APPRAISAL OF SENSITIVITY CORRELATIONS ON DATA FROM CLAYS OF WESTERN INDIAN OFFSHORE

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ABSTRACT: Sensitivity (S_t) of cohesive soils is defined as the ratio of peak undisturbed shear strength (s_u) to the remoulded shear strength (s_{ur}) at the same water content. In offshore geotechnics, sensitivity is an important design parameter for clays especially where strength of remoulded clays is an important input in foundation analysis and design e.g. in design of some anchors in deep waters, assessment of lateral and vertical pile capacity in the zone disturbed by jack-up spudcan penetration. In many instances in offshore projects, results of laboratory or field tests for remoulded shear strength of clays are not available and in such cases empirical correlations are used which correlate either the remoulded strength or the sensitivity directly with other index parameters measured or derived in laboratory. Presently such correlations have not been derived or investigated for the fields of western Indian offshore and the available correlations in literature may not be applicable for the clayey soils of Western Indian Offshore. This paper discusses the results of evaluation of published correlations, for the soil data from top 30 m of soil profile from various fields of Western Indian Offshore. Results of attempts to develop new correlations for the specific application for the soils of Western Indian offshore are also presented.

KEYWORDS: Sensitivity, Remoulded Shear strength, Correlations

1 INTRODUCTION

Sensitivity (S_t) is defined as ratio of peak undisturbed shear strength (s_u) to the remoulded shear strength (s_{ur}) at the same water content.

In offshore geotechnics, sensitivity is an important design parameter for clays especially where strength of remoulded clays is an important input in foundation analysis and design e.g. in design of some anchors such as suction and drag anchors in deep waters, assessment of lateral and vertical pile capacity in the zone disturbed by jack-up spudcan penetration.

There are a number of tests in practice for the measurement of remoulded shear strength both in laboratory and in the field. Miniature (motorised) Vane and fall cone test are the most commonly used laboratory tests for the purpose of soil investigation in Western Indian offshore.

In many instances in offshore practice worldwide, results of laboratory or field tests for measuring the remoulded strength of clays are not available and in such cases empirical correlations are used which correlate either the remoulded strength or the sensitivity directly with other index parameters measured in laboratory or parameters measured by Cone Penetration Test (CPT) or Piezocone Penetration tests (CPTU).

Presently such correlations have not been derived or investigated for western Indian offshore soils.

In the present paper, the available published correlations are evaluated for the soils from various fields of Western Indian Offshore. Efforts made to develop new correlations for the area of Western Indian Offshore, are also presented.

The results of this project will help in deriving sensitivity of clays during the soil investigations, where remoulded shear strengths are not available. The results will also be used as a check where the test results are available.

2 SELECTED CORRELATIONS FOR INVESTIGATION

The following correlations were investigated for the western Indian offshore data:

2.1 Wroth and Wood (1978)

$$s_{ur} = 170 \exp^{(-4.6 I_L)} \quad (1)$$

Where, s_{ur}= remoulded undrained shear strength
I_L = Liquidity index of the soil

2.2 Leroueil et al. (1983)

$$s_{ur} = {}^{1}/_{(I_L - 0.21)^2} \quad (2)$$

2.3 NGI (2002)

$$s_{ur} = 4.2(I_L)^{-1.6} \quad (3)$$

2.4 Ramsay (2002)

$$s_{ur} = 2/3 f_s \quad (4)$$

Where f_s = measured value of sleeve friction from CPTU

2.5 Bjerrum (1954)

Bjerrum proposed a relationship between Sensitivity and Liquidity Index for Norwegian marine clay.

$$S_t = 10^{(0.15+0.73I_L)} \quad (5)$$

3 THE DATA

The soil data used in this study have been taken from ONGC's recent Soil Investigation Projects for 27 locations from 8 different Fields of Western Indian Offshore. The selected data are from the top about 30.0 m of soil profile at each location.

The basic intact and remoulded strength data for MV tests are from tests performed on-board the geotechnical vessel. The data for fall cone are from laboratory tests performed at IEOT laboratory. Other laboratory tests data i.e. water content; liquid limit and plastic limit, at specific depths have been taken from tests performed at IEOT laboratory. CPTU parameter sleeve friction, also taken from the background data of soil investigation reports for the study.

4 EVALUATION OF CORRELATIONS

Figures 1 and 2 show the evaluation of the correlations by Wroth and Wood (1978) and Ramsay (2002) using s_{ur} values determined in the laboratory by the Miniature vane test plotted against the corresponding I_L and CPT f_s respectively.

Figure 3 shows the evaluation of the correlation proposed by Bjerrum (1954); using Sensitivity (S_t) values (determined from laboratory Miniature vane test) plotted against the corresponding I_L values. The corresponding correlations are also plotted on the figures for comparison.

From the figures, it is clear that the data are scattered and correlations do not predict well for the western offshore Indian clays. The other existing correlations evaluated using both Miniature vane and Fall Cone data also did not fit the data well.

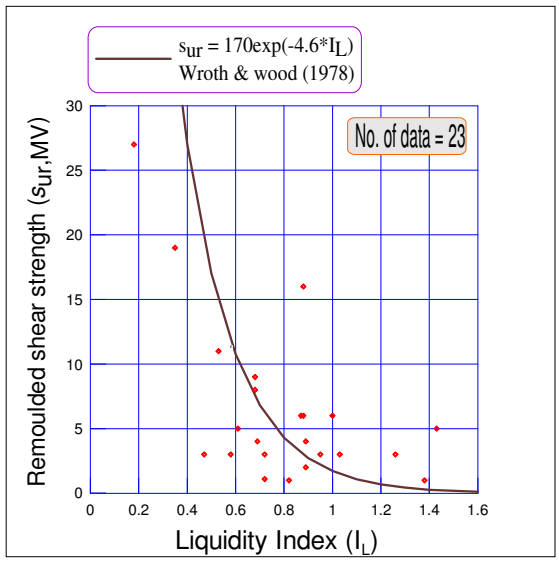

Fig. 1 Evaluation of correlation for Remoulded shear strength by Wroth & wood (1978) for the soil data from western Indian Offshore (Miniature Vane)

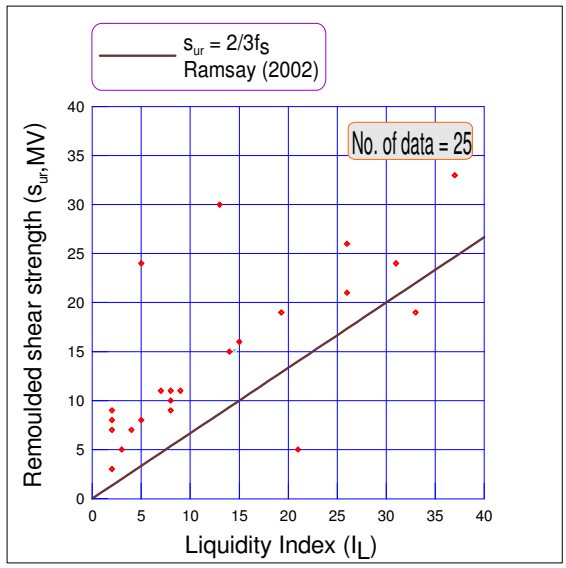

Fig. 2 Evaluation of correlation for Remoulded shear strength by Ramsay (2002) for the soil data from western Indian Offshore (Miniature Vane)

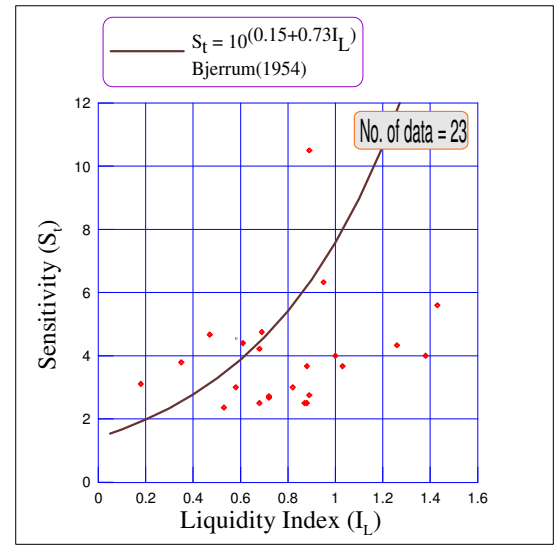

Fig. 3 Evaluation of correlation for sensitivity by Bjerrum (1954) for the soil data from western Indian Offshore (Miniature Vane)

5 REGRESSION ANALYSIS

Regression Analysis is a statistical process for the investigation of relationships between variables. It includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent (response) variable and one or more independent variables. So, the output of a Regression Analysis is a function that predicts the dependent variable based on independent variables.

Since the predictions by the available published correlation are not very good for the fields of western Indian offshore, development of some new correlations was attempted using Regression Analysis.

Simple Regression Analyses were performed between remoulded shear strength / sensitivity and the Index parameters measured in the laboratory and CPTU measured parameters.

The results of the regression analyses are presented in Table 1. Results which show reasonable strength of correlations only are included in the table.

Table 1 Results of regression analyses

Equation	Results of regression Analysis	n	R^2	S.E.
A	$\log_{10}(s_{ur,MV}) = 2.219 - 1.717\left(\frac{w}{w_L}\right)$	17	0.691	0.2016
B	$\log_{10}(s_{ur,MV}) = 3.359 - 4.694\left(\frac{w}{w_L}\right) + 1.624\left(\frac{w}{w_L}\right)^2$	17	0.724	0.1975
C	$s_{ur,MV} = 2.254 + 0.6191(f_s)$; (kPa)	144	0.685	2.930
D	$s_{ur,FC} = 5.211 + 0.6421(f_s)$; (kPa)	25	0.894	2.63

Note: n is number of data points, R^2 is Coefficient of Determination, S.E. is Standard Error, w = natural water content, w_L= water content at liquid limit, $s_{ur,MV}$= Remoulded shear strength from Miniature vane test, $s_{ur,FC}$= Remoulded shear strength from Fall cone test

6 DISCUSSION

Due to paucity of space only equation D (refer table 1) along with the data is presented in Figure 4, being the strongest correlation statistically. It can be seen that the equation predicts the remoulded shear strength reasonably well although the number of data points are low and some

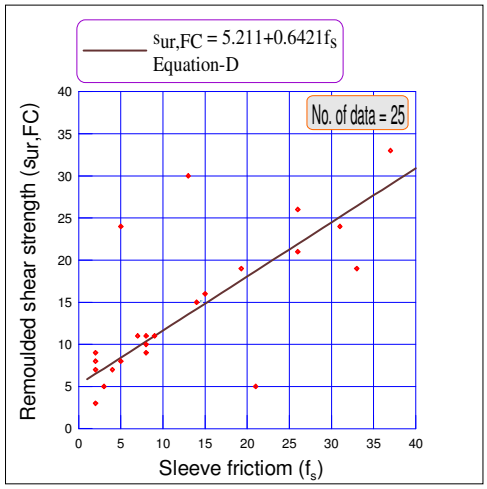

Fig. 4 Evaluation of correlation of remoulded shear strength by regression analysis (Eqn. D) for the soil data from western Indian Offshore (fall cone)

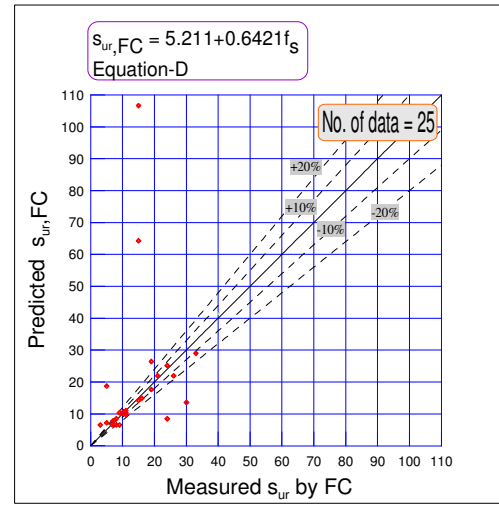

Fig. 5 Predicted Remoulded shear strength from Eqn. D vs. Measured Remoulded shear strength (fall cone)

obvious outliers exist. The data is re-plotted in Figure 5 with 10% and 20% bounds included. Barring a couple of outliers, most of the measured values are within 20% of prediction.

Since the correlation was not forced through the origin, an anomaly exists that at zero f_s, remoulded strength of about 5 is predicted. With additional data generated during the future soil investigations, all the correlations derived shall be revisited and refined. For the present, it is suggested that the remoulded shear strength shall be derived using the derived equations to arrive at the most reasonable value.

7 CONCLUSIONS

Data from 27 offshore locations, from 8 different fields of western Indian offshore have been used in this study to evaluate the applicability of the selected published correlations for deriving remoulded shear strength or Sensitivity of calcareous clays from western Indian offshore from index parameters and CPT parameters. It is found that none of the published correlations are directly applicable for such clays to evaluate the applicability of the selected published correlations for deriving remoulded shear strength or Sensitivity of calcareous clays from western Indian offshore from index parameters and CPT parameters. It is found that none of the published correlations are directly applicable for such clays.

Attempts were hence made to derive some new correlations by performing regression analyses using laboratory measured data and CPTU data. A total of four reasonably strong correlations could be derived for the Remoulded shear strength. Statistically, the best correlation found was between the remoulded shear strength measured with fall cone test and CPT measured

8 ACKNOWLEDGEMENT

Authors are grateful to the management of ONGC for granting permission to publish the paper.

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