Utilisation of Athel Leaves to Improve the Unconfined Compressive Strength of Soil

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Abstract

Athel Leaves (AL) are plentiful agricultural waste that might result in a detrimental effect on the environment owing to inadequate disposal. The purpose of this paper is to experimentally assess the impact of Athel leaves as a novel sustainable waste application on the unconfined compressive strength (UCS) of soil. For the purpose of fulfilling this main objective, five AL percentages (1%, 2%, 3%, 4%, and 5% by dry weight of soil) and four curing periods (3, 7, 14 and 28 days) were selected. The failure pattern was also studied to better understand the ultimate behaviour of the improved soil. Assessment of the derived conclusions revealed that the inclusion of AL into soil enhanced the UCS. Careful inspection of the stress-strain relationships showed that inclusion of AL resulted in increased peak stress at large strains. Additionally, it was found that bulging and shear were the two patterns observed in this research. This study confirms the possibility of incorporating AL in geotechnical applications with significant environmental benefits.

Keywords: Soil Improvement, Unconfined Compressive Strength, Stress-Strain, Failure pattern, Agricultural waste

1. Introduction

Owing to the significant rise in the population of the world, a growing demand for adequate land for the building and enhancement of infrastructures and new cities is imminent. This might result in the necessity for building on weak soils. It is expected that variations in the weather would worsen the volumetric changes. This leads to a substantial distress to the elements of the structure due to possible unequal movement, which, if preventive actions are overlooked, can have a significant negative impact on the reliability of structures [1]. It is suggested that you undertake precautions, such as partial replacement of ground surface layer, chemical improvement with lime, cement, fly ash, and soil reinforcement to mitigate or prevent the negative consequences of a possible volume change [2]. In general, an agreement was achieved that treated materials by chemicals exposed improved properties compared with those noted on unimproved soil.

Even though soil improvement by chemicals is a proven method, however, the utilisation of these additives requires relatively large quantities and lengthy curing periods for substantial enhancement. In addition, production of the chemical additives is characterised by CO₂ emissions which affect climate change. Moreover, large concentrations of these additives are considered to be unreasonable in terms of cost for significant negative impact on the reliability of structures [1]. It is suggested that you undertake precautions, such as partial replacement of ground surface layer, chemical improvement with lime, cement, fly ash, and soil reinforcement to mitigate or prevent the negative consequences of a possible volume change [2]. In general, an agreement was achieved that treated materials by chemicals exposed improved properties compared with those noted on unimproved soil.

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engineered projects [3], consequently, utilising eco-friendly agricultural wastes can partially substitute the chemicals responsible for greenhouse gas emissions and decrease global warming.

One of the primary categories of wastes produced regularly and in substantial quantities is agricultural wastes. The disposal of these wastes has a potential negative environmental impact leading to air and water pollution and finally affecting the local ecosystems [4]. For the time being, great efforts are being put to reuse these wastes for various enhancement purposes. Disposal of agricultural waste can be decreased if the waste has desirable properties such that they could be utilised as additives in soil improvement. In soil system, additives such as salts, silica, rice husk, sugar cane straw, etc. act as catalysts to improve the physico-mechanical properties of treated soils. Based on the chemical analysis performed in previous studies [5-7], it was noticed that agricultural wastes are rich in SiO₂, Al₂O₃, Fe₂O₃ and salts that can be utilised to enhance the soils' engineering characteristics.

Soil improvement with agricultural waste materials is among the eco-friendliest and inexpensive methods. The reported findings of Akinwumi, Ojuri [8], Aziz, Saleem [9], Fauzi, Fauzi [10], Ekeocha and Agwuncha [11], and Pourakbar, Asadi [12] suggest that beneficial impacts of adding agricultural wastes to soil could be obtained. Moreover, Numerous researches were conducted to clarify the benefit of utilising agricultural wastes in enhancing the mechanical characteristics of soil. Rice husk is an agricultural waste obtained from milling of rice. Approximately 108 tons of rice husks are produced globally every year. Meanwhile, the ash has been categorised under pozzolana, with about 67-70% silica and about 4.9 and 0.95% aluminium and iron oxides, respectively [13]. Alhassan [14] studied the impact of rice husk ash (RHA) on soil strength. The results of strength showed a rising pattern at 6% RHA and with cumulative curing time. This increase is probably owing to the reactions between the pozzolans presented in the RHS and the grains of soil. The quantity of clay and silt which existed in soil decreased because of the development of cementitious materials. Sarapu had made identical findings in this regard [15]. The influence of wheat husk and sugarcane straw ash on soil’s strength behaviour was documented in studies carried out by Singh, Sharma [16], Naik, Patil [17] and Amu, Ogumniyi [18], it was noticed that the treated soils’ strength improved significantly.

Athal tree (Tamarix aphylla or salt cedar) is halophyte plant that has been found growing in sites of high levels of soluble salts. Sites with Athel tree (Tamarix aphylla or salt cedar) are being, because of the development of cementitious materials. Sarapu made identical findings in this regard [15]. The influence of wheat husk and sugarcane straw ash on soil’s strength behaviour was documented in studies carried out by Singh, Sharma [16], Naik, Patil [17] and Amu, Ogumniyi [18], it was noticed that the treated soils’ strength improved significantly.

Athal leaves were collected from Awjila oasis in Libya and used as additives in soil improvement. In soil system, additives such as salts, silica, rice husk, sugar cane straw, etc. act as catalysts to improve the physico-mechanical properties of treated soils. Based on the chemical analysis performed in previous studies [5-7], it was noticed that agricultural wastes are rich in SiO₂, Al₂O₃, Fe₂O₃ and salts that can be utilised to enhance the soils’ engineering characteristics.

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The experiments were remarkably with 4% AL (49%). Although increasing AL, UCS test is the key test for the soil, should not deviate by more than 5% which reflects the effectiveness of specimen preparation technique.

3. Results and Discussion

UCS Characteristics:
For quantifying the impact of Athel leaves on the strength, series of UCS tests were executed. The unconfined compression strengths versus different periods of curing and AL contents are plotted in Figure 4. The UCS number of the unimproved soil was determined to be 604.9 kPa. Because there are no chemical reactions between the soil and water, no changes during the curing time would be observed as confirmed by Zhang, Zhang [28].

The data clearly illustrate a rise in strength as the specimens were tested after 72 hours of curing. Effect of adding various amounts of AL on the UCS of soil revealed that the UCS in improved specimens was increased from 604.9 kPa to 654.6, 670.8, 750.1, 905.7 and 755.0 kPa with adding of 1, 2, 3, 4 and 5% of Athel leaves. Moreover, the specimens were tested over a 3, 7, 14 and 28-days of curing period.

Unconfined Compressive Strength:
Due to its affordability and ease of use, UCS tests were implemented to study the assessment of soil compressive strength [24]. In addition, as recommended by Geiman [25], UCS test is the key test for the investigation of the needed amount of additive to be used in soil stabilisation. The UCS tests were undertaken abiding British standards BS1377-7 [26]. All the specimens were tested without considering any confining pressure throughout the test. The specimens were tested at a rate of an axial movement of 1 mm per minute and the maximum load reached was recorded. This is abiding with the British Standard which specifies a strain rate in the range of 0.5% to 2.0% per minute. The highest UCS value from the UCS tests for each specimen was selected to analysis the strain-stress relationships. The UCS findings of 3 identical specimens, as advised by Consoli, da Silva Lopes Jr [27], should not deviate by more than 10 percent from the mean strength. The differ of UCS from the mean strength was found to not exceed ±5% which reflects the effectiveness of specimen preparation technique.

Fig. 3: Particle size distribution of AL

Fig. 4: Evaluation of UCS with AL content and curing time
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and the carbonate (CO$_2$) in the AL reacts with the water (H$_2$O) to give free OH$^-$ ions, accordingly raising the pH where based on Ball [29], soil pH can be increased by liming the soil by lime or calcium carbonate. An increase in hydroxyl ions (OH$^-$) results in raising the alkalinity. In a high pH environment, the solubility of silica and alumina is greatly enhanced [30]. This process is termed as pozzolanic reaction which is time-dependent. However, large amount of salt can reduce the unconfined compressive strength of the soil [31] where higher pH (raised by 5% AL) can break down the flocculated structure resulting in forming a dispersed one [32].

The unconfined compressive strength of soil increased gradually as the number of curing hours increased. Curing the specimens up to 7 days resulted in a gain of strength of about 12, 13, 52, 66 and 27% for 1, 2, 3, 4 and 5% AL- soil specimens compared to the improved soil. Furthermore, A significant improvement in strength was achieved by extending the curing period to 28 days. The soil’s UCS increased by 84, 86, 120, 244 and 63% compared to the UCS findings of the native soil. The observed increase in UCS might be explained by the composition of aluminate and silicate hydrate products owing to the existing of silica (available in Athel leaves and soil) for the pozzolanic reactions [33]. Moreover, it could be also interpreted as being a result of the excessive Ca$^{++}$ in the Athel leaves that promotes a greater production of pozzolanic materials [34]. This implies that during the allotted curing period in this investigation, there was enough reactive silica in the AL-clay combination to continuously react with the soil grains. In addition, calcium-sodium silicate could be formed where the Athel leaf contains Albite and Feldspar that have sodium. Davoudi [35] stated that calcium-sodium silicate gel improves the cementation faster than a calcium silicate gel.

**Stress-Strain Behaviour:**

The alterations in the stress–strain pattern of unimproved and improved soil tested after 72, 168, 336 and 672 of curing hours are shown in (Figure 5) to contrast the impact of the Athel leaves. The graphs below show that variation in strains did not exceed 10.5%. As noticed, the strain of all AL percentages reduced with curing period. An attribution can be said that the decline in axial strain might be caused by the development of cementing materials between the grains. It can be noted that the rise in the peak of stress was corresponded to the increase in curing time that found to play a major role in the underpinning stabilising. The cementing products development owing to the curing of the specimens results in an increased peak axial stress.

The addition of AL reduces the intra/inter-assemblage of pore spaces along with the creation of the CSH gel, which effectively bonds the grains of soil together. Different from unimproved specimens, inclusion of AL resulted in larger deformation at maximum compressive stress. The AL in specimens snapped and following the completion of the compression tests, the specimens had not fully disintegrated, and this could be attributed to the different particle sizes of AL that may held together some significant parts of the soil matrix, delaying failure. As the cracks were growing, AL hindered relative slippage of damaged sections and prevented soil block deformation, thus restraining crack development and improving the ultimate strain.

**Failure Pattern:**

The patterns of failure of unimproved and AL-improved specimens are depicted in (Figure 6). The specimens were collected after completing of the UCS tests and compared. Figure 6a shows that there is no noticeable shear band is observed. This type of failure is referred to as plastic failure, and it is in line with the strain-stress behavior that was noticed (see Figure 6). It is evident that bulging and uneven lateral dilatation were the causes of the untreated specimen’s failure. The collapse pattern is relevant to the specimen’s strength at the time of testing, which is relevant to the treatment and curing conditions. With curing period (28 days), the factor of AL is significant in changing the failure mode. A greatly different failure mode from the plastic failure mode discussed...
above characterises the failures of AL treated soil, as indicated in (Figure 6). There was a translational failure noted for the specimens improved by 1, 2, 3, 4 and 5 % AL which were showed evidence of shear failure that started at the top end of the 2, 3 and 4% specimens, whereas started at the bottom end of the 1 and 5% specimens. According to Chakraborty, Bisai [37], shear failures occur when the adjacent cracks in close proximity coalesce together. This justifies that the AL within the soil increased the soil stiffness and limited the lateral deformation mentioned in bulging.

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4. Conclusion
Utilising agricultural waste is particularly advantageous because it is an economical and environmentally friendly method. The biggest benefit is that disposing of waste is no longer a major issue. The current research is a laboratory program to study the influence of Athel Leaves on the strength. for investigating this mechanism, the geotechnical properties as UCS were studied before and after improvement. Based on these investigations, the following findings can be drawn:

- The UCS of the soil enhanced with increasing AL percent up to 4 % and beyond that, a reduction in UCS occurred.
- According to stress-strain curves, all of the enhanced specimens demonstrated ductile behavior, which was defined by a gradual decrease in the post-peak stress as the axial strain increased.
- It was seen that bulging and shear are the two patterns noticed in this research.
- This study confirms the possibility of incorporating AL in geotechnical applications with significant environmental benefits.

5. References


