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Water Susceptible Properties of Silt Loam Soil in Sub grades in South West Pennsylvania

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Abstract: *Water susceptible properties of subgrade soils play important role in the structural design of highways. In this research study laboratory investigations were conducted on subgrade soil samples for determining the influence of water susceptible properties on Natural moisture content, Optimum moisture content, Compaction, California Bearing Ratio (CBR)-soaked and unsoaked, and Unconfined Compression Strength (UCS). All tests were done using appropriate ASTM standards. Relationships were developed using regression equations for predicting the performance of seven engineering variables.*

Key Words: *Water Absorption characteristics, Engineering Properties, Optimum Moisture Content, CBR, UCS.*

I. Introduction

Water is an enemy of road materials [1, 2, 3]. This is because water plays an important role in causing cumulative damage of road structure over time [4, 5, 6]. Because of highwater absorption property silt loam poses performance problems especially under heavy loads over longer periods of time [7, 8, 9]. The problem is aggravated during rainy season because of significant loss of bearing capacity and shear strength of the subgrade material [10, 11, 12]. These losses in the subgrade material will translate into the loss of structural performance of the road itself. Silt loam soils are found on and around the river beds in Southwest Pennsylvania. In these regions many rural roads are usually constructed on compacted silt loam soils. Therefore, there is need to study in detail the influence of water susceptibility on various engineering properties of this material as applicable to Southwest Pennsylvania. This research study attempts to determine relationship between the degree of water absorption of loam soils at subgrade level and essential engineering properties.

II. Materials and Methods

Twenty samples were collected at 3 feet depth of the subgrade soil of US 19 near Pittsburg.

The following laboratory tests were conducted on the soil according to the ASTM standards.

1. Grain size distribution (wet/dry sieving),
2. Soil classification, ASTM D2487 – 11
3. Natural moisture content, ASTM D2216 – 10
4. Optimum moisture content ASTM D558 – 11
5. Compaction test, ASTM D 698, D 1557
6. California Bearing Ratio (CBR) – soaked and unsoaked, ASTM D1883 - 07e2 and
7. Unconfined Compression Strength (UCS). ASTM D2166 – 06

The following statistical tests were conducted to establish the mean values and associated variances of the parameters. The variances were determined for inter and intra-groups of samples at a statistical significance of $\alpha = 0.05$.

1. One-way Analysis of Variance (ANOVA)
2. Two-way ANOVA

Seven regression equations were establishedshowing the influence of independent variable on the dependent variable. For each regression equation correlation coefficient was determined. The correlation coefficient was significant at $\alpha = 0.05$ level for the following correlated quantities: Swell and UCS, Swell and CBR (soaked), Void Ratio and MDD, Shrinkage limit and liquid limit, Clay content and NMC.

The correlation coefficient was significant at $\alpha = 0.01$ level for the following correlated quantities: Swell and CBR (unsoaked), Plasticity index, and Shrinkage limit. All the significance tests were done at 2 tailed tests.

III. Results and Discussions

3.1 Soil Classification

As per the ASTM D 2487 standard the Unified Soil Classification System was used in classifying the soils. 57% of the samples were classified as inorganic sandy clays of low to medium plasticity (CL). Others were classified as elastic silt (MH).

3.2 Comparison of Sections

Comparison of the mean values of many of the geotechnical properties of soils beneath the stable and unstable sections of roads in the region revealed that there was significant differences shown in the results of California Bearing Ratio (CBR) and Maximum Dry Density (MDD), swell and UCS.The high values for these propertieswere due to the presence of high clay content (though statistically insignificant in difference)and low degree of compaction of the subgrade.

3.3 Natural Moisture and Clay Contents

The minimum and maximum natural moisture contents were 10% and 24% respectively as shown in Table I. The mean moisture content was 17%. The minimum and maximum clay contents were18 and 54% respectively. The mean clay content was 38%. Alinear correlation with R = 0.98 was established between the clay content and the natural moisture content as shown in Table II and Fig. 1. The correlations between shrinkage limit and liquidlimit; and shrinkage limit and plasticity index were R = 0.78 and R = 0.89 [13,14,15] respectively as shown in Fig. 2 and Fig.3.The correlation established in this study indicates that the clay content has a strong positive influence on water content. Other researchers established that there is strong attraction between the water and the clay particles. This is because the high ratio of particles surface to particle mass for clay soils attracts large amount of water [16].

3.4 Void Ratio and MDD

The minimum and maximum void ratio were0.44 and 0.65 respectively as shown in Table I. The mean void ratio was 0.52. The minimum and maximum MDD were 1594 kg/m^3 and 1884 kg/m^3respectively. The mean MDD was 1788 kg/m^3. A linear correlation with R = 0.81 was established between the void ratio and MDD as shown in Table II and Fig.4.

The void ratio has a linear relationship with the Maximum Dry Density (MDD). The coreThe soil void increased rather than decrease as shown by the laboratory compaction tests ASTM D 698 and D 1557 as shown in Fig. 4. The results indicate that adequate field compaction was not obtained.

3.5 Swell, CBR and UCS

The minimum and maximum Swell were 0.02 and 0.267 respectively as shown in Table I. The mean Swell was 0.14. The minimum and maximum CBR unsoaked were 3% and 6% respectively. The mean CBR unsoaked was 4%. A linear correlation with R = 0.88 was established between Swell and CBR unsoaked as sown inTable II and Fig. 5. The minimum and maximum CBR soaked were 1% and 3% respectively. The mean CBR soaked was 2%. A linear correlation with R = 0.93 was established between Swell and CBR soaked as shown in Fig. 6.

The minimum and maximum UCS were 16 KN/m^2 and 63 KN/m^2 respectively. The mean Swell was 28 KN/m^2. A linear correlation with R = 0.21 was established between Swell and UCS as shown in Fig. 7.

It is important to note that swell has a negative influence on the CBR unsoaked and CBR soaked. This means that a swell % increased both CBR unsoaked and CBR soaked decreased indicating strength loss. Similarly swell has negative influence on the UCS indicating strength loss while swell % increased.

Table I: Comparison of ranges and mean values of various geotechnical properties of subgrade soils.

Properties	Stable Location Range	Unstable Location Range	Differences	Mean Value
Clay content (%)	18-48	22-54	Insignificant	38
Natural Moisture Cont. (%)	10-19	12-24	Insignificant	17
OMC (%)	10-18	13-20	Insignificant	18
Shrinkage limit	2-9	2-9	Insignificant	6
Plastic Limit (%)	13-21	16-25	Insignificant	21
Liquid Limit (%)	36-48	38-52	Insignificant	44
Absorption Limit (%)	17-39	21-42	Insignificant	32
Max. Dry Density (kg/m^3)	1742-1884	1594-1676	Significant	1788
CBR (%)-unsoaked	4-6	3-4	Significant	4
CBR (%)-soaked	2-3	1-2	Significant	2
Void Ratio	0.44-0.58	0.56-0.65	Significant	0.52
UCS (KN/m^2)	20-63	16-43	Significant	28
Swell	0.02-0.18	0.10-0.267	Significant	0.14

Table II: Correlation and regression equations among the variables

Correlated Quantities	Correlation Coefficient	Significance	Regression Equation
Swell and CBR (soaked)	0.93	0.018, α = 0.05	Y=-8.2873x+3.1375
Void Ratio and MDD	0.81	0.018, α = 0.05	Y=1069.9x+1215.4
Swell and CBR (unsoaked)	0.88	0.007, α = 0.01	Y=-8.2026x+6.2326
Swell and UCS	0.21	0.112, α = 0.05	Y=-60.703x+36.433
Shrinkage limit and liquid limit	0.78	0.038, α = 0.05	Y=2.4165x+30.073
Clay content and NMC	0.98	0.016, α = 0.05	Y=0.3404x+4.865
Shrinkage limit and Plasticity index	0.89	0.004, α = 0.01	Y=1.7463x+10.887

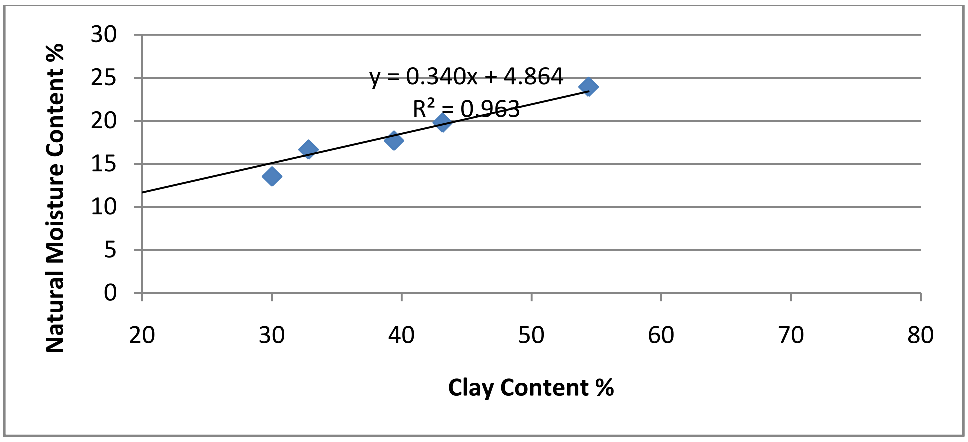

Figure 1: Influence of clay content on natural moisture content.

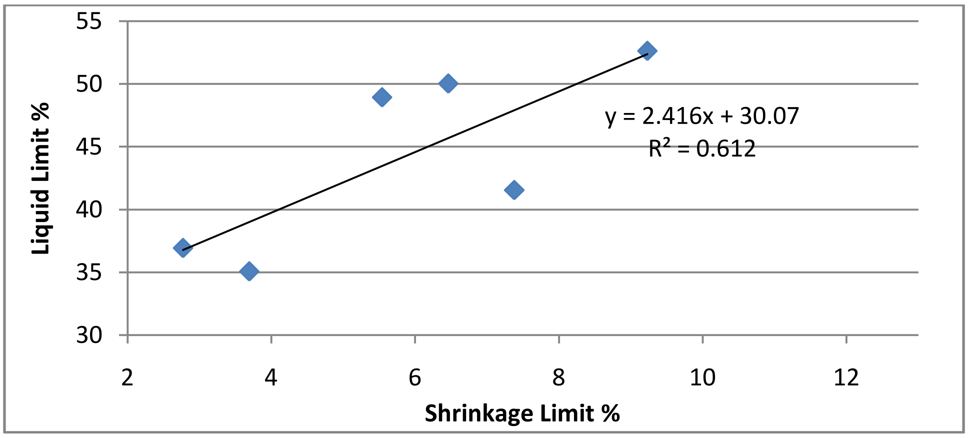

Figure 2: Influence of shrinkage limit on liquid limit.

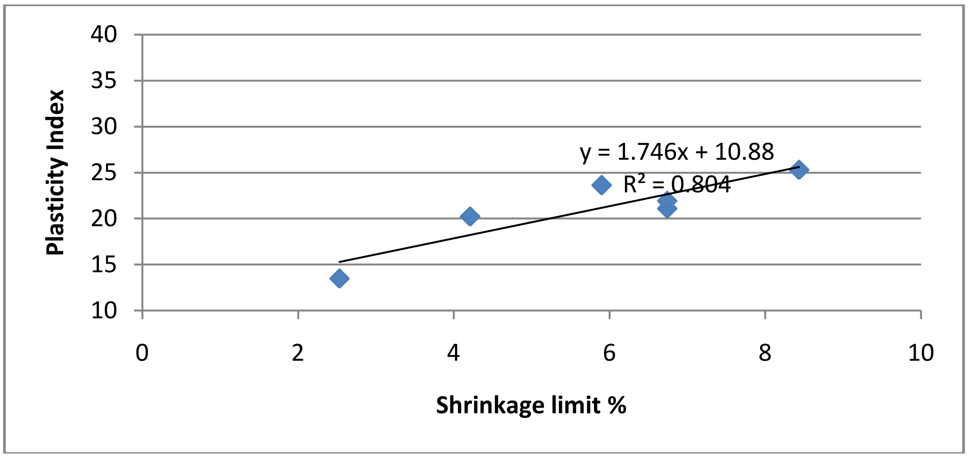

Figure 3: Influence of shrinkage limit on plasticity index.

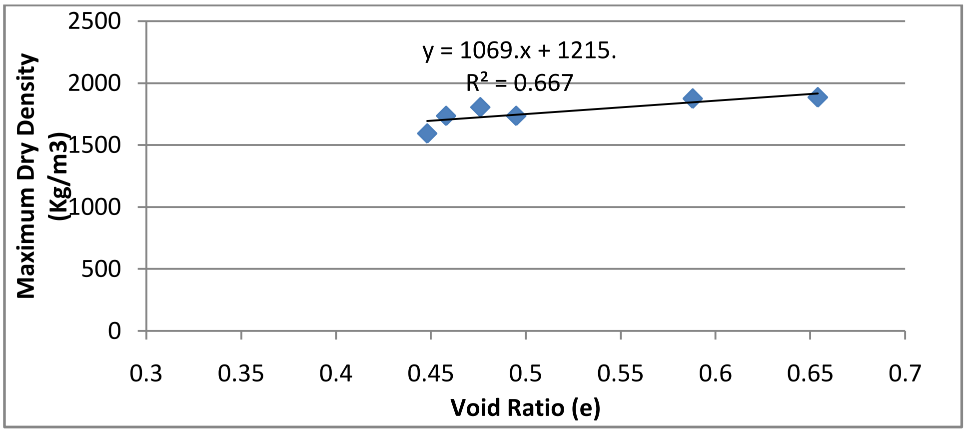

Figure 4: Influence of void ratio on maximum dry density.

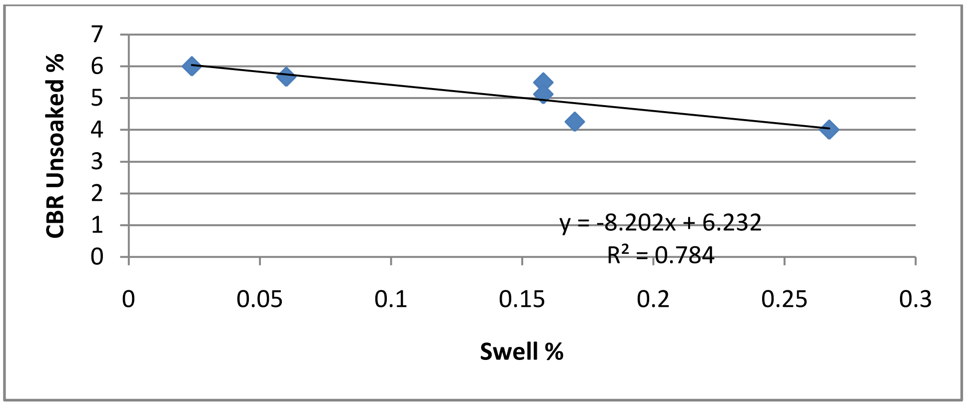

Figure 5: Influence of swell on CBR unsoaked.

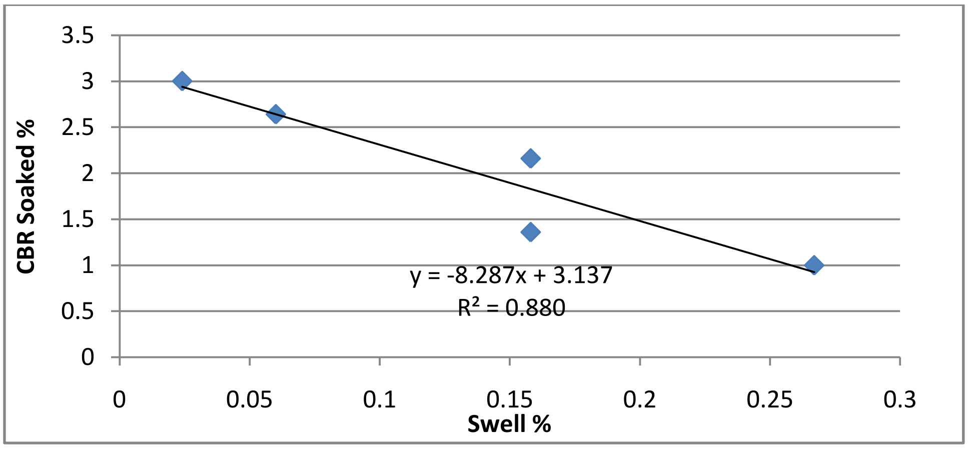

Figure 6: Influence of swell on CBR soaked.

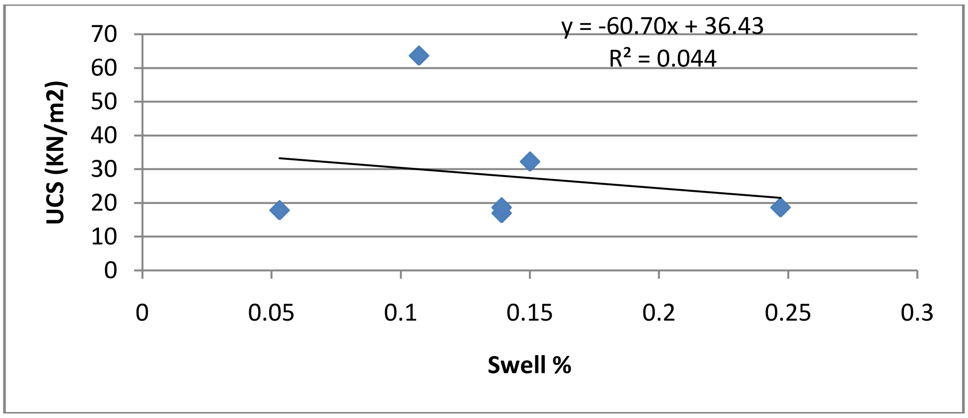

Figure 7: Influence of swell on UCS.

Similar results were found by Alayaki F. M. (2012) [17].

When an engineer is encountered with subgrade soils with high water absorption properties it is important for him or her to consider improving the drainage condition of the pavement. Additionally, the engineer should also consider improving the soil performance by adding admixtures such as lime, fly ash, cement.

IV. CONCLUSIONS

The following seven regression relationships were found with statistically significant correlation coefficients for predicting the performance of several engineering variables.

1. Clay is content is directly proportional to the moisture content of the soil with a linear correlation with R = 0.98.
2. Shrinkage Limit is directly proportional to the Liquid Limit of the soil with a linear correlation with R = 0.78.
3. Shrinkage Limit is directly proportional to the Plasticity Index of the soil with a linear correlation with R = 0.89.
4. Void Ratio is directly proportional to the Maximum Dry Density of the soil with a linear correlation with R = 0.81.
5. Swell percentage is inversely proportional to the Unsoaked California Bearing Ratio of the soil with a negative linear correlation with R = 0.88.
6. Swell percentage is inversely proportional to the Soaked California Bearing Ratio of the soil with a negative linear correlation with R = 0.93.
7. Swell percentage is inversely proportional to the Unconfined Compressive Strength of the soil with a negative linear correlation with R = 0.21.

V. ACKNOWLEDGMENTS

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