inspection, and this can be explained by the biochar itself that can be considered fines, adding to the total amount of fines of the Ultisol sample. Figure 10 shows the first trial GSDC of the pure soil sample. It should be noted that the trend of the GSDC shows that the Ultisol at a baseline is poorly graded. When ANOVA analysis was performed, the P-values obtained for gravel, sand, and fines were 0.37, 0.14, and 0.14 respectively. This implies that there is no significant change in values with respect to the amount of biochar within all groups.

Table 5 Percentage of Particle Size by Biochar Amended for Ultisol Samples

	% Passing										
Soil	0% WHBC			5% WHBC		10% WHBC		15% WHBC		20% WHBC	
Trial	1	2	3	1	2	1	2	1	2	1	2
Gravel	0.1	0.3	0.6	0.1	0.3	0.2	0.1	0.0	0.0	0.0	0.0
Sand	82.7	84.8	88.0	82.5	83.6	86.3	86.5	78.5	82.7	82.7	78.9
Fines	17.3	15.0	11.4	17.4	16.1	13.5	13.4	21.5	17.3	17.3	21.0

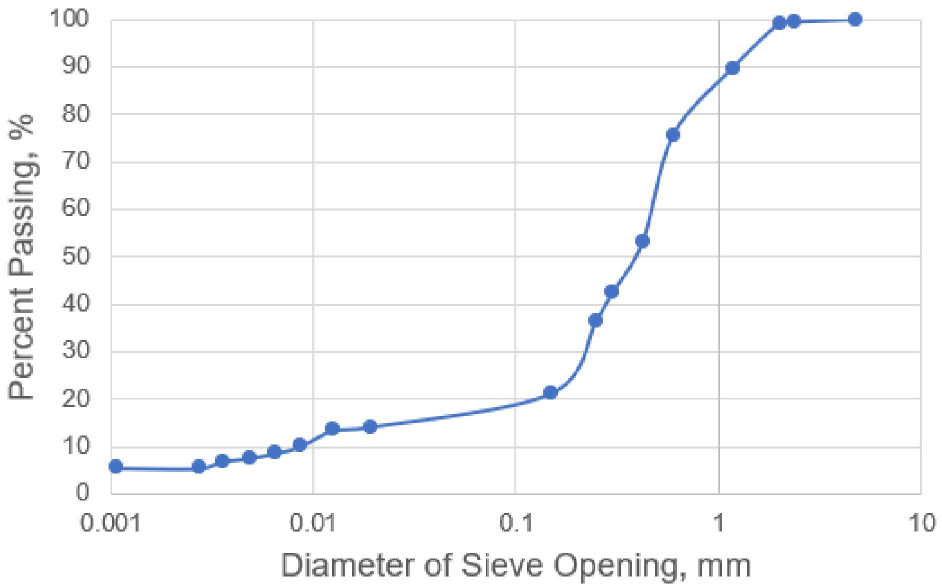

Figure 11 Grain Size Distribution Curve for 0% Amended Biochar

This is further seen through Figure 12 since the trend of increasing and decreasing between particle sizes seem to fluctuate. The reason behind this may be that while the amount of biochar amended does increase the amount of fines present, the removal of soil particles decreases about the same percentage of fines. It should be noted that the amount of gravels is less than 1% of the total trials, as such, their true nature for this study would prove difficult to completely quantify since their presence seems to be an irregularity within the soil sample. In addition, the soil was classified using the Unified Soil Classification System (USCS). Specifically, it lies underneath the category of SC (clayey sands, sand-clay mixtures). This is because throughout all amendment groups, there is at least 10% of fines present for each of the samples. Additionally, this classification agrees with the Atterberg Limits obtained. Balaban et al. (2019) found that increasing the fines-content of a soil sample improves the cohesion of said soil sample, therefore increasing its shear strength. The study highlighted that this increased improvement is more pronounced for lower normal stress values. However, Islam et al. (2016) claims that for their soil type, this increase in shear strength can only be observed up to 5% fines, decreasing when further fines are introduced to the sample. As such, an excessive amount of fines may prove detrimental towards increasing the strength of soil.

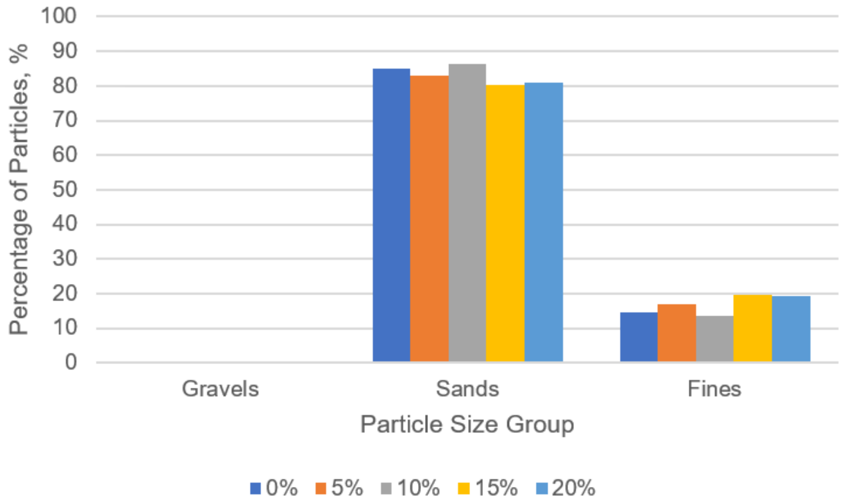

Figure 12 Bar Chart of Percentage of Particles by Group for each Biochar Amendment

4.4 Standard Proctor

For the standard proctor test, the soil's optimum moisture content and maximum dry unit weight were obtained. The results of these tests are tabulated in Table 6. The results of the pure soil sample can be seen to have an average optimum moisture content (OMC) value of 36.64% and an average maximum dry unit weight (γ_{dmax}) of 12.66 kN/m^3. These values, as found by Kumar et al. (2018), lie within the ranges of clay. This is because in their study, it was found that the fines content of a soil sample is directly related to the OMC of said sample. While the determined OMC is larger than the typical values, it can be inferred that it is related to the high percentage of fines with little to no gravel. However, these values also seem to be highly affected by the amount of biochar added to the soil sample. As the amount of biochar is increased, the OMC of the sample also increases, however, its γ_{dmax} decreases in turn. The increase in the moisture content in relation to the amount of biochar may be a direct result of the biochar's properties, such as its hydrophobicity. Due to the WHBC's inherent property to repel water particles, the amount of moisture needed for the soil is greater than without it. As such, more water is required for the soil to reach its maximum compaction.

By performing ANOVA, the P-value for the amount of amended biochar on the soil's OMC and γdmax is 0.002 and 0.0002 respectively. Since both these values are less than 5%, it can be inferred that the amount of biochar has an effect on the soil's OMC and γdmax. This increase in OMC implies the need for additional amount of water so as to achieve the maximum compaction of the soil. Due to the increase in WHBC, the OMC increased which resulted to a decrease in γdmax. Langfelder and Nivargikar (1967) explained in their study that while increasing the dry density of a soil sample may not always increase its shear resistance, decreasing it does have an adverse effect on the sample's strength. In addition to this, their study also indicates that for soil types of constant dry density, an increase in moisture content also decreases the shear strength of the soil. Typically, in the usage of shear resistant soils, a minimum dry unit weight of 11 kN/m^3 is used as an indicator whether a soil may be used for such purpose. This may imply that while the 0% WHBC sample may be used for these projects, amending biochar makes it less suitable for them.

Table 6 Percentage of Biochar Amended in relation to the soil's Optimum Moisture Content and Maximum Dry Unit Weight

<table>
<tr><th>Biochar Amended (%)</th><th colspan="6">Optimum Moisture Content (%)</th><th>Average OMC (%)</th><th colspan="6">Maximum Dry Unit Weight (kN/m^3)</th><th>Average γ_{dmax} (kN/m^3)</th></tr>
<tr><td>0</td><td colspan="2">36.02</td><td colspan="2">36.96</td><td colspan="2">36.95</td><td>36.64</td><td colspan="2">12.78</td><td colspan="2">12.56</td><td colspan="2">12.63</td><td>12.66</td></tr>
<tr><td>5</td><td colspan="3">42.34</td><td colspan="3">40.85</td><td>41.60</td><td colspan="3">6.10</td><td colspan="3">6.30</td><td>6.20</td></tr>
<tr><td>10</td><td colspan="3">49.91</td><td colspan="3">45.43</td><td>47.67</td><td colspan="3">5.18</td><td colspan="3">6.08</td><td>5.63</td></tr>
<tr><td>15</td><td colspan="3">51.50</td><td colspan="3">57.31</td><td>54.41</td><td colspan="3">7.09</td><td colspan="3">2.45</td><td>4.77</td></tr>
<tr><td>20</td><td colspan="3">52.65</td><td colspan="3">60.86</td><td>56.76</td><td colspan="3">2.92</td><td colspan="3">2.09</td><td>2.51</td></tr>
</table>

Overall, the amendment of WHBC to Ultisol had an effect on the index properties. Due to the hydrophobic nature of the biochar, it repels water which has a potential as a stabilizer or additive in clay liners.

5.0 CONCLUSION

The goal of this study was to determine the impact of WHBC on the index properties of soil. Using the data obtained from the various index property tests conducted, several conclusions were drawn. For the specific gravity test, it was found that biochar actually decreased the specific gravity of the given Ultisol sample. This proves detrimental towards the objective of strengthening the soil since several studies have highlighted the direct relationship between specific gravity and soil strength. In the Atterberg Limits test, it was established that the biochar increased both the liquid limit and plastic limit of the sample. Other literatures have associated an increase in liquid limit with a decrease in cohesion. As such, this test also proves that the addition of biochar may decrease towards the strength of the soil. The sieve and hydrometer tests observed that the amendment of biochar had no significant effect on the sample. It should be noted that an increase in fines can actually prove beneficial as they are typically associated with an increase in cohesion. However, other studies have highlighted that an excess amount of fines may actually negatively affect the strength of the soil sample. This implies that while the biochar had no effect on the particle size distribution of clays, they may prove beneficial for sands to an extent. Lastly, the standard proctor test determined that the amount of biochar not only increased the optimum moisture content of the soil, but also decreased its maximum dry unit weight. Other studies have found that both an increase in OMC and a decrease in maximum dry unit weight have a detrimental effect on the soil's shear strength.

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