Stabilizing black cotton soil using iron ore waste

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Abstract. Using discarded iron ore powder to settle subgrade soil will improve the characteristics of black cotton soil. The soil's engineering properties are analysed using various tests, such as specific gravity, grain size analysis, Atterberg's limits, compaction properties, and unconfined compressive strength. These tests examine the classification of the soil, the optimum moisture content (OMC), the maximum dry density (MDD), the strength of the soil, and other variables. The black cotton soil (BCS) was taken from Ghatkesar Mandal in the Malkalgiri-Medchal region, while the iron ore was procured from a small-scale local enterprise. For this, a clay soil sample with a medium degree of plasticity was combined with iron ore powder in concentrations ranging from 0% to 20% with a 5% increment. The data obtained demonstrated a steady rise in specific gravity with the addition of scrap iron ore and raised from 2.54 to 2.81 when it comes to unconfined compressive strength. Adding more iron ore increased the UCS to stabilize the soil from 149.31kPa to 232.22kPa. The OMC increased from 16% to 12.5%, MDD from 1.86gm/cc to 1.98gm/cc and Plasticity Index from 42.8% to 28.08%. For all mixes, the soil is well-graded. The results demonstrate that iron ore waste can successfully stabilize the soil.

Keywords. Black cotton soil, iron ore waste, unconfined compressive strength, Plasticity Index, OMC, MDD.

1 Introduction

Soil stabilisation is the process of modifying soils to enhance their physical qualities. Stabilisation, which may regulate the shrink-swell characteristics of a soil and/or increase its strength, increases a subgrade's ability to support pavements and bear more weight. [1-8]. Black cotton soils are weak soils that are the most problematic from a technical standpoint because they may expand or contract. This results in the structure having noticeable swelling and shrinking characteristics when exposed to changes in moisture content. Low permeability, significant volume change, and limited bearing capacity are characteristics of the soil as the environment changes.

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1.1 Objectives

- Determination of index properties of soil such as liquid limit, plastic limit, specific gravity and sieve analysis.
- Determination of Engineering Properties of soil such as standard compaction and unconfined compression test.

2 Methodology and mixes

The Soil sample was gathered from Ghatkesar, and iron waste was taken from nearby areas. Compaction tests were carried out with and without the introduction of iron waste at various weight percentages for the experiment work. The soil that passed through a sieve with a No. 4.75 size was utilized as the iron waste material for the tests. On the other hand, tests were carried out with and without including iron waste in the soil in specific percentages on the black cotton soil for the tests. The soil sample was collected at about 100 kg at a depth of 0.5m after site clearance of 0.2m from within a one-meter square area and brought to the soil mechanics laboratory. In this investigation, an effort has been made to examine the impacts and results of adding waste iron in varying percentages on the engineering characteristics of the soil, particularly the maximum dry density and the ideal moisture content behaviours. Standard Proctor Compaction and Atterberg Limit experiments (plastic and liquid limit tests) were performed on the black cotton soil by partially substituting iron waste samples (0%, 5%, 10%, 15%, and 20%). Specific gravity using density bottle [9] (IS-2720-Part-3-1980), Sieve Analysis [10] [IS: 2720 (Part 4) – 1985], Atterberg limits (plastic limit, liquid limit [11] [IS 2720(Part 5)-1985], Compaction [12] [IS 2720(Part 7)-1980], Unconfined Compressive Test [13] [IS 2720-10 (1991)] were conducted on Black Cotton soil with 0%, 5%, 10%, 15% and 20% variations of iron ore waste.

Table 1. Mix Proportions.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Mix</th>
<th>BCS (%)</th>
<th>Iron waste (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>mix-1</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>mix-2</td>
<td>95</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>mix-3</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>mix-4</td>
<td>85</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>mix-5</td>
<td>80</td>
<td>20</td>
</tr>
</tbody>
</table>

3 Results and Discussions

From Figure-1, the BCS used for this project has a specific gravity of 2.54, but the ideal soil for construction should have a specific gravity of 2.6 to 2.8. Through tests, it has been demonstrated that adding stabilizing substances such as iron ore in amounts of 5%, 10%, 15%, and 20% increases the soil's specific gravity to 2.59, 2.62, 2.71, and 2.81, respectively. Specific gravity increases by 10.63% for 20% replacement of iron ore waste.
Fig. 1. Specific gravity for different mixes.

It can be seen from Figures 2 and 3 that there is not much variation in the curves, and all blends have shown a similar pattern. All of the mixes are rated adequately as the same. The result is all mixes are well-graded.

Fig. 2. Particle size distribution for BCS without iron ore waste.

Fig. 3. Particle size distribution for BCS with 20% iron ore waste.
The liquid limit for each combination is shown in Figure 4. For building construction, the maximum permitted liquid content of the soil should be lowered. This project's initial liquid limit for Black Cotton Soil is 57.5%. By adding stabilising elements such as iron ore in portions of 5%, 10%, 15%, and 20%, the values were further shown to be 53.33, 52.25, 50, and 45 and the liquid limit has decreased by 21.73%.

Figure-5 shows the plasticity index variation for all mixes. The foundation soil should contain a lower plasticity index value for stable heavy structures; the soil sample's initial plasticity index was 42.8%. The values were further revealed as 37.57, 36.07, 33.11 and 28.08 by adding the iron powder percentages like 5%, 10%, 15% and 20%. The percentage decrease in the plasticity index is 34.39%.

The results of the standard proctor test with and without 20% substitutions of iron ore for soils were shown in Fig 6 and 7. Maximum dry density (MDD) and optimum moisture content (OMC) for average black cotton soil are 1.86 g/cc and 16%, respectively; however, when 20% more iron ore waste was added, these values were determined to be 1.98 g/cc and 12.5%. The MDD rise is 6.45% in percentage terms.
Fig. 6. OMC and MDD curve for BCS without iron ore waste.

Fig. 7. OMC and MDD curve for BCS with 20% iron ore waste.

Fig. 8. Unconfined compressive strengths test results stress-strain curve for black cotton soil.
Fig. 9. Unconfined compressive strengths, the stress-strain curve for black cotton soil with 20% iron ore waste

Figures 8 and 9 show test results of black cotton soil with 0% and 20% addition of iron ore waste. For construction purposes, the soil should have good load-bearing properties. This load-carrying capacity was calculated based on the outcomes of the Unconfined Compression Strength test. The strength of the black cotton soil is 149.31 kPa. The addition of 20% iron ore with stabilising chemicals added is 232.22 kPa and the Unconfined compressive strength has increased by 38.6%.

4 Conclusions

- Iron ore has been added to black cotton soil, and all mixtures have improved in specific gravity. For a 20% replacement of iron ore, this increase in specific gravity represents a percentage increase of 10.63.
- The liquid limit for all mixtures has been reduced by including iron ore, which is necessary for any construction-related use. By replacing 20% iron ore, the liquid limit has been reduced by 21.73 percentage points.
- For structures to be stable, the foundation soil should have a lower plasticity index value; substituting iron powder in all percentages has had positive outcomes. By replacing 20% iron ore, the plasticity index has dropped by 34.39 percentage points.
- Optimum moisture content (OMC) and Maximum dry density (MDD) have shown encouraging results. By substituting 20% of the iron ore, the MDD increases by 6.45%, and the moisture content decreases by 21.87%.
- The findings of tests on unconfined compression strength were used to determine the load-bearing capacities of soils. Iron ore with 20% replacement enhanced unconfined compressive strength by 38.6%.
- The soil was found to be well-graded for all mixes.
- Stabilising elements like iron ore waste can improve black Cotton soil's mechanical properties, such as unconfined compressive strength, its liquid limit, compaction characteristics.

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