive soil using Quarry Dust-marble powder mixture. He concluded that the optimum proportions of soil, Quarry Dust, and marble powder in the mixture in percentage by weight to give the best result were 65%, 20% and 15% respectively.

Rajesh et al. (2006) talked about experimental investigation of clay beds stabilized with Quarry Dust-lime segments and Quarry Dust segments. An observation of swelling in clay beds of 100 mm thickness strengthened with 30 mm diameter Quarry Dust-lime and Quarry Dust segments. There was a considerable decrease in heave in both Quarry Dust-lime and Quarry Dust columns. However, lime-Quarry Dust mixture generated better results.

Wagh (2006) utilized rock flour, lime and Quarry Dust independently, furthermore in diverse extent to stabilize the black cotton soil from Nagpur Plateau, India. Rock flour or Quarry Dust, or both together, when added to the black cotton soil showed an improved value of CBR to some degree, and there was an increase in angle of shearing resistance



with the reduction in cohesion value. CBR values increased significantly with the increase of both frictional resistance and cohesion where lime, in addition to both Quarry Dust and rock flour, as added into the mixture.

Sharma et al. (2007) contemplated the impact on swelling of highly plastic expansive clay, and the compressibility of another non-expansive but highly plastic clay when Quarry Dust was employed. At a given dry unit weight of the mixture, the swelling pressure and swell potential showed a decrease by nearly 50%. A decrease by 40% at 20% Quarry Dust content in coefficient of secondary consolidation and compression index of both the samples was observed.

Buhler et al. (2007) considered the usage of lime and Class C Quarry Dust in stabilization of expansive soils. He observed better results with lime than with Class C Quarry Dust, when the reduction in linear shrinkage was better when the former was employed. This, however, established the characteristics of Quarry Dust as a stabilizing material.

### III. MATERIALS AND METHODOLOGY

#### 3.1 Materials

##### Expansive soil

As a part of this investigation, the expansive black cotton soil was acquired from the site Jhansi, Uttar Pradesh. The black cotton soil thus obtained was carried to the laboratory in sacks. A small amount of soil was taken, sieved through 4.75 mm sieve, weighed, and air-dried before weighing again to determine the natural moisture content of the same. The various geotechnical properties of the procured soil are as follows:

Table 1: Geotechnical properties of expansive soil

Sl. No.	Properties	Code referred	Value
1	Specific Gravity	IS 2720 (Part 3/Sec 1) - 1980	2.44
2	Maximum Dry Density (MDD)	IS 2720 (Part 7) - 1980	1.52 gm/cc
3	Optimum Moisture Content (OMC)	IS 2720 (Part 7) - 1980	22.65%
4	Natural Moisture Content	IS 2720 (Part 2) - 1973	7.28%
5	Free Swell Index	IS 2720 (Part 40) - 1977	105%
6	Liquid Limit	IS 2720 (Part 5) - 1985	65%
7	Plastic Limit	IS 2720 (Part 5) - 1985	37.08%
8	Shrinkage Limit	IS 2720 (Part 6) - 1972	17.37%

##### Quarry Dust

Quarry dust is a material obtained from stone crushers as a waste material and has found its utility in production of concrete and as Landfill of late it is being used as material for soil improvement owing to the presence of abundance of cationic ions.

In our case it was obtained from a Quarry in Haldwani District, Uttrakhand.

#### 3.2 Methodology Adopted

To evaluate the effect of Quarry Dust along with lime as a stabilizing additive in expansive soils, series of tests, where the content of Quarry Dust in the expansive soil was varied in values of 10% to 50% (multiples of 10) by weight of the total quantity taken. The Indian Standard codes were followed during the conduction of the following experiments:

- Standard proctor test – IS : 2720 (Part 7) – 1980
- Unconfined compressive strength (UCS) test – IS : 2720 (Part 10) – 1991



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- California bearing ratio (CBR) test – IS : 2720 (Part 16) – 1987
- Free swell index test – IS 2720 (Part 40) – 1977
- Liquid & Plastic limit test – IS 2720 (Part 5) - 1985

**IV. RESULTS**

Standard proctor test for soil – Quarry Dust Lime mixture

Table 2: Standard proctor test for expansive soil only

Volume of Mold (m <sup>3</sup> )	Weight of soil in mold (kg)	Moist unit weight (g/cm <sup>3</sup> )	Moisture content (%)	Dry unit weight (g/cm <sup>3</sup> )
0.00099795	1.56	1.56	17.76	1.32
0.00099795	1.73	1.73	19.53	1.45
0.00099795	1.86	1.86	22.65	1.52
0.00099795	1.87	1.87	24.87	1.50
0.00099795	1.82	1.82	27.92	1.42

Table 3: Standard proctor test for expansive soil + 1% Lime + 10% Quarry Dust mixture

Volume of Mold (m <sup>3</sup> )	Weight of soil in mold (kg)	Moist unit weight (g/cm <sup>3</sup> )	Moisture content (%)	Dry unit weight (g/cm <sup>3</sup> )
0.00099795	1.60	1.60	15.18	1.39
0.00099795	1.76	1.76	19.09	1.48
0.00099795	1.83	1.83	22.13	1.50
0.00099795	1.80	1.81	27.96	1.41
0.00099795	1.77	1.77	32.71	1.33



Table 4: Standard proctor test for expansive soil + 1% Lime + 20% Quarry Dust mixture

Volume of Mold (m <sup>3</sup> )	Weight of soil in mold (kg)	Moist unit weight (g/cm <sup>3</sup> )	Moisture content (%)	Dry unit weight (g/cm <sup>3</sup> )
0.00099795	1.62	1.62	19.6	1.36
0.00099795	1.72	1.72	20.95	1.42
0.00099795	1.86	1.86	22.56	1.52
0.00099795	1.87	1.88	25.21	1.50
0.00099795	1.82	1.82	29.13	1.41

Table 5: Standard proctor test for expansive soil+ 1% Lime + 30% Quarry Dust mixture

Volume of Mold (m <sup>3</sup> )	Weight of soil in mold (kg)	Moist unit weight (g/cm <sup>3</sup> )	Moisture content (%)	Dry unit weight (g/cm <sup>3</sup> )
0.00099795	1.64	1.64	15.12	1.43
0.00099795	1.76	1.76	18.96	1.48
0.00099795	1.86	1.86	21.27	1.53
0.00099795	1.87	1.88	24.71	1.50
0.00099795	1.82	1.82	28.13	1.42

Table 6: Standard proctor test for expansive soil + 1% Lime + 40% Quarry Dust mixture

Volume of Mold (m <sup>3</sup> )	Weight of soil in mold (kg)	Moist unit weight (g/cm <sup>3</sup> )	Moisture content (%)	Dry unit weight (g/cm <sup>3</sup> )
0.00099795	1.59	1.59	16.22	1.37
0.00099795	1.71	1.71	18.52	1.45
0.00099795	1.82	1.82	23.57	1.47
0.00099795	1.84	1.84	26.42	1.46
0.00099795	1.80	1.80	31.81	1.36





Table 7: Standard proctor test for expansive soil + 1% Lime + 50% Quarry Dust mixture

Volume of Mold (m <sup>3</sup> )	Weight of soil in mold (kg)	Moist unit weight (g/cm <sup>3</sup> )	Moisture content (%)	Dry unit weight (g/cm <sup>3</sup> )
0.00099795	1.53	1.53	14.11	1.34
0.00099795	1.61	1.61	17.23	1.37
0.00099795	1.73	1.73	21.34	1.42
0.00099795	1.78	1.78	25.76	1.42
0.00099795	1.76	1.76	31.2	1.34

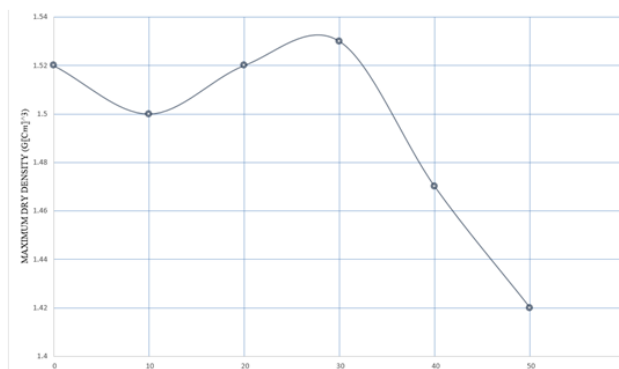


Figure 2: Variation of MDD values with different Quarry Dust content in expansive soil

### V. CONCLUSION

Based on the results obtained and comparisons made in the present study, the following conclusions can be drawn:

- The Maximum Dry Density (MDD) value of the black cotton soil initially decreased with the addition of Quarry Dust and Lime. Then, it showed increment with increasing Quarry Dust content in the soil-Quarry Dust mixture. The maximum value of MDD was observed for a mixture of soil and 30% of Quarry Dust content by weight. The MDD values consistently decreased thereafter.
- The Unconfined Compressive Strength (UCS) of the soil with variation of Quarry Dust content showed similar trend as that of the MDD values, except the fact that the peak value was observed for a Quarry Dust content of 20% by weight.
- In un-soaked California Bearing Ratio (CBR) tests of soil conducted with varying Quarry Dust content, the CBR increased gradually with the increase in Quarry Dust content till its valuation was 20% by weight of the total mixture; it decreased thereafter.
- The change in case of soaked California Bearing Ratio (CBR) tests of soil with varying Quarry Dust and Lime content was, however, uneven. It decreased with the initial addition of Quarry Dust (10% by weight of total mixture), and then increased till Quarry Dust content reached 30% by weight of total mixture. The values decreased thereafter.
- With the increasing Quarry Dust and Lime content in the soil-Quarry Dust mixture, the decrease in value of free swell ratio was remarked. This decrease was also reciprocated by the plasticity index values. Plasticity index values are directly proportional to percent swell in an expansive soil, thus affecting the swelling behavior of the soil-Quarry Dust mixture.
- Thus, Quarry Dust and Lime as an additive decreases the swelling, and increases the strength of the black cotton soil.



#### Scope for future study

Quarry Dust along with another additive like murrum, cement, and other such materials can be used together, and may be varied in quantity to obtain the best possible stabilizing mixture.

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