Strength Gain of Organic Soil Deposits Subjected to Increase in the Effective Stress

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ABSTRACT

Organic soil has weak shear strength properties in its natural texture. However, a significant gain in strength can be achieved in such soils by increasing the effective stresses using preloading techniques. This research focuses on the organic soil deposits in Sri Lanka by analyzing the data from Colombo-Katunayake Expressway (CKE) project and Elevated Highway (EH) project spanning from New Kelani Bridge to Athurugiriya. As a developing country, Sri Lanka is facing a huge challenge due to its limited land available towards the infrastructure development. Therefore, construction should also be directed on organic soils despite of considering its weak shear strength properties as the soil can be modified to enhance its properties. To predict the strength gain of organic soils subjected to effective stresses, empirical correlations are used such as Skempton and Bjerrum equation (1957). As depicted in such correlations, the ratio of undrained shear strength and effective overburden pressure is observed against the Plasticity Index (PI) using field data. From the results of the analysis, it is discovered that using empirical correlations is very conservative for organic soils within the Sri Lankan context. Particularly, use of empirical correlations is very safe but beyond the economic considerations. In the extension of the research, an argument is generated to validate the use of PI to predict normalized shear ratio. To validate the argument, SPSS statistical software was used to perform the multiple regression analysis having PI, natural void ratio and organic content as the independent variables. From the statistical analysis, it was found that using only PI to predict the strength gain is not conservative for Sri Lankan organic soils subjected to effective stresses. These generated results are identical to conclusions drawn governing the inorganic soils in the state of Missouri (2011).

KEYWORDS: *Shear Strength, Plasticity Index, Organic Soil, Sri Lanka, Colombo Katunayake Expressway, Elevated Highway, Effective Stress*

1 INTRODUCTION

In many developing countries like Sri Lanka, infrastructure development plays a crucial role due to the growth of population. Nevertheless, the limited land availability in those countries demands the construction to be implemented despite of considering about the soil condition. Therefore, soils having identity to organic soil deposits such as peat should be treated and improved to be utilized in infrastructure development.

In comparison to the mineral soils, organic soils have widely varying properties such as high void ratios, high moisture content, high compressibility, and low permeability (Baker et al., 1988). Dealing

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with such soils is a great risk in the field of construction since there is a possibility of geotechnical failure due to their weak shear properties. The weak natural texture of organic soil deposits can be significantly improved using chemical stabilizers but, it cannot be accepted for a developing country like Sri Lanka due to higher cost of implementation. Therefore, remedying methods such as application of effective stresses on soils by preloading techniques can be defined as a sustainable option in terms of economical and serviceability aspects. When the effective stress on the organic soil deposits is increased, pore water from the voids will be dissipated vertically leading to gain in shear strength of the soil. However, due to low permeable properties of the organic soils, the densification by pore water dissipation will be a time-taking process and in such a case, introducing Prefabricated Vertical Drains (PVD) is helpful to increase the rate of pore water dissipation.

Due to the weak soil texture of organic soil deposits at its fundamental stage, a special attention should be enforced when predicting their strength for the industrial applications. According to the current practice in the Sri Lankan industry, the empirical equations such as Skempton and Bjerrum (1957) are widely used to predict the strength gain of organic soil deposits subjected to effective stresses. They are mainly focused on evaluating the undrained shear strength of the soil using the Plasticity Index (PI). Use of such empirical correlations directly in the presence of Sri Lankan organic soil is a fact to open the third eye since they were originated in bottom-up environmental and soil conditions. In addition to the Skempton and Bjerrum equation, Table 1.1 shows some of the existing relationship which were introduced by assessing the relationship of strength gain in organic soil deposits.

Table 1.1 Some Published Empirical Correlations for Strength Gain Predictions

Equation	Reference	Remark
$\frac{S_u}{\sigma_v'} = 0.11 + 0.0037PI$	(Skempton and Bjerrum, 1957)	NC Clay
$\frac{S_u}{\sigma_v'} = 0.11 + 0.0037PI$	(Chandler, 1988)	OC Clay
$\frac{S_u}{\sigma_v'} = 0.129 + 0.00435PI$	(Worth and Houlsby, 1985)	NC clay
$\frac{S_u}{\sigma_v'} = 0.11 + 0.0037 logPI$	Kempfert and Gebreselassie, 2006)	NC soil, PI < 60%
$\frac{S_u}{\sigma_v'} = 0.23 \pm 0.004$	(Larsson, 1980)	Soft Sediment Clays, PI < 60%
$\frac{c_u}{\sigma_v'} = 0.45(\frac{I_p}{100})^{0.5}$	(Bjerrum and Simons, 1960)	NC Clays

Where,
Su = Undrained Shear Strength
σ_v' = Effective Overburden Stress
PI = Plasticity Index

Under the normally consolidated state, the initial stability of the soil is critical due to low undrained shear strength of the organic soil deposits. Edil et al. (2000) presented his journal to estimate the strength parameters of organic soils compared to the inorganic soils and to quantify the undrained behavior of such soils under normally consolidated and over consolidated states. For the estimation, he used triaxial test, consolidated undrained (CU) test, and a special consolidation cell to estimate the coefficient of lateral pressure at rest (k_0). From the results, Edil et al. (2000) stipulates that, compared to inorganic soils, organic soils have a lower k_0 value hence, the stability of the soil at the natural state is comparatively low. Further, he revealed that even though the organic soils are supposed to behave like a "drained" soil due to higher porosity and hydraulic conductivity, it will be rapidly converted to "undrained" when it is subjected to an increase in the effective stresses. Therefore, he further extended his research to analyze the behavior of such soils under effective stresses by estimating the normalized undrained strength for normally consolidated soils carrying the organic content as the independent variable. The results indicate that, unlike in CU test, the normalized undrained shear strength of a soil does not vary with the organic content, type of soil and level of consolidation. Edil et al. (2000) concludes his research showing that, compared to inorganic soils, a significant strength gain can be achieved on organic soil deposits by pre-loading the ground. Colleselli et al. (2000) contributed to establish the same conclusion made by Edit et al. (2000) by evaluating the compression characteristics of soils. For the analysis, he extracted soil with peaty characteristics from three locations of Northern Adriatic Coast, Italy representing normally and over consolidated states. The samples were subjected oedometer test by varying the load increment ratio and the results stipulates that, the soil samples in the over consolidated state have a significantly lower secondary consolidation settlement than the normally consolidated sample. Hence, it can be identified that, pre-loading can significantly enhance the soil strengthening properties.

However, Edil et al. (2000) and Colleselli et al. (2000) both failed to identify the field behavior of soft soils whereas Hussein (2000) addressed. He has tested the soft soil behavior of embankments in Kuala Perlis, Malaysia under two construction rates : South embankment at a slow construction rate and the North embankment at a rapid construction rate which are identical to each other in dimension. The settlement of each embankment was monitored using settlement gauges. From the results, Hussein (2000) concluded that the field behavior of both the embankments were identical, and differences were noted due to construction techniques and rate of construction. He did the test without using any ground improvement techniques. Hence, according to the strength parameters he obtained, it can be identified that higher strength of such soils is achievable from ground improving techniques such as pre-loading and step-loading.

Pre-loading leads the organic soils to consolidate and achieve significant gain in strength from its weak soil texture. Preloading can be applied as a fill, as a vacuum preload or as a combined fill and vacuum load. To predict the improvement of soft soils, coefficient of consolidation can be tracked either by monitoring the pore water pressure dissipation or by monitoring the settlement. The general equation used to estimate the coefficient of consolidation suggested by Terzaghi and Barron cannot regain accurate predictions as they assume coefficient of consolidation in the horizontal and vertical direction as constant which are not constants to a soft soil under practical considerations (1948). The tests were conducted to check the effectiveness of fill surcharge, vacuum load, and combined method. To predict the improvement, monitoring the degree of consolidation was used in the tests which demanded to find the ultimate settlements. However, the usual practice of predicting the ultimate settlements using the oedometer test was found to be not very reliable hence, the prediction was done by field settlement monitoring data. As a result, Chu et al. (2012) found that even though the surcharge application from a fill can achieve a significant shear strength gain in soft soils, it is a time-consuming process compared to vacuum loading. But, under vacuum loading, a maximum of 80kPa can be applied hence, if the desired surcharge is more than 80kPa vacuum preloading is not a viable option. Combined fill and vacuum load method addresses these problems, and it can improve the shear properties of soft soil in a comparatively lesser time span. In conclusion, it was identified that among the proposed methods to apply a preload on soft soils, combined method is the most viable option. Also, Perforated Vertical Drain (PVD) installation was found to be accelerating the pore water dissipation further.

This extensive study is mainly focused on identifying strength gain predictions by assessing the relationship between Normalized Shear Ratio (NSR) vs Plasticity Index (PI). According to the published correlations, they exhibit a linear relationship as depicted in Table 1.1. To examine the validity of published empirical correlations for inorganic soils in the state of Missouri, Kang et al. (2011) assessed the inorganic soil data from several sites within the state to observe their field behavior. He collected soil samples from Warrensburg, New Florence, Set. Charles and Hyati (Pemiscot) representing three out of four geological zones in the Missouri, United State. With the contribution of sample data from 10 boreholes, statistical analysis was performed, and the results show that, St. Charles and New Florence site behave non-linearly even though Warrensburg and Pemiscot behave linearly as depicted from Figure 1.1-1.4. Data dispersion in the scatterplots generated by Warrensburg and Pemiscot were distributed widely on the plot hence, it produced a low coefficient of correlation and St. Charles and New Florence resulted in polynomial correlations with mid-range coefficient of correlation. The generated results were compared with the back calculated values from the published empirical correlations and the values from the empirical correlations were lesser than those that were obtained from the field analysis. Therefore, he established that the use of empirical correlations is conservative.

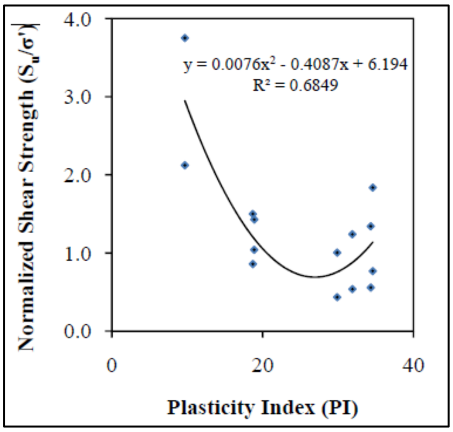

Figure 1.1 NSR vs PI of Warrensburg site

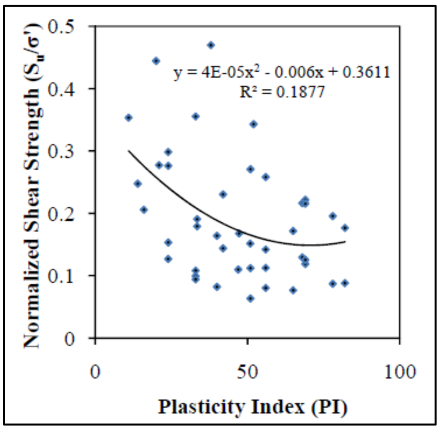

Figure 1.2 NSR vs PI of St. Charles site

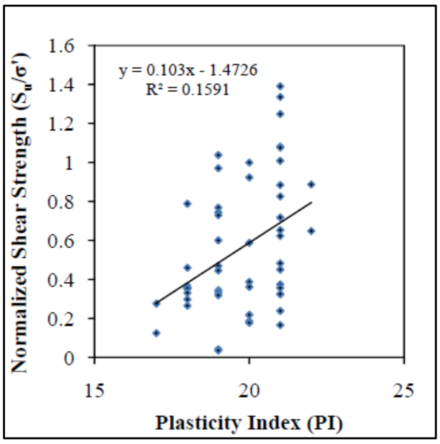

Figure 1.3 NSR vs PI of New Florence site

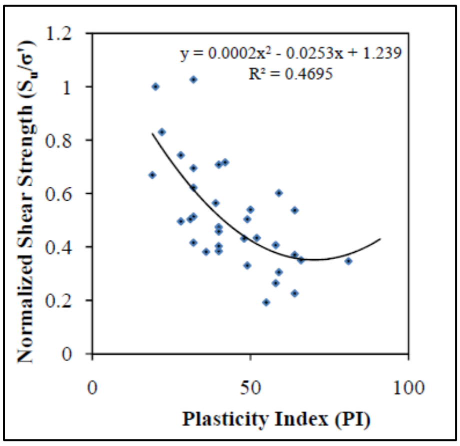

Figure 1.4 NSR vs PI of Pemiscot site

Further, he assessed the spatial correlation of data sets by considering the soil types from all the sites to increase the sample size. According to the results generated by Kang et al. (2011) in his journal, MH and CL soil types were shown a second order polynomial relationship and for CH, it was linear (refer table 2.1). Based on the above results and observations, it has been concluded that there is no uniform correlation to explain the behavior between S_u and PI. Further, it is also concluded that, using PI only to predict S_u is not reliable.

As explained by Kang et al. (2011) for inorganic soils in the state of Missouri, it should be accepted that the published co-relations were derived under different environmental and soil conditions hence, their applicability within the local context should be validated. Having that in the research problem, this research is conducted to address the question of using empirical correlations within the Sri Lankan context and to identify their drawbacks for the Sri Lankan organic soils.

In this research, the strength gain of organic soil deposits subjected to increase in the effective stresses is tackled by observing the behavior of Normalized Shear Ratio (NSR) and Plasticity Index (PI). To contribute a strong argument as research output, data is analyzed from two sites in the Sri Lankan context which are Colombo-Katunayake Expressway (CKE) project and Elevated Highway (EH) project. CKE project was constructed on marshy and waterlogged land plot linking the Katunayake international airport with Colombo through a 25.8km run. Construction of embankments over soft soils such as organic soils, peat, and clay is one of the major challenges encountered in the CKE project (Hsi et al., 2015). Same as the CKE project, EH project which spans from new Kelani bridge to Athurugiriya is also constructing over organic soil layers hence, this research governs both the sites to make a strong conclusion about the strength gain prediction of Sri Lankan organic soil deposits subjected to effective stresses.

2 METHODOLOGY

Initially, the pre-construction and post-construction data were extracted from the borehole logs of Colombo-Katunayake Expressway (CKE) project. Based on the availability of data, raw data of 10 borehole locations were contributed for the analysis. Among the extracted data, Plasticity Index (PI), Organic Content (OC), Plastic Limit (PL), Liquid Limit (LL), natural void ratio, unit weights of the soil layers (dry unit weight, bulk unit weight) and shear strength properties of organic soil layers (friction angle, cohesion) were prominent to proceed with the analysis. Sample depths of organic soil layers which had PI greater than 100 were omitted from the analysis by considering them as theoretical outliers (Kaliakin, 2017).

The following equations were used when calculating the saturated unit weight (γ_{sat}) of the soil layers and topsoil properties. For the calculations of the topsoil properties, energy method proposed by Bowles (1997) were used as shown below.

$$\gamma_{sat} = \gamma_{dry} + \left(\frac{1+e_o}{e_o}\right)\gamma_w \quad (1)$$

$$C_N = \sqrt{\frac{95.76}{p_o'}} \quad (2)$$

$$\eta_1 = \left(\frac{E_r}{70}\right) \quad (3)$$

$$N_{70}' = N_{field} C_N \eta_1 \eta_2 \, \eta_3 \eta_4 \quad (4)$$

Where,
C_N = Overburden Correction Factor
p_o' = Effective Overburden Pressure at the Test Depth
E_r = Energy Ratio of the Standard Penetration Test (SPT) Set Up
N_{field} = Field SPT-N Value
N_{70}' = Corrected SPT-N Value
η_1, η_2, η_3, η_4 = Correction Factors

The Bowles (1997) method was used to calculate the wet unit weight (γ_{wet}) of the coarse sand layers at the top of the soil profile and a conservative value of 3.5kN/m^3 was added to obtain the saturated unit weight (γ_{wet}) (British Standards Institution, BS 8002:1994 – Code of Practice for Earth Retaining Structures).

To initiate the analytical procedure, the dependent and independents were identified as follows.
Dependent Variable – Normalized Shear Ratio (NSR)
Independent Variables – Plasticity Index (PI), Organic Content (OC), natural void ratio (e_o), Liquid Limit (LL), Plastic Limit (PL)

Among the above variables, the behavior represented by NSR, and PI was taken as the emerging pair as the same relationship was checked in most of the empirical correlations for the strength identifying applications. The empirical correlations shown in Table 2.1 was chosen from the depicted relationships in Table 1.1 to compare the scatter generated by the field data from due to its wide use in the Sri Lankan context and their relevancy to the Skempton and Bjerrum equation (1957).

Table 2.1 Summary of the Correlations

Empirical Correlation	Equation
Skempton and Bjerrum (1957)	$\frac{S_u}{\sigma_v'} = 0.11 + 0.0037PI$
Bjerrum and Simons (2006)	$\frac{S_u}{\sigma_v'} = 0.45(\frac{PI}{100})^{0.5}$
Worth and Houlsby (1985)	$\frac{S_u}{\sigma_v'} = 0.129 + 0.00435PI$

Followed by the analysis of the field behavior with the existing empirical correlations, statistical analysis was conducted using SPSS statistical software. It was used to establish the arguments generated from the analysis of field data. In the outset of the statistical analysis, the reliability and validity of the data set was checked by evaluating the Cronbach's alpha referring the results to the following scale.

After checking the normality of the data dispersion using histograms of variables, correlation analysis was conducted to evaluate the relationship between each independent variable with the dependent variable. The strength of the relationship was measured using the Pearson correlation coefficient (R) and the following scale was used in parallel.

To ensure the relationship between the selected independent variables for the statistical analysis is minimum, multi-collinearity tests were conducted. The test was done following two main criteria in particularly by assessing the Pearson coefficient, tolerance, and Variance Inflation Factor (VIF). For higher degree of multi-collinearity effect, R should be higher than 0.79, tolerance not lesser than 0 and not higher than 0.2 and the VIF higher than 5.

After confirming the independency of the independent variable using multi-collinearity tests, multiple regression analysis was performed. In the multiple regression analysis, the statistical outliers were checked by assessing the standard residual of the data set. Thereafter, the linearity of the plot and the scatter was observed to identify the behavior of the variables and their data dispersion in a scatterplot. The model summary for the data tool was generated to evaluate the Durbin-Watson value and the R square value to identify the interest of the independent variables to the dependent. Finally, the coefficient summary was generated to observe the significance of the independent variables. According to (Pallant, 2020), significance beyond the limit of 0.05 was expected to be strict with the argument.

Finally, to represent the reliability of the generated results in a different site condition, the pre-construction data of Elevated Highway (EH) Project was contributed to the research. The chart shown in Figure 2.1 shows a graphical representation for the methodology executed in the research.

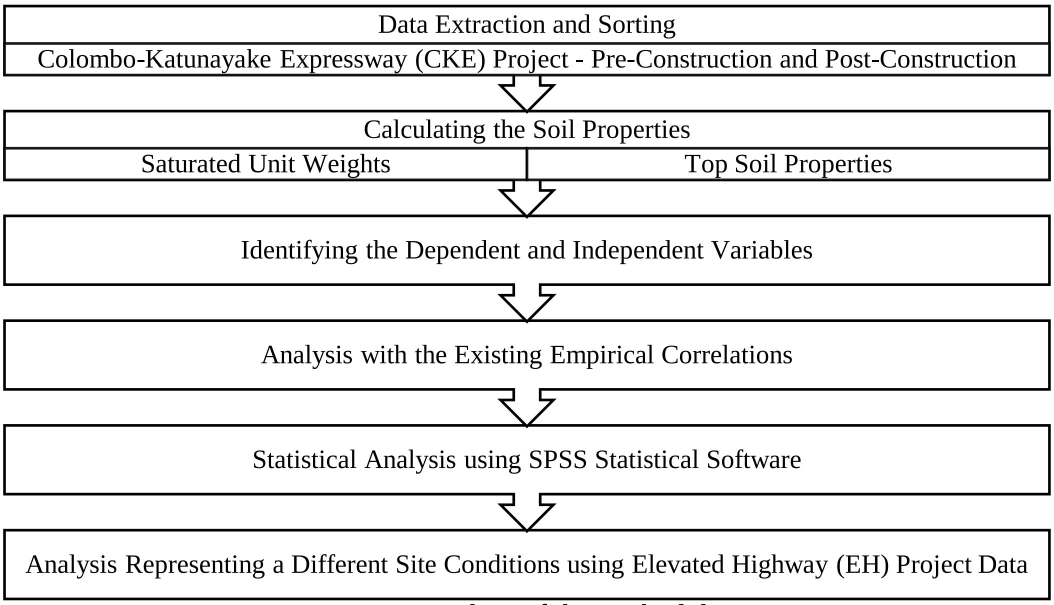

Figure 2.1 Chart of the methodology

3 RESULTS

Initially, the pre-construction data of Colombo Katunayake Express (CKE) project used to identify the behavior of the data set by observing the scatterplot of Normalized Shear Ratio (NSR) vs Organic Content (OC). As shown in Figure 3.1, two distinct phases of the data set were identified as 0-32% and 39-55% in terms of the OC. The research was mainly conducted on the OC range 0-32% since a typical OC in the Sri Lankan Context lies below 50% (Karunawardena et al., 2011).

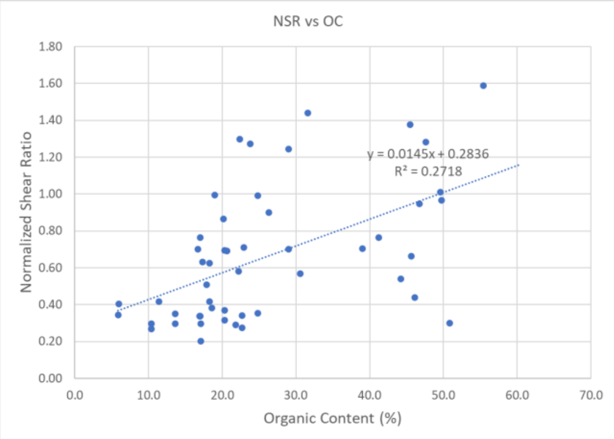

Figure 3.1 NSR vs OC graph

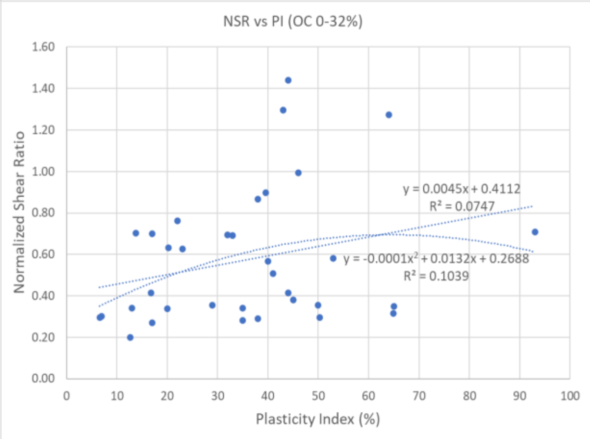

Figure 3.2 NSR vs PI graph in 0-32% OC range

When observing the behavior of NSR vs Plasticity Index (PI), the non-linear behavior was also observed since Kang et al. (2011) discovered non-linear behavior of inorganic soils in the state of Missouri. To identify the field predictions along with the widely used empirical correlations, back calculated values of the empirical correlations were compared, and according to Figure 3.3, it was identified that the prediction of the field are considerably higher than the prediction generated by the empirical correlations. The post-construction data of CKE project also generates the same results. To validate the results further, Elevated Highway (EH) project data were also used to check their NSR vs PI behavior with the empirical correlations. The results further established the results generated from the CKE project.

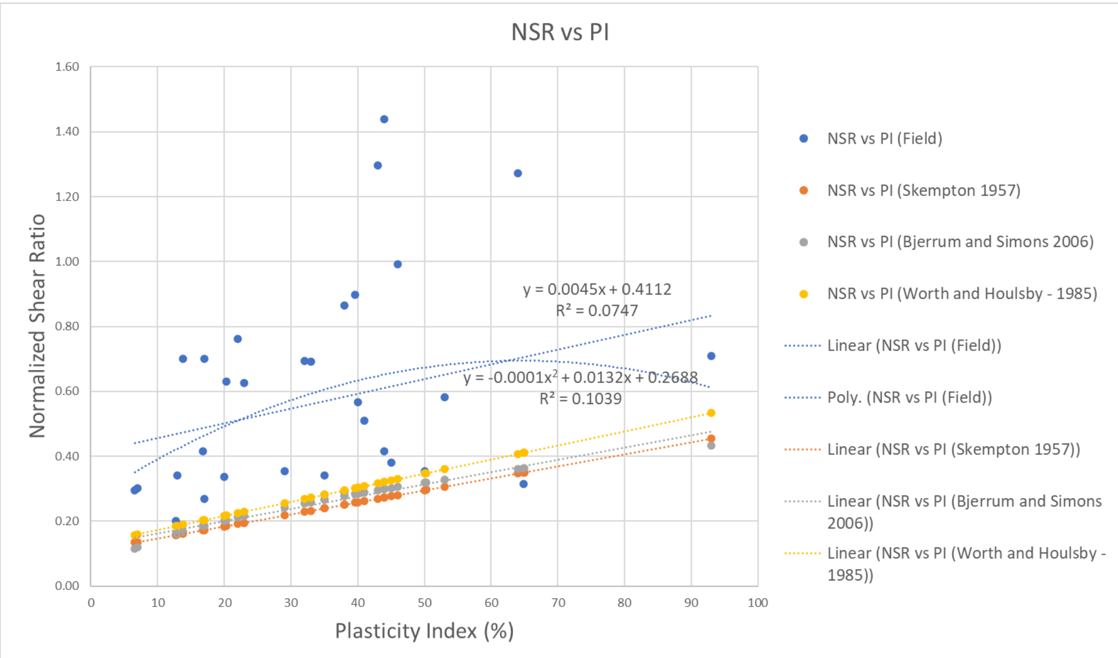

Figure 3.3 NSR vs PI field with empirical correlations – CKE Pre-Construction

The research was further extended to identify the applicability of using only PI to predict the strength gain predictions in compliance to the current practice in the industry. To serve the purpose, SPSS statistical software was used by feeding pre-construction data of CKE project. Initially, the reliability and validity of the data sets were checked by evaluating the Cronbach's alpha (α). According to the generated results, α was 0.778 with a significance of 0.778. Further, the normality of the histograms was checked, and the results exhibit that the data dispersion is normal.

After identifying the reliability and normality of the inserted data, correlation analysis was performed using NSR as the dependent and PI, OC, e_o, LL, PL as the independence variables.

Table 3.1 Summary of the Correlations

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.148	.126		1.175	.247
	Plasticity Index (%)	.002	.003	.118	.681	.500
	Organic Content (%)	.007	.007	.205	.979	.334
	Natural Void Ratio	.070	.050	.341	1.413	.166
a. Dependent Variable: Normalized Shear Ratio						

As depicted in Table 3.1, it was identified that the correlation between NSR and all the independent variables have moderately strong Pearson correlations. Furthermore, the inter-correlation matrix was evaluated in the multi-collinearity test to identify the relationship between the independent variables. As shown in Table 3.2, the Pearson Correlation Coefficient in the inter-correlation matric is lesser than 0.9 hence, the risk multi-collinearity is low. Further, the tolerance and the Variance Inflation Factors (VIF) were evaluated, and the results depicted for the favor of lower degree of multi-collinearity.

Table 3.2 Summary of the Inter-Correlation Matrix

Independent Variable 1	**Independent Variable 2**	**Pearson Correlation**
Plasticity Index (%)	Organic Content (%)	0.513
Organic Content (%)	Natural Void Ratio	0.591
Natural Void Ratio	Plasticity Index (%)	0.837

In the outset of the multiple regression analysis, the data set was checked for any statistical outliers and the results exposed that there were not any statistical outliers since the minimum and maximum standard residual lied between -3.29 and +3.29. After confirming the plot does not have any statistical outliers, model summary was generated to evaluate the R square value. From the results generated, it was identified that only 36.3% of the variants in the NSR predicted from the independent variables. Also, the significance ($P > 0.05$) of the coefficient summary shown in Table 3.3 exhibits that the variables are not making unique contribution to the prediction of dependent variable.

Therefore, it is proved that from the statistics, using PI only to predict the strength gain of organic soil deposits within the Sri Lankan context is not conservative.

Table 3.3 Summary of Coefficients

Correlations							
		Normalized Shear Ratio	Plasticity Index (%)	Organic Content (%)	Liquid Limit (%)	Plastic Limit (%)	Natural Void Ratio
Normalized Shear Ratio	Pearson Correlation	1	.457**	.538**	.505**	.483**	.583**
	Sig. (2-tailed)		.002	.000	.001	.001	.000
	N	43	43	43	43	43	43
**. Correlation is significant at the 0.01 level (2-tailed).							

4 DISCUSSION

To demonstrate the behavior of strength gain predictions, Normalized Shear Ratio (NSR) vs Plasticity Index (PI) scatterplot was drawn from the field data of pre-construction stage of CKE project. NSR was used as the dependent variable of the research to predict the strength gain of organic soil deposits subjected to increase in effective stresses. The rational to use NSR as the dependent variable was, as it represents the ratio between undrained shear strength (S_u) and effective overburden pressure ($\sigma_v{}'$), it is not vulnerable to the effect of $\sigma_v{}'$ fluctuations. The comparison between the field behavior of NSR vs PI with the back calculated values of empirical correlations articulates the fact that the NSR predictions are much lower than the regression line generated from the field observations (Figure 3.3). Therefore, a soft conclusion can be made as "using empirical correlation is very safe but not economical for Sri Lankan organic soils".

To establish the soft conclusion further, post-construction data of CKE project was contributed to the research, and it also generated the same results obtained using the pre-construction data as, using empirical correlations for organic soil deposits is conservative. However, a proper conclusion cannot be drawn only from the site investigation data from a single project. At the outset of the research, it was anticipated to use a machine language to predict the validity of the soft conclusion, but getting a reliable result was a problem due to the lower amount of complete data sets presented in the data logs. Therefore, Elevated Highway (EH) project which spans from New Kelani Bridge to Athurugiriya was blended to the research to ensure the same results in a different site condition. As shown in Figure 4.1, it also contributed to the same conclusion that was drawn from the CKE project as it generated the regression line explicitly above the predictions from the empirical correlations. Therefore, it can be identified that using the empirical correlations to predict the strength gain of organic soil deposits within the Sri Lankan context is very safe but beyond not economical.

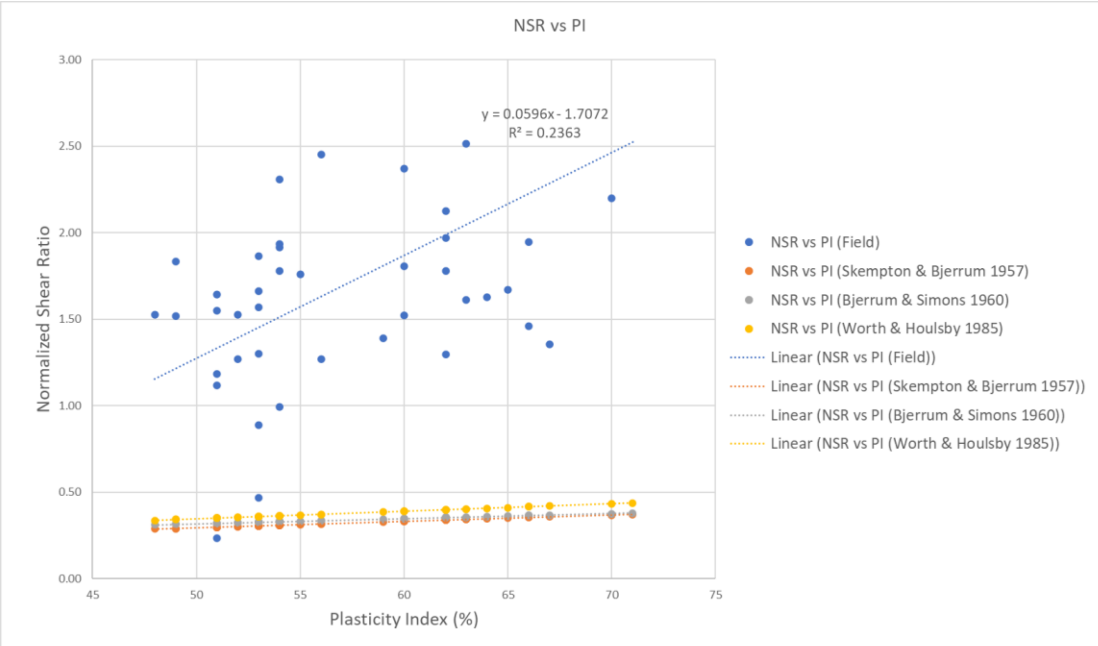

Figure 4.1 NSR vs PI field with empirical correlations – EH project

Kang et al. (2011) has observed the same behavior using inorganic soil samples representing four site conditions in the state of Missouri, United States and he has generated the same results as obtained in this research addressing inorganic soil deposits. In his conclusions, he stipulates that the strength gain predictions of inorganic soils in the state of Missouri are significantly below the regression line generated using the field data and hence, use of empirical correlations are conservative. The same conclusion is drawn for organic soil deposits addressing two site conditions in the Sri Lankan context. In addition, Kang et al. (2011) discovered that for St. Charles and New Florence sites, the NSR vs PI behavior was non-linear hence, when conducting this research for organic soils, the non-linear behavior has also checked by assessing the Pearson correlation coefficient. However, it was discovered that the behaviors are linear as it generated a good correlation in terms of the Pearson coefficient as shown in Table 3.1.

The research was extended to an extensive statistical study to identify the validity of PI to predict the empirical correlations. To serve the purpose, the data sets extracted from the pre-construction stage data logs were inserted to SPSS statistical software having NSR as the dependent variable and PI, LL, PL, OC and e_o as the independent variables. Before proceeding with the descriptive statistics, an argument was made to run throughout the statistical analysis as "using PI only to predict the strength gain of organic soil deposits within the Sri Lankan context is not conservative". Under this argument, it was anticipated to perform the multiple regression analysis but to influence the reliability and accuracy of the conclusions, several tests were conducted before proceeding with the multiple regression analysis. As presented in the results, the data sets fed into the software were reliable since the Cronbach's alpha value is 0.778 and the significance is less than 0.005 according to the F value test in the ANOVA table. Therefore, the internal consistency requirements were satisfied to give credible results from the analysis.

According to the correlation summary shown in Table 3.1, all the independent variables seem to have a positive and strong correlation with the dependent variable (NSR) since the Pearson correlation coefficient lay nearly 0.5. To ensure the correlation between the independent variables are minimum, multi-collinearity tests were conducted governing two criteria. However, before the conductance of the test, LL and PL were omitted from the analysis since those independent variables explain another independent variable which is the PI [PI = LL-PL]. From the multi-collinearity test results, it can be concluded that the independent variables consist with a low risk of multi-collinearity. The generated tolerance and VIF values support the same conclusion by resulting that, there is a lower degree of multi-collinearity effect in the analysis.

Finally, to address the argument, multiple regression analysis was performed. The coefficient summary illustrated in Table 3.3 shows that the significance of PI to explain the dependent variable

(NSR) is greater than 0.05. According to Pallant (2020), generating a significance greater than 0.05 means that the variable is not making a unique contribution to predict the NSR.

Kang et al. (2011) has concluded his research with the same conclusion in which, using PI only to predict S_u is not reliable by evaluating the spatial correlation of inorganic soil types collected from the state of Missouri, United States. He further established that there are many factors that influence on the strength gain prediction thus, abiding with PI is not very reliable. Same as that, this research conducted using organic soil deposits subjected in increase in effective stresses drawn the similar conclusions. From the model summary depicted in Table 3.3, it explicitly identified that the selected independent variables represent the dependent variable only 36.3%.

Despite of relying only on PI to predict the strength gain of organic soils, there are many other factors which explain the shear strength of soils. According to Trauner et al. (2005) and Matsuo & Shogaki (1988), ground water table, geological condition, sample disturbance, clay content has a significant effect on the prediction of S_u. The fluctuation of shear strength of organic soils was not addressed in this research and hence, it is recommended to include these variables and investigate further on this research area.

Limitations

In this research, some of the data used in the analysis of CKE project were obtained from the direct shear test results. Therefore, the results may have been subjected to slight fluctuations due to the sample disturbance and errors which are possible during the test conductance.

The density data related to the backfill layers were lacking hence, the energy method proposed by Bowles (1996) was used based on the field SPT N values. Also, the borehole logs for unavailable chainages were chosen from the vicinity of the selected chainage. However, the results are still conservative since the ground profile deviation for 100m is not very accountable.

Lack of data to perform the cross-validation analysis from python is a limitation faced in the research and further investigation on sites in the Sri Lankan context are encouraged to validate using machine language.

5 CONCLUSION

It is necessary to check the reliability of the empirical correlations used within the Sri Lankan context since they are originated under the foreign environmental conditions. In this extensive study, Colombo-Katunayake Expressway project (CKE) and Elevated Highway (EH) project data are contributed to identify the behavior of strength gain predictions by assessing the relationship between Normalized Shear Ratio (NSR) and Plasticity Index (PI). To make the analysis reliable, SPSS Statistical software was used to ensure the validity of using only PI for the strength gain predictions.

The empirical correlations currently practicing in the domestic industry rely only upon the PI value to predict the strength gain in organic soil deposits. With reference to that, analysis using the empirical correlations and field relationship between NSR and PI shows that, using such relationships are very safe but beyond the economical limits. From the descriptive statistics, the inter-correlation matrix explicitly shows that there are other independent variables such as natural void ratio (e_o), Organic Content (OC) that make strong correlations with NSR. Hence, the use of PI alone for the strength gain predictions cannot be validated for Sri Lankan organic soil. Therefore, to predict accurate strength gain predictions for organic soil in the domestic constructions encountering both safe and economical aspects, further investigations are demanded while concerning the contribution of the other index soil properties.

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