RESEARCH ARTICLE

Subgrade Characteristics of Clayey Soil Admixed With Waste Foundry Sand and Lime

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Abstract

In overall world the major issues now days are dumping of waste materials. The dumping of waste material in environment causes harmful disease and pollutes the surrounding areas. This research aims to employ industrial waste materials like waste foundry sand (8 %, 16 %, and 24 %) and lime (3 %, 6 %, and 9 %) in the stabilisation of clayey soil so the combined mixture is being utilized as a sub-grade. On waste foundry sand and lime, various tests such as compaction, particle size distribution, Atterberg's limits, specific gravity and California bearing ratio were performed. According to the research, the addition of 16 percent waste foundry sand and 6 percent lime produces the highest dry density. The CBR value was increased by mixing the perfect amount of both components into clayey soil, indicating its suitability as a sub grade material.

Keywords: atterberg's limits, waste foundry sand, lime, compaction, unconfined compressive strength, california bearing ratio.

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1 Introduction

Basically, earth must be able to support the structure's weight. The carrying capacity of the structure is determined by the soil quality, which further ensures that the structure is stable [1]. Clay has a variety of poor engineering features, including poor shear strength, significant plasticity and compressibility, and the ability to expand when wet and shrink when dry [2]. Since the swelling and shrinkage behaviour of clayey soil when interacting with moisture content makes it difficult to build foundations over it, it is preferable to stabilize it first before constructing any construction [3]. Soil stabilisation is the practise of modifying soil characteristics [4].

During stabilization the most commonly adjustable qualities are Atterberg's limits, compaction, water content, etc. [5, 6]. Due to economic and environmental concerns, waste materials for soil stabilization have gained popularity [5, 6]. One of the waste material used in soil stabilization is waste foundry sand (WFS). The sand becomes unsuitable after multiple uses and is known as WFS. Such kind of waste is disposed in landfills causing environmental pollution which leads to harmful health issues, as well as cost of disposal increases due to the requirement of transportation and machinery [7].

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The use of high-quality silica sand in the foundry industry is done for metal molding and casting reasons because the sand that is often used in the foundry industry is readily available. The same sand is used for numerous castings in the foundry industry until it loses all of its original qualities, or if it is used again, it will alter the casting materials by changing their physical and chemical properties [8, 9].

During an experimental study, it was discovered that when the WFS content increased, the cohesiveness decreased and the friction angle increased [10]. WFS were recognized as having the potential to raise CBR and UCS values in expansive soil, which can be employed as a subgrade material in pavements [7]. More than any other composite additive, adding 24 percent WFS to a composite increased maximum dry density (MDD), UCS, and CBR [11].

In 1924, hydrated lime was utilized as a soil binding material for the first time in recent history highway construction works on short stretches [12]. When lime is applied to clay soil, clay minerals precipitate ions, making them unavailable for pozzolanic reactions until this attraction is met. The technique is also known as lime fixation since the lime is fixed in the soil and not available for additional reactions [13]. The point of lime fixation is defined as the point at which adding more lime has no effect on the variation of the plastic limit. This is the optimal amount of lime to add to the soil for ultimate modification that is generally between 1 and 3 percent by weight. Lime can be used after this stage to improve the soil's strength. Lime is extensively used to stabilize soil or improve its strength characteristic. lime has been utilized in a number of studies to enhance the sub-grade and the strength of clayey soil. Lime enhances CBR and OMC while decreasing plasticity and MDD in clayey soil. To stabilize soil, the use available soil mixed with volcanic ash lime found to be cost-effective [14]. The use of lime and natural pozzolana to stabilize soft soil was found to be cost-effective and reduce building expenses [15]. Add on of lime into clay originally enhanced the plasticity index by upto 3 percent. As a result, the overall plasticity was altered by raising the lime index [16]. Quick lime is a kind of lime produced by the combustion of calcium carbonate-containing stone. Ground improvement with quicklime or hydrated lime is an old approach that several researchers have successfully adopted in recent times [17]. The purpose of this work is to consolidate and critically examine the current understanding of the mechanism or processes responsible for the waste material and lime stabilising process. The addition of lime to clayey soil enhanced the mechanical strength and load-bearing capability of the composite [18]. When building demolition debris, fly ash, and lime were mixed, Differential Free Swell (DFS) and Maximum Dry Density (MDD) decreased, while CBR, UCS, and OMC values increased [19].

2 Materials and Test

2.1 Clayey Soil

This study's soil came from Morinda, Punjab, India. According to the Unified Soil Classification System, the resulting soil was categorised as clay with greater flexibility (USCS)The soil was dried naturally under sunlight for 3 to 4 days to remove all moisture content, and the remaining moisture content was removed using the oven drying method. According to the gradation curve, approximately 90% of soil particles value is finer than 0.075mm and approximately 18% of soil particles value is finer than 0.002mm (Figure 1). The soil's plasticity index was 26.7% indicating a high level of plasticity in the soil.

2.2 Waste foundry sand

Waste foundry sand used in the research work was brought from Saurabh Foundry Industry, Ludhiana (Punjab). The percentage of WFS used for testing is (8%, 16%, 24%) respectively. The gradation curve obtained using dry sieve analysis revealed the nature of WFS as poorly graded sand (SP) (Figure 1). The lime used in this investigation was a commercially available lime that is widely used in construction.

3 Discussions and Results

3.1 Gradation Curve

Hydrometer analysis and a wet sieve analysis test were used to produce the soil gradation curve (Figure 2). The obtained gradation curve was tested to ensure that it complied with ASTM criteria. Dry sieve analysis was used to establish the gradation curve for waste sand. The gradation curve of virgin soil shows that around 90% of particles value is finer than 0.075 mm and approximately 18% of particles value is finer than 0.002 mm. The plasticity index of the soil was 26.2 percent, implying that it has a high level of plasticity. The coefficient of uniformity (Cu) obtained from the gradation curve of waste foundry sand is 3.20; while the coefficient of curvature (Cc) is 0.87, indicating that the sand is poorly graded (SP).

a) Clayey Soil

b) Waste Foundry Sand

c) Lime

Figure 1. Materials used in the study.

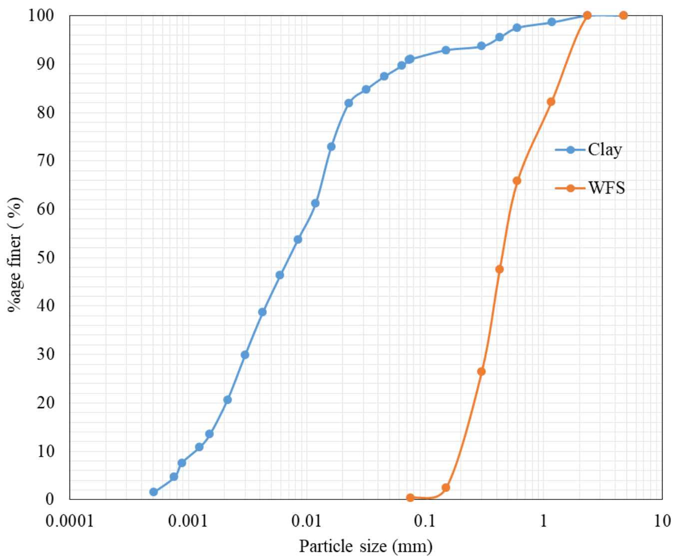

Figure 2. Gradation curve of materials used.

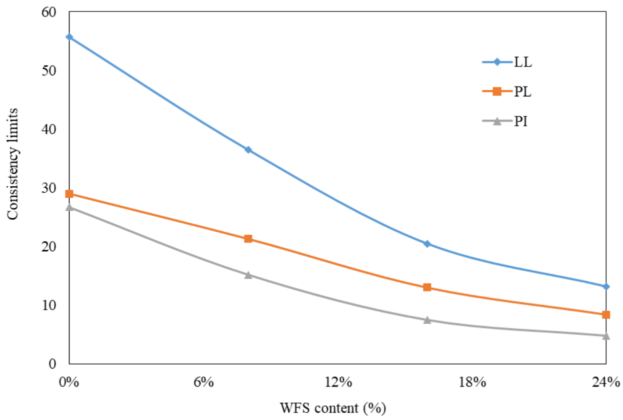

Figure 3. Atterberg's limit test.

3.2 Atterberg's limits tests

WFS were introduced to clayey soil in various percentages in order to conduct several experimental tests in order to determine Atterberg's limit. When WFS was add on to clayey soil in varied percentages, the liquid limit of the combination as well as the plasticity index were reduced (8 percent , 16 percent , 24 percent) (Figure 3). This could be due to the non-plastic characteristic of WFS, as well as the fact that coarser material (WFS) was mixed with finer material (clay). The plasticity index for clayey soil produced at 16 percent WFS is 7.5 percent, which falls between (6 percent and 8 percent) and is appropriate for sub grade soils.

3.3 Differential Free Swell Test

The DFS index of clayey soil and clay in conjunction with various additions is shown in Figure 4. Clayey soil was found to have a DFS value of 42 percent. The value of DFS decreased as the content of lime, WFS, increased. The DFS value was reduced to 0 when 6 percent lime was added to clayey soil; however, once the lime concentration was increased beyond 6 percent, the DFS value began to rise again. It's possible that the calcium in lime is substituting for other cations, resulting in a decrease in DFS value after adding lime [20]. When WFS was added to clayey soil at a rate of up to 24 percent, the DFS value plummeted to zero; subsequent additions in WFS to clayey soil had no effect on the DFS value, which remained zero. The decrease in DFS value when WFS is used could be attributed to a higher proportion of coarser particles in clayey soil (which is responsible for the drop in surface activity) [21].

3.4 Compaction test

Compaction experiments on clayey soil and various combinations of Clay + Lime, Clay + WFS and Clay + WFS + Lime were conducted to determine the MDD and OMC. The OMC and MDD of virgin soil were respectively 16.8% and 1.74g/cc.

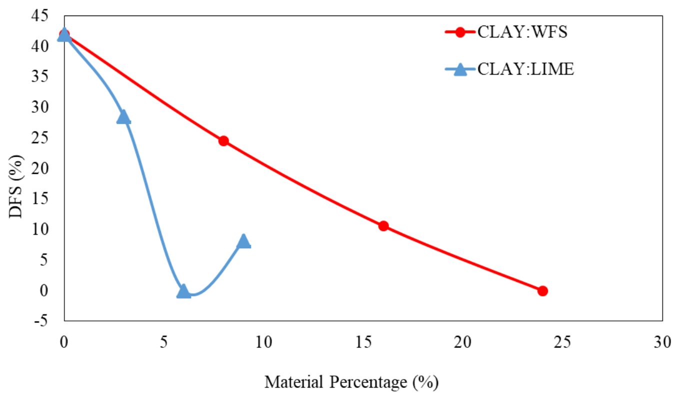

Figure 4. Differential Free Swell Test.

3.4.1 *Clay + Lime*

OMC increases from 16 to 24.5 percent and MDD drops from 1.76 to 1.62 g/cm^3 when lime is added to clayey soil in various amounts of about 9%, as shown in Figure 5. When more lime is added to clayey soil, the OMC and MDD change in the same manner. The MDD and OMC patterns are similar when clayey soil is included. The reduction in MDD after lime addition could be due to clay particle flocculation as well as lime's lower specific gravity. The pozzolanic interaction that occurs between lime and clay particles improves the OMC value. The findings are consistent with the findings of previous studies [15, 22].

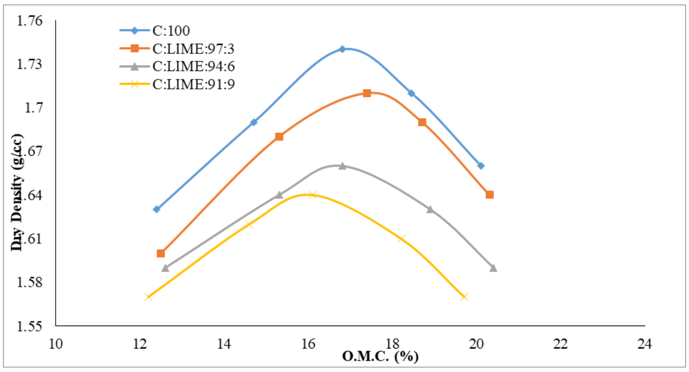

Figure 5. Compaction curves for various combinations of Clay+Lime.

3.4.2 *Clay + WFS*

Adding WFS in various ratios varying from 8 to 24 percent raised MDD from 1.71 to 1.84 g/cm^3 and OMC from 16 to 18.3 percent on clayey soil, as evidenced by the compaction curves in Figure 6. WFS particles have a bigger surface area than clayey soil particles, which explains the increasing MDD values with higher WFS concentration shown in Figure 6. Because WFS has a greater specific gravity than clay, the MDD value of the C:WFS mixture may be increased further. The addition of bentonite (a montmorillonite-rich substance) to WFS increases water holding capacity, which raises the OMC value of the C:WFS mixture, consistent with the trends observed in Figure 6. Previous research found comparable behavior when adding WFS into clayey soil [11].

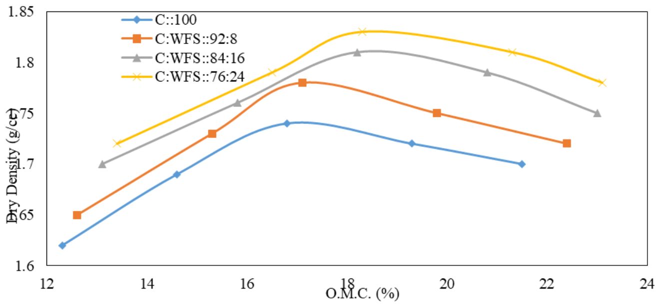

Figure 6. Compaction curves for various combinations of Clay + WFS.

3.4.3 *Clay + Waste foundry sand +Lime*

As shown in Figure 7, at 3% lime concentration the MDD value falls from 1.75 to 1.57 g/cm^3 while the OMC value rises from 12.5 to 20.3 percent. The flocculation of clay particles, as well as the lower specific gravity of lime and WFS as compared to clay particles, could explain why the MDD value decreased after lime addition. The rise in OMC value can be attributed to the pozzolanic reaction between lime and clay particles, as well as the higher OMC of WFS.

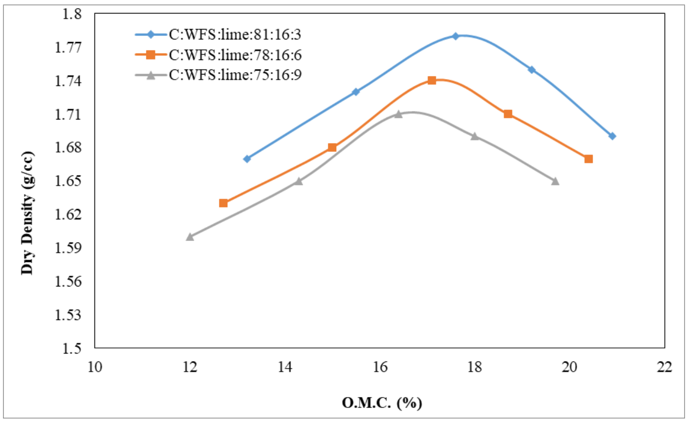

Figure 7. Compaction curves for various combinations of CLAY + WFS + LIME.

3.5 Unconfined Compressive Strength Test

The UCS of various clay: WFS, clay: Lime and clay: WFS: lime combinations are given below.

3.5.1 *Clay+WFS*

The UCS values presented in Figure 8 show that clayey soil after 3 days curing was 99 kN/m^2, which increased to 146, 295, and 313 kN/m^2 when 8, 16, and 24% WFS was added. Clayey soil had value of UCS after curing of 7-days was 214 kN/m^2, which increased to 336, 506, and 545 kN/m^2 when added 8, 16, and 24 percent WFS, respectively. Clayey soil had value of UCS after curing period of 28-days of457 kN/m^2, which increases to 581, 816, and 885 kN/m^2 when 8, 16, and 24% WFS content is added. The pozzolanic reaction of WFS with clay particles, as well as the frictional resistance caused by WFS particles, could explain the increase in UCS value following WFS addition. A comparable increase in UCS value was previously recorded when WFS was added [23].

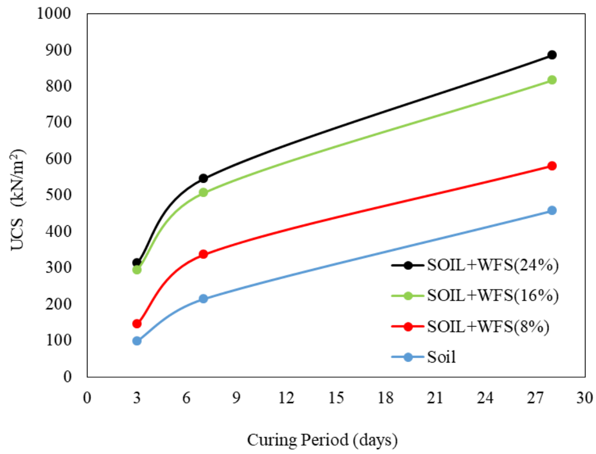

Figure 8. UCS curves for various combinations of Clay + WFS.

3.5.2 Clay+Lime

As demonstrated in Figure 9, clayey soil with a UCS value of 99kN/m^2 after three days increased to 138, 281 and 305kN/m^2 when 3, 6 and 9 percent lime were added, respectively. The UCS value of clayey soil was 214 kN/m^2 after 7 days of curing, but it increased to 315, 488, and 520 kN/m^2 when 3, 6, and 9 percentage lime were added, respectively. The UCS value of clayey soil was 457 kN/m^2 after a 28-day curing period, however this was increased to 555,792 and 825 kN/m^2 when 3, 6 and 9 percentage lime were added, respectively. This reveals that the UCS value increases at a constant rate as even more lime is added to clayey soil, but the rate of growth decreases after 6 percent lime content. As a result, a lime content of 6% may be chosen as the optimal content. When the lime is applied, the chemical reaction between lime and soil particles is likely to induce an increase in UCS value. A comparable increase in UCS value was previously found when lime was added to clay (17, 6].

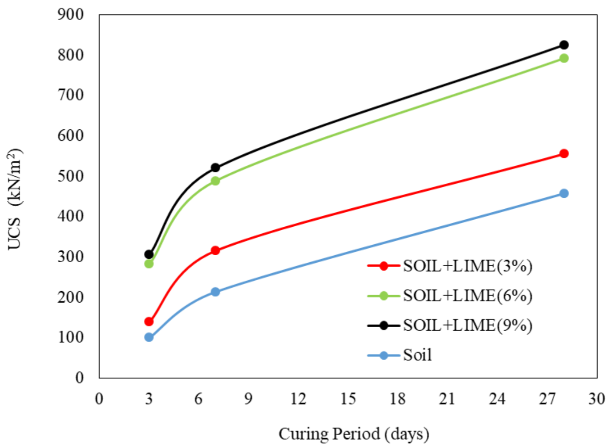

Figure 9. UCS curves for various combinations of clay + lime.

3.5.3 Clay+WFS+Lime

The UCS trends shown in Figure 10 indicate that after three days, the UCS value of optimal clay: WFS (16%) soil was 295 kN/m^2, which increased to 415, 565 and 396 kN/m^2 when 3, 6 and 9% lime was added respectively. After a 7-day curing period, the value of UCS for clay:WFS (16%) was 506 kN/m^2, which increased to 728, 906, 960 kN/m^2 when 3, 6 and 9% lime was added respectively. After curing period of 28-days, UCS of clay:WFS (16%) was 816 kN/m^2, which climbed to 1057, 1227 and 1274 kN/m^2 when 3, 6 and 9% lime was added. As a result, it has been shown that 6% lime is the best combination for optimised clay:WFS (16%) blend as there is no swelling at 6% lime content. A chemical reaction between the clay:WFS content and lime particles could explain the increase in the UCS value of the clay:WFS combination when lime is introduced. When WFS and lime were mixed in clayey soil, a comparable increase in UCS value was previously seen [19].

3.5.4 California Bearing Ratio Test

The CBR test is intended to evaluate the strength of clayey soil. CBR studies on clay were carried out, and the best combination of admixtures with clay was discovered. The various CBR values are shown in Figure 11. CBR of virgin soil yielded a value of 1.93. When 16 percent WFS were applied, the CBR value for soil was 4.8. After adding 6% lime to clayey soil, the CBR value was 6.2. The CBR value was 9.8 after adding lime (6%) to the optimum clay: WFS (16%) mixture. It was discovered that applying WFS and lime to clayey soil, both independently and in combination had a positive effect., increased CBR values, Because fine sand particles in WFS help in the shear resistance

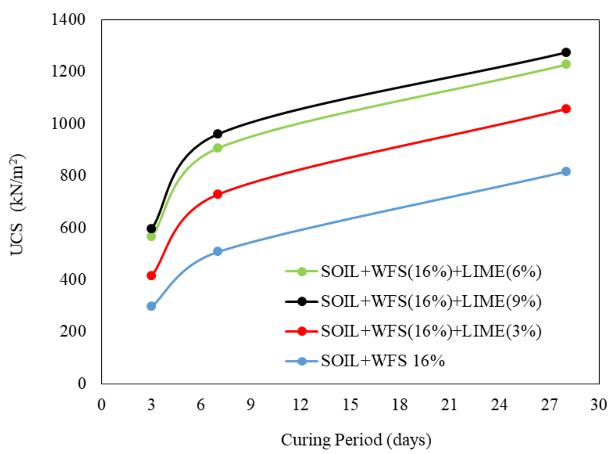

Figure 10. UCS curves for various combinations of Clay + WFS + Lime.

angle, the CBR value increased when WFS was added, resulting in higher composite strength.

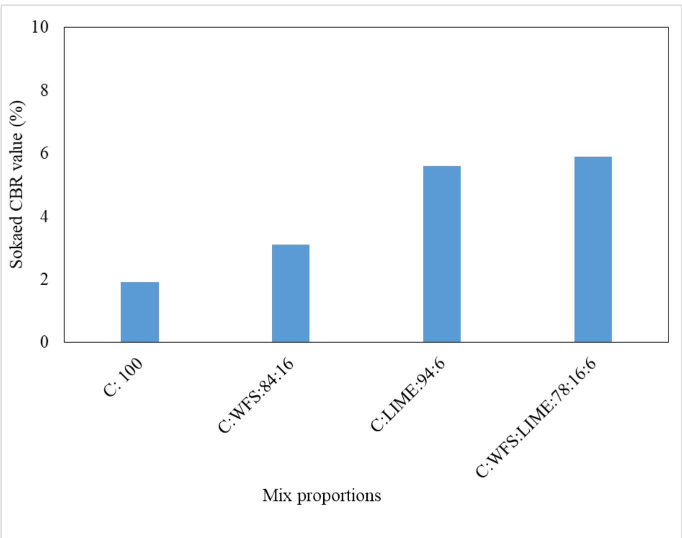

Figure 11. CBR Values of various combinations.

4 Conclusion

Finding of the study are summarized as follow:

1. On adding 16% of WFS to soil, the LL varies from 55.7% to 13.2%, and the PL of the soil continues to decline, at plasticity index of 7.5%.

2. When WFS is added to clayey soil, the MDD value increases but the OMC value drops; the increase in MDD remains stable after adding 16 percent WFS. On adding lime, the MDD decreases while OMC remains almost constant.

3. The soaked CBR increases if WFS and lime are added to the soil. The maximum soaked CBR value obtained at 16 percent WFS and 6 percent lime is 9.8.

WFS with Lime is a better and more environmentally friendly approach for improving the geotechnical qualities of clayey soil, and it is used in the construction of low-density highways, shallow foundations, and pavement sub-base layers, among other things.

Data Availability Statement

Data will be made available on request.

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Conflicts of Interest

The authors declare no conflicts of interest.

Ethical Approval and Consent to Participate

Not applicable.

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