Effect of Stone dust and Lime in the Geotechnical Properties of Clayey Soil

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Abstract. Clayey soils are commonly stiff in dry state but lose their stiffness when saturated with water. Soft clays are characterized by low bearing capacity and high compressibility. In this research, stone dust obtained from stone processing area used for Stabilization of clayey soil with lime. Thus, the effectiveness of using stone powder and lime in stabilizing fine-grained clayey soil (CL) was investigated in the laboratory. The soil samples in natural state and when mixed with varying percentages of lime and waste stone powder were used for the laboratory tests that included Atterberg limits tests, standard Proctor compaction tests, unconfined compression tests and California bearing ratio tests. The value of maximum dry density, Unconfined Compressive Strength and California Bearing Ratio decreased with increase in % of stone dust and lime. The Optimum Moisture Content value remain same with increasing stone dust content and lime.

1. Introduction

1.1. 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

1.2. Materials for soil stabilization

1.2.1 Clayey Soil
Clay may be defined as a soil variant which may be found directly from the Earth’s surface which contains many types minerals, also it includes chemical compounds like metal oxides certain types of organic matters. These types of materials show plasticity behaviour because of moisture holding capacity thereby it becomes firm, fragile and non-plastic upon dehydrating. This classification of materials contains tiniest particles among all the other groups of soil variants. Due to this small size the solitary particles cannot be viewed by naked eyes and it requires a microscope to get into the details. This particular attribute permits a bulk of clay particles to accommodate in a small space. As a result of which clay has a very smooth texture as the small particles cannot create unevenness on the surface.
The composition of clay is very murky due to miniature particle proportion. Plant roots cannot perforate due to the strong bonding between the inter particles which is firm. Clayey soils are much thicker and substantial due to high density as a result of which the time taken to warm up is longer after spells of cold atmosphere. Clay substances due to less void spaces are impervious to erosion than other soil varieties.

For the growth of flora in clay type of soil certain alterations are done for the successful growth and development. Clay soil usually has scarce nutrients and micro-nutrients which are essential components for plant development, hence organic matter is added. After the addition of organic matter, the clay may become alkalescent as a result of which certain modifications may be carried out to balance the clay’s pH to convert it to a neutral medium. Therefore, the clay soil is examined before planting to determine soil’s pH and amount of essential nutrients present. Due to a very high water holding capacity clay soil shows very little permeability. Clay materials are closely packed so water takes much more time to penetrate through the particles as a result of which clay sucks up the water and expands. This issue prevents water from perforating deep and also it hampers plant roots due to unnecessary expansion. [8-11]

Table 1. Properties of clay

| Properties                                   | Code referred      | Value       |
|----------------------------------------------|--------------------|-------------|
| Specific Gravity                             | IS 2720 (Part 3/Sec 1) - 1980 | 2.62%       |
| Maximum Dry Density (MDD)                    | IS 2720 (Part 7) - 1980 | 17.55 KN/m³ |
| Optimum Moisture Content (OMC)               | IS 2720 (Part 7) - 1980 | 16%         |
| Liquid Limit                                 | IS 2720 (Part 5) - 1985 | 72%         |
| Plastic limit                                | IS 2720(Part 5) - 1985 | 39%         |
| Unconfined compressive strength (UCS)        | IS : 2720 (Part 10) | 1048 KPa    |

1.2.2. Stone Dust

Stone dust is like a gloomy, coarser version of sand. It is an end product of running stones gone through a crushing machine to make crushed stones. Its exact structure will definitely depend on what variety of stone was run through the crushing device. For instance, sometimes granite is pushed through such a machine; in other situations, it could be limestone, for example. The machine has a screen that entraps the bigger material (that is, the crushed stone). The smaller material or "screenings" falls through the screen. Relying on the dimension of the holes in the screen used, the material can be so fine in texture that it basically looks like a powder.

Table 2. Chemical properties of stone dust

| Component | Weight (%) |
|-----------|------------|
| CaO       | 3.5-40     |
| Al₂O₃     | 0.5-40     |
| MgO       | 2.5-25     |
| SiO₂      | 1-12       |
| SO₃       | 0.23-3     |
| Alkalis   | 0-4        |

Stone dust or powder is a type of crushed stone; it consists of similar variants of stones but it converted into powder form. Stone dust is always resistant to water also it acts a binding agent. Stone dust is impervious hence they are used in various civil applications. Due to its impervious quality, it never allows the mould to grow. This is an end product of stone crushing factory. Maximum amounts of stone dusts that are produced goes unused. It can be exploited for concrete works as a result of which it will
mitigate the solid waste along with proper recovery. Stone dusts concrete gains about 15% better strength than normal sand.

Table 3. Index properties of stone dust Source

| Property                        | Value  |
|--------------------------------|--------|
| Natural Moisture Content (%)   | 9.11   |
| Optimum moisture content (%)   | 11.5   |
| Particle Size distribution     |        |
| Silt (%)                       | 2.9    |
| Sand (%)                       | 97.1   |
| CBR Un soaked (%)              | 26.28  |
| Specific Gravity               | 2.76   |
| CBR Soaked (%)                 | 11.5   |
| Cohesion (kN/m²)               | 0.07   |
| Maximum dry density (g/cm³)    | 1.97   |
| Angle of internal friction (degree) | 35    |

1.2.3. 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 formed by 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.

1.3 Scope and objectives
To study the effect of stone dust and lime on properties of clay.

2. Materials and methodology

2.1 Materials
As a part of this overall investigation, the clayey soil was taken up from the staff quarter’s area at Silicon Institute of Technology, Sason, Sambalpur. The clayey soil materials which was procured from the locality was carried to the laboratory for further processes. Some amount of soil was taken and sieved through 4.75 mm sieve and air-dried. Then some other tests such as California bearing ratio test(CBR), unconfined compressive strength test(UCS) and standard proctor test (SPT) were carried out to find the value of California bearing ratio strength (CBR value), unconfined compressive strength(UCS value), maximum dry density(MDD) and optimum moisture content (OMC). The stone dust that is used in the investigation was acquired from Debadihi, Jharsuguda.

2.2 Methodology
To examine the impact of stone dust and lime as a additive agent in clayey soils, some of tests were carried out, where the amount of stone dust in the clay was varied in values of 10%, 20%, 30% and 40%
(multiples of 10) by weight of the total quantity of soil. Then by adding 1% and 2% lime in each mix, the experiments for various properties were carried out. 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

3. **Results and discussions**

After conducting the experiments, the various results were obtained and accordingly the graphs were plotted. Where S represents soil, S.D. represents stone dust and L represents lime.

**Figure 1.** Liquid limit of the soil

**Figure 2.** Density-moisture content variation of the soil

**Figure 3.** Density-moisture content variation of the soil 90% + stone dust 10%

**Figure 4.** Density-moisture content variation of the soil 80% + stone dust 20%

**Figure 5.** Density-moisture content variation of the soil 70% + stone dust 30%

**Figure 6.** Variation of Density-moisture content of the soil 60% + stone dust 40%
Figure 7. Variation of Density-moisture content of the soil 90% + stone dust 10% + lime 1%

Figure 8. Variation of Density-moisture content of the soil 80% + stone dust 20% + lime 1%

Figure 9. Variation of Density-moisture content of the soil 70% + stone dust 30% + lime 1%

Figure 10. Variation of Density-moisture content of the soil 60% + stone dust 40% + lime 1%

Figure 11. Variation of Density-moisture content of the soil 90% + stone dust 10% + lime 2%

Figure 12. Variation of Density-moisture content of the soil 80% + stone dust 20% + lime 2%
Clay was substituted with varying different percentage of stone dust (10% - 40% in multiple of 10) and addition of lime of 1% and 2% by weight which affects as an additive on the clay.

The magnitude for MDD value of clay soil initially increased with the replacement of soil by stone dust. Then it showed decrement with increment of stone dust percent. Maximum Dry Density value was detected for a mixture of 60% soil and 40% stone dust.

The value of every proportion of Optimum Moisture Content remains constant.

It was interpreted that the Unconfined Compressive Strength value of soil with replacement of stone dust and addition of lime with different proportion is decreasing, as the percentage of stone dust increasing and the maximum dry density was observed for a mixture of 90% of soil and 10% stone dust and 1% of lime and the minimum value of Unconfined Compressive Strength was observed for mixture of 60% of soil 40% of stone dust and 1% of lime.

It was interpreted that California Bearing Ratio value of soil with replacement of standard matter and addition of lime with different proportion is decreasing except for an addition of 2% lime. The maximum California Bearing Ratio values observed for a mixture of soil 80% and 20% stone dust.
and 2% lime. It was observed that, California Bearing Ratio value was minimum for a mixture of 90% soil, 10% stone dust and 2% lime.

4. Conclusion
On the basis of results procured and after comparing we got following conclusions
- The Optimum Moisture Content value remain same with increasing stone dust content and lime.
- The value of maximum dry density, Unconfined Compressive Strength and California Bearing Ratio decreased with increase in % of stone dust and lime.
- Hence Stone dust is not a proper substitution of clay.

In future scope, Stone dust may be replaced by red mud and using some additive like lime or other substances.

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Figure 17. Variation of UCS value with different stone dust contain
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