

**UNDRAINED SHEAR STRENGTH BASED ON PIEZOCONE
AND LABORATORY TESTS FOR TROPICAL SOILS**

BY

DAVID MUBIRU

B. Eng. (Civil) (NDU)

19/U/GMES/18815/PD

**A DISSERTATION SUBMITTED TO THE DIRECTORATE OF
RESEARCH AND GRADUATE TRAINING IN PARTIAL
FULFILMENT OF THE REQUIREMENTS FOR
THE AWARD OF MASTER OF SCIENCE IN
STRUCTURAL ENGINEERING DEGREE
OF KYAMBOGO UNIVERSITY**

JUNE, 2024

DECLARATION

I, *Mubiru David*, hereby declare that this submission is my work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material that has been accepted for the award of any other degree of the university or other institute of higher learning, except where due acknowledgment has been made in the text and reference list.

Signature :

Name :

Date :

APPROVAL

The undersigned approve that they have read and hereby recommend the submission to the Graduate school of Kyambogo University, a final dissertation entitled: Undrained shear strength based on piezocone and laboratory tests for tropical soils, in fulfillment of the requirements for the award of Master of Science in Structural Engineering Degree of Kyambogo University.

Dr.:

Date:

Signature:

Dr.:

Date:

Signature:

DEDICATION

This work is dedicated to my Father Mr. Mubiru Nathan, my Mother Miss Mutesi Christine, my wife and my three sons who gave me courage for my education upon which I continue to build.

ACKNOWLEDGEMENTS

The will of God can't take me where his grace can't sustain me. Without his grace and wisdom, I wouldn't have accomplished my goal. In addition, I also thank the engineering faculty at Kyambogo University for the resources and support provided during the course.

I thank my former supervisor, the late Dr. Kyambadde S. Benjamin, for having provided all the necessary support, continuous encouragement, and guidance on my thesis; and I also deeply thank Dr. Bulolo Sam for enabling me to bring the research into shape. I also thank my co-supervisor, Dr. Michael Kyakula, for the information. In addition, thanks to Eng. Joel Mubiru and Eng. Morris Oleng for the exciting lectures.

I also thank Eng. Alex Turihohabwe (CEO-Blessed Investments Limited), Mr. Achire Michael (CEO-AM West Engineering Consult Limited), and Mr. P. Ochieng for contributing valuable comments.

I am pleased to extend thanks to Mr. Lubaga Godfrey and Kantuguka Sunday Bruce for the provision of Laboratory and In-Situ Field database details within the area of research.

Finally, I want to offer thanks to my lovely family.

TABLE OF CONTENTS

DECLARATION	I
APPROVAL.....	II
DEDICATION	III
ACKNOWLEDGEMENTS.....	IV
TABLE OF CONTENTS.....	V
LIST OF FIGURES	IX
LIST OF TABLES	XI
LIST OF APPENDICES.....	XII
LIST OF ACRONYMS/ABBREVIATIONS/SYMBOLS	XV
ABSTRACT	XXI
CHAPTER ONE: INTRODUCTION	1
1.1 Background	1
1.2 Statement of the problem	6
1.3 Research Objectives	7
1.3.1 Main Objective.....	7
1.3.2 Specific Objectives.....	7
1.4 Research Questions	7

1.5 Research Justification.....	7
1.6 Significance.....	8
1.7 Study scope	8
1.7.1 Site	8
1.7.2 Period	8
1.7.3 Activity.....	8
1.8 Conceptual Framework.....	9
1.9 Chapter Summary.....	9
CHAPTER TWO: LITERATURE REVIEW	11
2.1 Tropical Residual Soils	11
2.2 Shear Strenght	12
2.2.1 Development of Soil Shear Strenght Models.....	14
2.2.1.1 Total and Effective stress Mohr-Coulomb shear strenght model.....	14
2.2.1.2 Extended Mohr-Coulomb shear strength model	15
2.2.1.3 SHANSEP	15
2.2.1.4 State Parameter μ	17
2.2..2 Measurement of shear strenght	19

2.2.2.1 Laboratory using triaxial apparatus.....	19
2.2.2.2 In-situ using CPTU	20
2.3 Empirical correlations	26
2.4 Chapter summary	28
CHAPTER THREE: RESEARCH METHODOLOGY.....	31
3.1 Introduction	31
3.2 Research strategy	31
3.3 Data collection	32
3.3.1 Sampling	32
3.4 SHANSEP Procedure.....	32
3.5 Laboratory Tests.....	34
3.5.1 Moisture Content.....	34
3.5.2 Atterberg Limit (cone penetrometer method)	34
3.6 Cone factor	36
3.7 Empirical Relationship creation.....	36
CHAPTER FOUR: ANALYSIS,DISCUSSION OF RESULTS.....	37
4.1 introduction	37

4.2 Site characterisation and results	37
4.3 Formulation of the proposed model for estimation of S_u	43
4.3.1 Determination of the constants for the SHANSEP approach.....	43
4.3.2 Determination of the cone factor N_{kt} from existing equations.....	44
4.3.3 Estimation of S_u using SHANSEP approach.....	44
4.3.4 Estimation of S_u using cone factor, N_{kt}	47
4.4 Proposed correlations	51
CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS	53
5.1 Conclusions	53
5.2 Recommendations	53
References	54

LIST OF FIGURES

Figure 1: Conceptual Framework.	9
Figure 2: Troll Marine clays S_u CAUC results linear.	13
Figure 3: Troll Marine clays S_u CAUC results de-trending.	13
Figure 4: linear least squares regression CPTU S_u (Lacasse et al., 2007).	13
Figure 5: Geo-materials Failure envelopes.	14
Figure 6: Upsilon parameter, $Y = e_{\text{initial}} - e_{\text{SSL}}$	18
Figure 7: CD Multiple Stage Triaxial Test results (Machado, 1998).	18
Figure 8: Shear Strength envelopes for different soil suctions	18
Figure 9: Δu and against CAUC S_u	22
Figure 10: Akbar Cheshomi, 2016 N_{kt} versus previous studies (a-d).	25
Figure 11: OCR against Q_t	28
Figure 12: Variation of NMC with depth.	39
Figure 13: Variation of Atterberg limits with depth.	39
Figure 14: Variation of internal friction with depth.	40
Figure 15: Variation of S_u with depth.	40
Figure 16: CPTU Profile Site 1 borehole 1.	41

Figure 17: CPTU Profile Site 2 borehole 1.....	41
Figure 18: SHANSEP S_u versus laboratory results.....	47
Figure 19: Various S_u from N_{kt} values versus S_u TXT.	49
Figure 20: Current S_u values versus previous literature TXT lab S_u	52
Figure 21: Location of the sites under study.....	71

LIST OF TABLES

Table 1: SHANSEP Parameters and coefficients ranges for various soils	16
Table 2: Recommended values for numerous soil types.....	24
Table 3: Classifications for sites 1 and 2	37
Table 4: Laboratory S_u for sites 1 and 2	42
Table 5: Variation of the constants s and m	45
Table 6: N_{kf} values obtained from Equations 11 –16.....	47
Table 7: S_u values determined by use of equations from 11 to 16.....	48

LIST OF APPENDICES

Table 8: SHANSEP S_u measured by substituting $s=0.26, 0.40, 0.49, 0.55$	72
Table 9: SHANSEP S_u measured by substituting $s=0.38, 0.41, 0.70, 0.53$	73
Table 10: SHANSEP S_u measured by substituting $s=0.60, 0.60, 0.24, 0.47$	74
Table 11: SHANSEP S_u measured by substituting $s=0.37, 0.28, 0.39$	75
Table 12: SHANSEP S_u measured by substituting $s=0.69, 0.53, 0.45$	76
Table 13: SHANSEP S_u measured by substituting $s=0.65, 0.63, 0.41$	77
Table 14: SHANSEP S_u measured by substituting $s=0.73, 0.21, 0.53, 0.49$	78
Table 15: S_u determined for site 1 from Equation 11.....	79
Table 16: S_u determined for site 1 from Equation 12.....	80
Table 17: S_u determined for site 1 from Equation 13.....	81
Table 18: S_u determined for site 1 from Equation 14.....	82
Table 19: S_u determined for site 1 from Equation 15.....	83
Table 20: S_u determined for site 1 from Equation 16.....	84
Table 21: S_u determined for site 2 from Equation 11.....	85
Table 22: S_u determined for site 2 from Equation 12.....	86
Table 23: S_u determined for site 2 from Equation 13.....	87

Table 24: S_u determined for site 2 from Equation 14.....	88
Table 25: S_u determined for site 2 from Equation 15.....	89
Table 26: S_u determined for site 2 from Equation 16.....	90
Table 27: S_u determined for site 1 from Akbar Cheshomi, 2016 N_{kt} values.....	91
Table 28: Site 1 S_u obtained from Otoko et al., 2016 N_{kt} values	92
Table 29: Site 1 S_u obtained from Stefanik 2015 N_{kt} values.....	93
Table 30: Site 1 S_u obtained from Remai 2013 N_{kt} values.....	94
Table 31: Site 1 S_u obtained from Hong et al.,2010 N_{kt} values	95
Table 32: Site 1 S_u obtained from Almeida et al., 2010 N_{kt} values	96
Table 33: Site 1 S_u obtained from Hassan 2004 N_{kt} values.....	97
Table 34: Site 1 S_u obtained from Ismail & Zein 1987 N_{kt} values.....	98
Table 35: Site 1 S_u obtained from Senneset et al., 1982 N_{kt} values	99
Table 36: Site 1 S_u obtained from Bowles 1995 N_{kt} values	100
Table 37: Site 2 S_u obtained from Akbar Cheshomi, 2016 N_{kt} values.....	101
Table 38: Site 2 S_u obtained from Otoko et al., 2016 N_{kt} values	102
Table 39: Site 2 S_u obtained from Remai 2013 N_{kt} values.....	103
Table 40:Site 2 S_u obtained from Almeida et al., 2010 N_{kt} values	104

Table 41: Site 2 S_u obtained from Hong et al.,2010 N_{kt} values	105
Table 42: Site 2 S_u obtained from Hassan 2004 N_{kt} values	106
Table 43: Site 2 S_u obtained from Gebreselassie 2003 N_{kt} values	107
Table 44: Site 2 S_u obtained from Chen 2001 N_{kt} values.....	108
Table 45: Site 2 S_u obtained from Karlsrud 1996 N_{kt} values	109
Table 46:Site 2 S_u obtained from Powell & Quaterman, 1988 N_{kt} values	110
Table 47: Site 2 S_u obtained from La Rochelle et al., 1988 N_{kt} values.....	111
Table 48: Site 2 S_u obtained from Ismail & Zein 1987 N_{kt} values.....	112
Table 49: Site 2 S_u obtained from Lunne et al., 1985 N_{kt} values	113
Table 50: Site 2 S_u obtained from Lunne & Kleven 1981 N_{kt} values	114
Table 51: Site 2 S_u obtained from Bowles, 1995 N_{kt} values	115
Table 52: Site 2 S_u obtained from Sanglerat, 1972 N_{kt} values	116

LIST OF ACRONYMS/ABBREVIATIONS/SYMBOLS

%	Percentage
%	Percentage
&	Ampersand
°	Degrees
Ø	Internal Friction
Δu	Excess Pore Pressure
Δv	Change In Volume
ACUT	Anisotropically Consolidated Undrained Triaixal
ASTM	American Society For Testing And Materials
B _q	Pore Pressure Ratio
BS	British Standard
c	Cohesion
CD	Consolidated Drained
cm	Centimeter
cm ²	Square Centimeter
CPT	Cone Penetration Testing

CPTU	Piezocone
CU	Consolidated Undrained
DPT	Dynamic Penetration Test
e	Void Ratio
e_i	Initial Void Ratio
FPDT	Flat Plate Dilatometer Test
f_s	Sleeve Friction
g	Gram
g	Unit Weight
I_r	Rigidity Index
IV	Four
k	Factor
kN	Kilonewton
K_o	In Situ Stress State
kPa	Kilopascal
lab	Laboratory
LI	Liquidity Index

LL	Liquid Limit
LS	Linear Shrinkage
m	Meter
m_1	Mass Of The Container
m_2	Mass Of The Container And Wet Soil
m_3	Mass Of The Container And Dry Soil
$N_{\Delta u}$	Pore Pressure Cone Factor
NC	Normally Consolidated
NGI	Norwegian Geotechnical Institute
N_{ke}	Effective Cone Factor
N_{kt}	Total Cone Factor
NMC	Natural Moisture Content
$^{\circ}\text{C}$	Celsius
OC	Over Consolidated
OCR	Over Consolidation Ratio
OMC	Optimum Moisture Content
p_a	Atmospheric Pressure

PI	Plasticity Index
PL	Plastic Limit
q_c	Cone Resistance
q_{net}	Net Cone Resistance
q_t	Corrected Cone Resistance
Q_t	Normalized Cone Resistance
R^2	R-Squared
R_f	Friction Sleeve
SBT	Soil Behaviour Type
SHANSEP	Stress History And Normalized Soil Engineering Properties
SI	Systeme International
sm	Square Meter
SPT	Standard Penetration Test
S_t	Sensitivity
S_u	Undrained Shear Strength
$S_{u(ave)}$	Average Undrained Strength
TE	Tri-Axial Extension

ton	Tonne
TXT	Tri Axial Testing
u_1	Pore Water Pressure Measured On The Cone Face
u_2	Pore Water Pressure Measured Just Behind The Cone
u_3	Pore Water Pressure Measured On The Cone Face
u_a	Pore Air
UK	United Kingdom
u_o	Static Pore Water Pressure
USCS	Unified Soil Classification System
UU	Unconsolidated Undrained
u_w	Pore Water Pressure
V	Five
-ve	Negative
VI	Six
vs	Versus
VT	Vane Test
W	Percentage Of The Dry Soil Mass To The Nearest 0.1%.

Y	Upsilon Parameter
γ	Unit Weight
μ	State Parameter
Σ	Summation
σ	Total Normal Stress
σ'_1	Major Principal Stress
σ'_3	Minor Principal Stress
σ_c^j	Maximum Past Effective Vertical Pressure
σ_n	Field In-Situ Stress
σ'_{v0}	Present Effective Vertical Pressure
σ_{v0}	In-Situ Total Vertical Stress
τ	Shear Strength

ABSTRACT

This paper presents a study on the geotechnical properties of two residual soil sites (Buloba a less seismic zone and Buliisa an extreme seismic zone in Uganda) **to characterize, propose and recommend models for the estimation of Undrained shear strength (S_u)**. The analysis utilized data from 32 (Thirty-Two) piezocone penetration tests, Twenty-Eight (28) Liquid Limit tests, Twenty-Eight (28) Plastic Limit tests, Twenty-Eight (28) Linear Shrinkage tests, Twelve (12) Consolidation tests, 13 (Thirteen) Consolidated Undrained Triaxial tests. The results showed that the fine content, natural moisture content, liquid limit, plasticity index, and linear shrinkage varied within each site. Furthermore, the undrained shear strength, internal friction, and cohesive values also varied between sites. The study proposed appropriate empirical correlations for obtaining the S_u of residual soils, and observed that N_{kt} value of 56 is proposed for slightly consolidated residual soils while $N_{kt} = 288$ should be used for heavily consolidated residual soils during the obtaining of the S_u . **Furthermore, the study concluded that SHANSEP constants of $s = 0.07$ and $m = 0.82$ should be appropriate for estimating the undrained shear strength of residual soils. However, caution should be taken as these empirical relationships are site-specific and considerate of uncertainties.** Overall, this paper provides valuable insights for geotechnical engineers to consider for residual soil analysis.

Keywords; Residual Soils, Cone Penetration Test CPTU, Cone Factor N_{kt} , Over-consolidated soils, Undrained Shear Strength S_u .

CHAPTER ONE : INTRODUCTION

1.1 Background

Residual soils occur within regions with hot and humid conditions such as Ghana, Malaysia, and Nigeria while conditions in temperate zones are not conducive to them (Brand & Phillipson, 1985). Tropical/residual soils are partially saturated with water, with $-ve u_1, u_2,$ and u_3 values located in a zone above the water table containing boundary conditions with problems faced by geotechnical engineers. The geotechnical engineer's use of computers has changed the capability of engineers to solve those problems, so unsaturated soil mechanics has become important for examining the in-situ behavior of the soils within the zone (Huat et al., 2012).

The books," tropical and subtropical soils (Buringh, 1979), Tropical Residual Soils (Fookes, 1997b), Laterite soil: Pedogenesis and Principles (Gidigas, 2012) and Residual Soils Engineering (Huat et al., 2012), are comprised of various residual soils properties such as formation, characterization, behavior, volume change, shear strength models, slopes, foundations, uses, sampling and in-situ tests used. However, tropical soils have characteristics that were not well studied but their formation depends on the extent of transition during their genesis (Carvalho & Gitirana, 2021), and most works on soils in the tropics were done in Indonesia by Mohr, Trinidad by Hardy, Congo by Bayens before 1939, Cuba (Bennett & Allison, 1928), Puerto Rica (Roberts, 1942), Hawaii (Cline, 1955), and Indonesia by Mohr and later by (Mohr & van Baren, 1954). After 1945, the first commonwealth conference on tropical and subtropical soils was held in England in 1948 (Buringh, 1979).

Eighty percent of Uganda rocks were transformed by orogenic movements, and were made operational throughout the Precambrian period developed between 3,000,000,000 to 600,000,000 years back, hence the rocks were classified as Gneisses and Granites (Study et al., 2003).

Within this dissertation two areas were considered, one with an extreme seismicity that is Buliisa (4.1- 6.6) then the other with low seismicity which is buloba (3.3 - 4.0) (Bwambale et al., 2015). According to the Ugandan seismic code, Buloba has a low seismic zoning factor-1 and Buliisa has a higher seismic zoning factor-3 but as per rock description various authors described each of these areas differently for example Bwambale et al.,(2015) stated that Buliisa is composed of Precambrian metamorphic and sedimentary rocks, Neogene, Quaternary lacustrine and fluvial deposits; Mutebi et al., (2019) stated that they are made up of Neogene Sediments; Tumwesige et al., (2014) were comprised of Rift Valley Sediments; crystalline metamorphic rock by Worldatlas, (2017), Cenozoic rocks by Westerhof et al., (2014). Then Buloba according to Tumwesige et al., (2014) is comprised of Precambrian gneiss terrain; Archean plutonic rocks by Mutebi et al., (2019); Volcanic and intrusive rocks by Worldatlas, (2017) however the Ugandan Mesozoic rocks are majorly composed of rift valley sediments furthermore both sites by stages of weathering belong to Paleoproterozoic era, climatically they have short dry season according to Mcknight & Hess, (2000) , and for the case of the Pedogenetic classification both are comprised of ferrallitic soils according to (Fookes,1997). Uganda is chemically weathered intense according to (Strakhov,1967) thus the weathering by- products could have been transported to various locations/destinations by agents such as water while other products may remain in the same place, and those formed at the original place are called residual soils (Braja & Khaled ,2014).

According to David,(2014) metamorphic rock are comprised of Sand, then granite, gneiss will are comprised of Clayey sand so in general both areas under study the soils are tropical residuals as defined by climate, rock type, and pedogenetic classification. The European and North American temperate areas where the electrical cone penetration testing (CPT) apparatus was originally developed are also comprised of the soil conditions of tropical regions. Since 1977 in Sudan, the CPT has been put to practical use in the classification and characterization of soils for various design research projects (Peuchen et al., 1996; Zein, 2017).

The more complex of the conditions in the tropics are residual soils characterized by unpredictable strength which cannot be properly assessed using correlations developed by soil mechanics, so it has become increasingly important to understand their behavior (Peuchen et al., 1996; Rocha & Giacheti, 2018). Site characterization is very important because it is comprised of analyzing soil layers, thickness, type, groundwater level, physical properties, and mechanical properties instead of using the traditional methods for example drilling, sampling, and laboratory, so an advanced in-situ approach CPTU would be better and further when the logging with a particular measurement strategy is a modern.

Chemical and physical weathering's are the major ways tropical soils such as lateritic and saprolitic are formed. In Unsaturated soils when characterizing, factors such as cementing, and genesis showed a considerable effect on their behavior than the OCR so they should also be considered (Vaughan et al., 1988; Rocha et al., 2020).

In design lowest characterized strength values are always selected and a decision has to be taken after having checked through various procedures. Wroth, (1984) presented a simple relationship of soft soil characterization such as normally consolidated clayey which considered values

ranging from 0.2 to 0.25. Additionally Ting, (2003) adopted the same principles, and the Undrained strength ratio was used in in-situ sediments during characterization.

In Weathered formation applicable computation models are not easily achievable, and experimental relationships are not based on physical processes but closely related to measurement and complete structure monitoring. Furthermore, residual soils in their natural state have various behaviors that may be due to index properties (Bujang Huat et al.,2006).

Estimation of the key design properties is a challenging task. In clays, the undrained shear strength is adopted while in sand it is the friction angle (Junhwan & Jungmoo, 2020). Shear strength is a critical property for structures erected on residual soils and to be specific, the stress behavior of the residual soils is affected by various factors such as consolidation rate, and sample disturbance (Ladd et al., 1977), and there has been sufficiently great progress in the understanding of the factors over the years (Ladd et al., 1991; Terzaghi et al.,1996). These factors could be controlled by the laboratory, but there is still a lack of unrepresentative samples obtained. However, in-situ testing is productive while laboratory testing is time-consuming, although in-situ testing depends on empirical correlations for interpretation (Mitchell et al., 1999).

The dominant methods of soil investigation during the past 100 years in Europe were excavation ,soil boring, however at the beginning of January 1, 1901, modern penetration methods started to develop in Central and Northern Europe where loose soil deposits were encountered during the execution of infrastructures such as roads and buildings (Zbigniew & Jędrzej, 2014). Conversely, the SPT is commonly carried out within various field investigations (Bwambale et al., 2015) but the CPT is an ideal tool for the development of soil geotechnical properties and the evaluation of

soil S_u . Furthermore, numerous empirical correlations for determining the S_u of soils by the use of cone resistance using an empirical factor (N_{kt}) have been proposed (Eslami & Fellenius, 1997; Schneider et al., 2008; Abdul, 2017).

N_{kt} , the most reliable term for interpreting the field S_u in clays from CPTU even though several expressions are available, Effective stress controls soils S_u , no matter whether a failure occurs under drained or not drained conditions, but despite the developments, there are still many gaps in our understanding (Coduto, 2000; Duncan et al., 2014; Mayne & Peuchen, 2018; Abolfazl et al., 2020). Conversely, a lightly over-consolidated clay site showed that Normalized CPTU parameters correlated with OCR but there were no clear relationships to represent σ'_c from CPTU and index parameters therefore there was a need for it to be verified for other soil types such as clay soils with maybe of higher OCRs (Yang et al., 2019).

But the cone factor is further considered a soil characteristic because it is affected by soil characteristics and shear strength is one of the soil properties affected by sub-surface features then the design of any sub-surface is dependent on the sub-surface soil properties (Alexander & Book, 1984; Canace & Dalton, 1984; Stewart, 1987). According to Gleassociates (Robert B. Greene) even the best-designed geotechnical structure will fail if the soil lying on top deteriorates or has structural issues for example if the subsurface is already in poor condition the new surface will deteriorate quickly. Recently geotechnical structural conditions in Kampala were becoming progressively worse leading to reduced service lives (Kiggundu et al., 2000).

1.2 Statement of the problem

A common problem with geotechnical field investigation methods is the large amounts of uncertainties in results attributed to various factors (Caesar Kardan, 2014), and the frequent in-situ methods are CPT, SPT, FPDT (Business Bliss Consultants FZE, 2018). However, globally and nationally several geotechnical organizations rely on SPT for the selection of soil borings, which is the primary source of data for designing buildings and road foundations (Broms & Flodin, 1988; Bwambale et al., 2015; Yusof & Zabidi, 2018 ; Li et al., 2022) because of its availability, low cost, and no need for an expatriate (Twesigye et al., 2009) but for quick data and reliable results CPTU and Dynamic Penetration Test (DPT) are the most reliable methods to be used (Business Bliss Consultants FZE, 2018) conversely nowadays, most engineers use CPT method since it is effective and produces data in a short period and more importantly, it saves costs, for example, CPTU production rates vary (from 150 to 300 feet per day) as compared to other field tools (from 100 to 150 feet per day) thus CPTU is cost-effective where both services may be used (Coolidge, 2015).

However, although numerous investigations concentrated on empirical factors to estimate S_u , thus there are no agreements as per the factors observed by the larger scatter furthermore in Uganda there is the use of a default N_{kt} of 14 which can lead to under or over-estimation of S_u . Conversely, there are various tests for measuring S_u in the laboratory from which the results may be deployed for correlation with CPT data (Ertan et al., 2019).

So despite the advantages mentioned above about the CPTU over other in-situ tests, in developing countries for example Uganda, there is still a misconception that the CPTU is too expensive therefore, this master's thesis aims to create awareness by comparing piezocone and

laboratory soil parameters to formulate empirical equations for use in the Ugandan geotechnical practice.

1.3 Research Objectives

1.3.1 Main Objective

To improve the accuracy of S_u soil properties estimation.

1.3.2 Specific Objectives

- To characterize the soil engineering properties.
- To propose models for S_u estimation.
- To recommend the interpretation of geotechnical properties from the results obtained.

1.4 Research Questions

- What are the geotechnical properties?
- Which were the proposed models for estimating the S_u ?
- Which recommendations were developed for the interpretation of geotechnical properties?

1.5 Research justification

Yang et al., (2019) used three methods in lightly overconsolidated clay site to obtain the S_u which showed Normalized CPTU parameters correlated with OCR, and however there were no clear relationships to obtain σ_c^i from CPTU and index parameters results, therefore, there was a need to verify other clay types maybe such does of higher OCRs thus an indirect approach of substitution of earlier, N_{kt} and SHANSEP numerical values into literature equations to determine the laboratory S_u was conducted within this dissertation. Conversely, it is why a good

understanding of piezocone and its interaction with the laboratory parameters of residual soils in the geotechnical engineering industry would create awareness of a cost-effective site investigation, foundation design, and analysis.

1.6 Significance

This research will improve the estimation of S_u with the current proposed models according to various soil characteristics to simplify time together with cost.

1.7 Study Scope

This thesis concentrated on tropical residual soils, undrained shear strength and the current CPTU practice within Uganda.

1.7.1 Site

a) Location

The sites investigated are located in the central and southwestern regions of Uganda.

1.7.2 Period

This research dissertation was done from 1st February 2021 to 16th November 2022.

1.7.3 Package/Activity

This involved field works such as in-situ and laboratory tests, and focused on residual soils from 1.0 – 4.0 m depth.

1.8 Conceptual framework

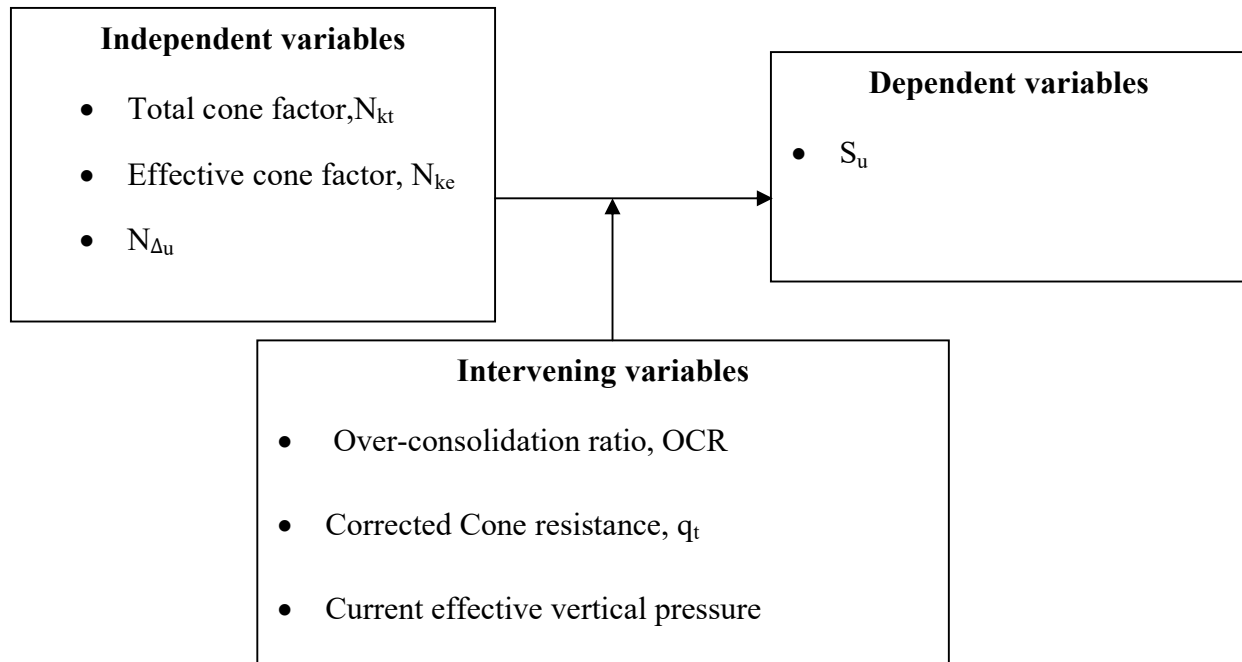


Figure 1: Conceptual Framework.

1.9 Chapter Summary

This master's thesis was comprised of five (05) chapters, and each contained the following;

Chapter 1 – Background, Problem Statement, Main Objective, Specific Objective, Research Justification, Significance, Conceptual Framework, and the Scope.

Chapter 2 - Literature review of residual soils, shear strength, soil shear strength models evolution, shear strength measurement, Empirical correlations, and chapter summary.

Chapter 3 – Introduction, Research Strategy, Data Collection, SHANSEP Procedure, Laboratory Tests, Cone Factor, Empirical Relationship creation.

Chapter 4 - site characterization, formulation of the proposed model for estimating the S_u , and proposed correlations.

Chapter 5 –This was comprised of conclusions and recommendations.

References

Appendices

CHAPTER TWO : LITERATURE REVIEW

This section provided relevant literature utilized as a background for this particular dissertation, and it was comprised of Tropical residual soils, S_u , creation of soil S_u models, determination of S_u , Empirical correlations, and chapter summary.

2.1 Tropical Residual soils

Tropical soils were created from majorly in-situ weathering, however, the term tropical soils is generally confusing. Residual soils are both lateritic and saprolitic such that the saprolitic retain the parent rock macro fabric while the lateritic soils may be transported and distinguished by the laterization process as per the climatic conditions at various rates. Due to the bonding structure presence within the tropical comprised of sedimentary soils interpretation of their behavior is not easy thus it cannot only be checked with the aid of the classical soil mechanics models (Vaughan, 1988).

Uganda, as a tropical region consists of residual soils. These weathered residual profiles were classified into grades, namely residual soil – VI depth ranging from 1–10m, completely weathered – V depth ranging from 5 – 15 m, and highly weathered IV. While the pedagogical horizon included humus and intermediate, the decomposition to fresh rock included weathered rock IV and slightly decomposed fresh rock, which ranged from 5 – 100 m (Deere, 1971; Vargas, 1974; Bujang et al., 2012).

However, there are no agreements on the boundary of the tropical soils because of different perspectives as per grades that constitute these soils (Fookes, 1997; Coolidge, 2015). But for this study, the soils from the CPTU results ranged between 1.0 to 12.0m, and additionally residual soil components are always turned into the soil, and then the mass structure will be destroyed,

resulting into silty or clayey soils of a homogenous color (Bujang et al., 2012). Having reviewed various CPT results from Uganda, various soils are comprised of clay, silty clay, and silty sand (Huat et al., 2012).

The climate being the major geological factor for the creation of residual soils, Uganda with its high average temperature together with abundant rainfall experiences the wet type of tropical climate (Huat et al., 2019) and clays occur widely in many parts of Uganda (Nyakairu et al., 2002) and because the soils are widely used in the construction sector there is a need to conduct a geotechnical investigation through proper data recording for a proper structural/geotechnical design to save costs in future.

Residual soil properties vary depending on the type of rock together with climatic regions and it is not easy to determine their behavior by use of mathematical methods (Blight & Leong, 2012) so they have to be characterized properly for a particular purpose and they are stationed above the groundwater table leading to unsaturation conditions within the soils (Saffari et al., 2019). Although some research has been conducted on residual soils (POH et al., 1985; chang et al., 1988 ;Todo et al., 1989), S_u characteristics of these soils are still not clear (Rahardjo et al., 1995).

2.2 Shear Strength

This is the quantity of shear stress, τ , before failure, and it depends on factors such as friction, and cementation (Larsson, 2008 ; Das & Sobhan, 2010). This is also a soil factor describing the soil's ability to sustain stress during shearing, and it depends on stress history as one of the factors, and the value that is used in analysis depends on the challenge on the ground (Mayne, 2007).

Depending on permeability and rate of loading, there are two conditions namely drained and undrained. In drained conditions, pore water will dissipate and no excess u_1, u_2 , or u_3 will be present while in undrained conditions pore water cannot dissipate before failure, so these two are different situations representing extreme cases. Furthermore, it is important to know the loading and unloading problems to understand the construction which may result in changes in σ_n values within the soils (Lambe & Whitman, 1969). The permanent construction includes loading problems then excavations involve unloading.

For denoting situations such as construction and failure, Undrained may be named as short-term/end of construction/UU (negligible change in water content), Drained also named as Long-Term/CD then Partially Drained also named as Intermediate (Ladd, 1992).

The S_u as a parameter is widely used, usually determined by laboratory tests such as Uniaxial, triaxial, direct shear while for the case of field test they usually use field vane shear, but the values always obtained depend on various factors such as the methodologies (Cheshomi, 2018; Mayne et al., 2009; Myftaraga, 2013).

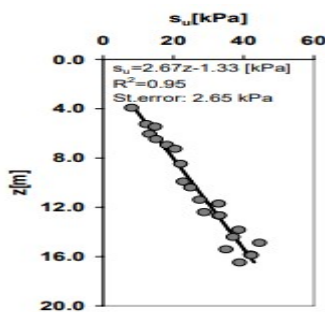


Figure 2: Troll Marine clays S_u CAUC results linear.

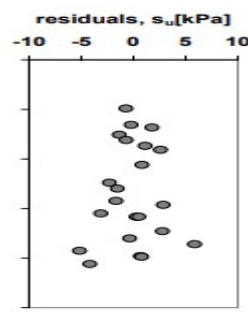


Figure 3: Troll Marine clays S_u CAUC results de-trending.

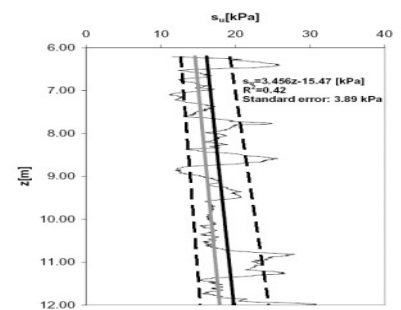


Figure 4: linear least squares regression CPTU S_u (Lacasse et al., 2007).

2.2.1 Development of soil shear strength models

2.2.1.1 Total and Effective stress Mohr-Coulomb shear strength model

Coulomb proposed an equation (1) in 1773 which was comprised of c, σ, ϕ however from 1934 to 1937 Hvorslev concluded that cohesion depends on OMC and normal stress depends on the soil properties so he introduced σ' in the place of σ as seen in equation (2).

$$\tau_f = c + \sigma \tan \phi \quad (1)$$

$$\tau_f = c + \sigma' \tan \phi = c + (\sigma - u) \tan \phi \quad (2)$$

Where; c - cohesion

σ' - Effective normal stress;

σ - Total normal stress;

ϕ - Angle of internal friction.

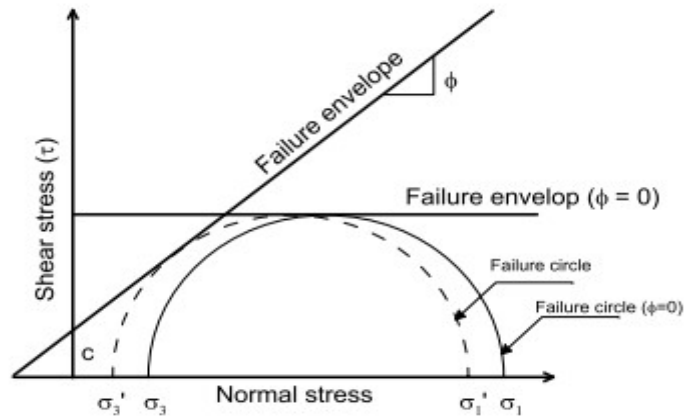


Figure 5: Geo-materials Failure envelopes.

In 1948 during a conference, Skempton presented the concept of $(\emptyset) = 0$ analysis and he stated that under undrained conditions in saturated cohesive soils, the increases in confining stress developed were carried by the pore water pressure in the sample but the effective stress remained constant and this agreed with the Terzaghi's effective stress principle. The recent development of testing techniques on soft soils have agreed with the σ' envelope as non-cohesive soils (Bell, 1915; Fellenius, 1922; Terzaghi, 1943; Tavenas, 1987; Aas, 1965; Bjerrum, 1961; Lambe, 1960; Janbu, 1967; Skempton, 1948; Bishop, 1966). However there is a tendency of carrying out numerous tests which has led to high expenditure so it is why various researchers have developed empirical relationships to relate with them S_u (Thakur et al., 2016).

2.2.1.2 Extended Mohr-Coulomb shear strength model

Shallow type of rainfall-induced slope failures for partially saturated soils shear strength behavior characterization are not only governed by effective stress so there is a need to consider $\sigma - u_a$ and $u_a - u_w$.

2.2.1.3 SHANSEP

This was formulated for OC Clays by Ladd and Foott in 1997 as seen in equation (3) and widely used for S_u Clay's characterization then its uniqueness is the σ'_{vo} normalization for NC Clays.

$$\frac{S_u}{\sigma'_{vo}} = \alpha(OCR)^b \quad (3)$$

Where; OCR - Over Consolidation Ratio

Parameter b - Empirical exponent and;

$$\alpha = \left(\frac{S_u}{\sigma'_{vo}} \right)_{NC} - \text{normalized } S_u \text{ of NC clay}$$

$$NC \text{ Clay} - \left(\frac{S_u}{\sigma'_{vo}}, OCR = 1 \right).$$

Over the years various authors have conducted research within various regions such as Hekkingen, Barents Sea, Draupne in the North Sea, England Clay, Fort William day, Fuller's Earth Oxfordshire in UK, Heather (1,2,3) in the North Sea, Ile in Norwegian Sea, Kimmeridge Wiltshire in UK, Kimmeridge Dorset in UK, London Clay and South Ockeden in UK, Ness (1,2) in North Sea, Not in Norwegian Sea, Opalinus and Lias, Rannoch in North Sea, Saga (1,2) in North Sea, Statjord in North Sea, Tabert in North Sea, Valhall in North Sea, Wald Clay and Warham in UK. The ranges of maximum, minimum, average SHANSEP Parameters and coefficients of correlation for various soils obtained from the above region ranges are shown below in Table 2-1 (Steiger & Leung, 1991; Berre, 1992 ;Marsden et al., 1992; Berre et al.,1995; Cook et al.,1990; Igenbrod & Burak 1991; Wu 1991 ; Berre et al., 1996)

Table 1: SHANSEP Parameters and coefficients ranges for various soils

No.	Range	A	b	R ²
1.0	Maximum	0.73	0.94	0.99
2.0	Minimum	0.21	0.45	0.65
3.0	Average	0.48	0.72	0.89

From the research conducted it was discovered that the higher constants were caused by the dilative response of OC materials (James, 2005), and various soils have shown the applicability of SHANSEP although there is a degree of cementation difference (Gutierrez et al., 2008; Karlsrud et al., 2005; Paniagua et al., 2019 ; Larsson et al., 2007; Chung et al., 2002; Watabe et al., 2002; Bo et al., 2003; Moses et al., 2003). Ancold, (2019) stated that contractive materials that generate pore pressures during shearing should use Ladd, 1991 and irrespective of the parent rock residual soil nonlinearly decreased with the increasing effective overburden stress

then S_u tended to nonlinearly increase with increasing effective overburden stress (Dareeju et al., 2021).

It was stated that the soil mechanics classical concepts and OCR were not almost universally applicable to residual soils although in sedimentary soils the behavior of the soils depends on the OCR (Blight & Leong, 2012; Vaughan, 1985; Wesley, 2010). For any given set of in-place conditions S_u values determined were based on s and m constant values extracted from the laboratory because S_u values from the lab were not representative of the in-situ conditions because they were different σ_{vo} and OCR (Video by Scott Brandenburg, SHANSEP-youtube).

The SHANSEP considers the results of OCR and stress path, and at the back of the SHANSEP a sequence of lab tests were performed to manage the stress conditions and path during consolidation and S_u , so the soil OC is then evaluated and the stress path to which the soil is imposed is measured. These laboratory strengths closely replicate in-situ conditions and can be used to predict in-situ behavior. So generally the SHANSEP analysis used in various types of research have shown a proper prediction of the S_u than classical approaches (James et al., 2005).

2.2.1.4 State parameter μ

In the modern constitutive this parameter has been used to assess the dilative and contractive behavior of sands and clays in the unified approach and it is sometimes called μ . The proportion of tangential stresses vs compression force produced underneath the analytical footings is one of the challenges with the parameter. A negative μ value indicates that the soil is compacted sands or highly over consolidated clays while a positive μ value indicates that the soil behaves as loose sand or as slightly over consolidated clay depending on the position (Altaee & Fellenius, 1994; Lommler, 2012; Michael & Student, 2021).

A soil molded into a solid mass always causes very high compressive stresses resulting in grain crushing and the challenges of interpretation were caused by the proportion of tangential stresses vs compression force produced underneath the analytical footings the μ was widely used for soil characterization and a controlling parameter in the modern constitutive understanding of soil however there is a perception that the control of soil strength by μ is merely a correlation and it is sometimes called upsilon. Below is Figure 6 showing the distance from the initial void ratio to the steady line. $\mu = e_i - e_{SSL}$ and Figure 7 ,Figure 8 show multiple-stage CD triaxial tests on undisturbed samples collected from the studied site at 2.5 and 8 m depth (Fellenius & Altaee, 1994; Lommler, 2012; Michael, 2021; Machado,1998).

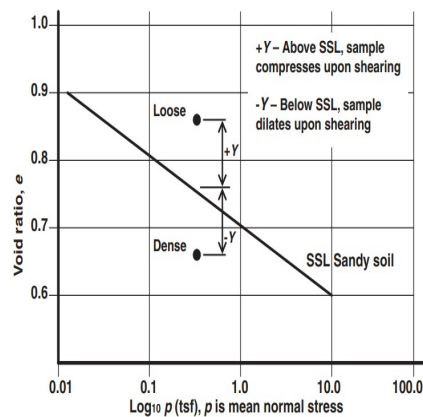


Figure 6: Upsilon parameter, $Y =$

$$e_{\text{initial}} - e_{\text{SSL}}$$

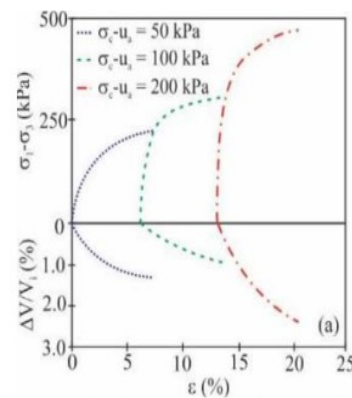


Figure 7: CD Multiple Stage Triaxial Test results (Machado, 1998).

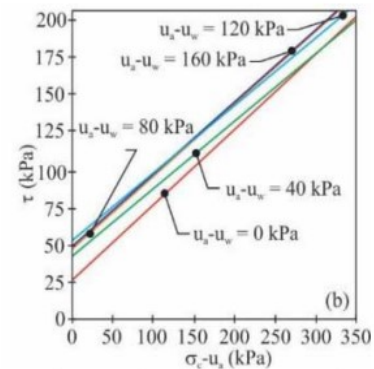


Figure 8: Shear Strength envelopes for different soil suctions

2.2.2 Measurement of Shear Strength

2.2.2.1 Laboratory using triaxial apparatus

Triaxial and shear box tests are common types of equipment used for ϕ , c , and S_u determination. The triaxial is advantageous over the shear box because actual field stress states are well replicated within the equipment by control of cell pressure, pore water pressure, pore air pressure, deviator stress, and the drainage conditions (Bujang et al., 2013). According to BS 1377: Part 8: 1990, the test is comprised of four main stages namely specimen and system preparation, saturation, consolidation, and shearing however in UU tests BS 1377: Part 7: 1990 there are no saturation and consolidation stages and additionally, S_u or soil parameters are characterized by saturated (conventional triaxial apparatus) and partially saturated specimens (double-walled triaxial apparatus)

There was an observation of an increase in c with an increase in the matric suction from a double wall triaxial test of tropical residual soils values however the (ϕ) decreased with an increase in the soil weathering grade from S_u parameters (Bujang et al., 2013). Various authors discovered that UU Triaxial cone factors relied heavily on the PI of soils while Terzaghi et al., 1996 showed that they varied from 11 to 30 (George et al., 2016) then N_{kt} values ranged from 14 to 16 in deposits where there was less experience when determining S_u by using the q_t to obtain realistic values close to the upper limit should be considered but for a deposit where there is experience suggested values must be adjusted to reflect the experience. In case there is the availability of high-quality in-situ and lab data site-specific correlations must be formulated accordingly based on the reliable value of S_u (Robertson & Cabal, 2010).

An effective stress method was recommended for the determination of the strength of silty soils. Triaxial tests using traditional approaches do not give a clear interpretation of undrained shear strength on silts, mainly because of the dilating effect of silty soils during shear. Estimating S_u can be done based on simple deviatoric stress regardless of strain, shear stress at some limiting strain, pore pressure parameter, reaching Mohr-Coulomb line, peak principal stress ratio, and peak pore pressure (Long et al., 2010).

Despite the disadvantages, laboratory analyses are the fundamental sources of information on soil geotechnical parameters. In the case of soils with poor bearing capacity strength parameters will be assessed based on both laboratories and in situ testing (Katarzyna, 2015).

2.2.2.2 In-situ using CPTU

In 1932 – 1953, the 1st CPT was developed, a manually operated 10-ton was designed, and a mechanical cone which had a conical part above the cone was used to keep soils to pass in the space within the casing and inner rods. Then a friction sleeve was fixed at the back of the cone for local sleeve friction measurement protection. From 1965 to 1974, an electric cone that measures pore pressures was created and its shape including dimensions was the benchmark of modern cones as per international reference. This cone formed corrected the q_z for pore pressure effects (Robertson, 2023). CPTU test apparatus was originally developed and refined for sedimentary soils of temperate areas. Since the early 1970s, Furgo used mechanical CPTs in tropical soils. In the 1970s, North Sea offshore hydrocarbon prospects promoted advancements in CPT apparatus for harsh environmental and ground conditions thus robust and accurate systems with electrical downhole sensors were developed. This development was followed by offshore experience with CPTs in calcareous soils (Peuchen et al., 1996).

Mechanical, Friction, Electric, and Piezocone cones are among the various types available and currently, the CPTU is widely used for testing purposes then the CPT is liked due to its reliability. During a site investigation, the rod will be directed into the soil underneath at a speed of 2 cm/sec then the information will be delivered every 2 cm (Hossain, 2018). Since 1989, electrical CPTs have been routinely used by Furgo for testing onshore and near-shore tropical residual soils (Campanella & Robertson, 1983; Peuchen et al., 1996).

Due to the CPTU applications and developments, valuable information on the soil characteristics across various countries has been gathered leading to the formulation of various empirical formulas in the determination of numerous soil parameters to be used in the foundation designs of structures of high-raised buildings in most cases by use of CPT databases (Abdul, 2017).

OCR, S_u , and Φ are among the most commonly used geotechnical parameters in foundation engineering (Eslami et al., 2019). On the other hand, Figure 9 shows how S_u determined from anisotropically consolidated undrained triaxial compression tests (CAUC) and there is a lower scatter, additionally (q_t), and ($\Delta u = u_2 - u_0$) are the common parameters in CPTU correlations.

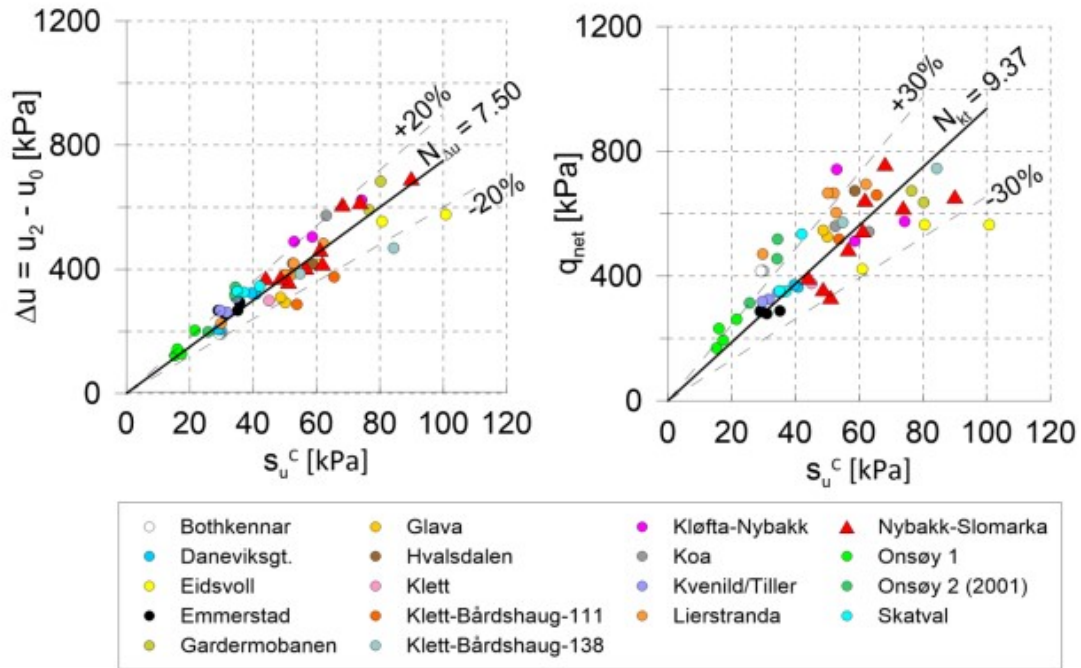


Figure 9: Δu and against CAUC S_u .

But for this research, we shall emphasize shear strength (S_u). In-situ tests are mostly used for practical applications to estimate sand and clay parameters. The complexity of the estimative of geotechnical parameters for residual soils can be associated with their unsaturated condition and a possible partially drained condition at the CPTU standard penetration rate. The success of a site investigation will need additional in situ and/or laboratory tests to support geotechnical design on these residual soils (Santos et al., 2015).

The increasing use of the CPTU in ground investigations because of its increased reliability, high speed, cost-effectiveness, and continuous soil profile makes it a valuable tool in characterizing subsurface conditions and assessing soil properties. This has resulted in the need for methods to determine the value of S_u . Theoretical correlations based upon bearing capacity theory (Terzaghi, 1943; Beer, 1977), cavity expansion (Skempton, 1951; Vesic, 1975), analytical and numerical

methods(Ladanyi, 1967), and strain path methods (The, 1987) were proposed, but because they required various assumptions, they offered no advantage over empirical methods.

When using CPTU data, S_u is determined by the use of two main groups, namely, theoretical solutions and empirical correlations. S_u is generally estimated by the use of experimental correlations rather than complex theoretical methods comprised of simple assumptions interpreting the in-situ conditions. For the case of the empirical correlations, they were further grouped into, q_c (Equation 04), q_t (Equation 05), or excess Δu (Equation 06) (Schertmann, 1978; Lunne et al., 1985; Lunne et al., 1997; Ye et al., 1998; Su et al., 2002; KG 2005; Hong et al., 2009).

$$S_u = \frac{q_t - \sigma_{vo}}{N_{kt}} \quad (4)$$

$$S_u = \frac{q_t - u_2}{N_{ke}} \quad (5)$$

$$S_u = \frac{u_2 - u_0}{N_{\Delta u}} \quad (6)$$

So,

q_t - Total cone resistance

σ_{vo} - In-situ total vertical stress.

$N_{kt}, N_{ke}, N_{\Delta u}$ - Empirical cone factor.

u_2 - Measured Pore Water Pressure

u_0 - Static Pore Water Pressure

S_u

-Undrained Shear Strength

The N_{kt} used to determine S_u based on q_t should be related to the reference values from the triaxial test and values differ highly significantly depending on the degree of subsoil over consolidation and cementation. Below are various N_{kt} values for various soil types, as detailed in Table 2 below.

Table 2:Recommended values for numerous soil types			
S/No	Soil Types	Reference	N_{kt} Values
1.0	Fine-grained soils clay Quaternary and Alluvium	Akbar Cheshomi, 2016	22-23
2.0	Saturated clays, Nigeria	Otoko et al., 2016	34.2-57.2
3.0	Silty normally consolidated	Stefanik ,2015	7-10
4.0	Cemented silty soils	Stefanik ,2015	15.5
5.0	Soft Holocene clays, Hungary	Remai, 2013	12 - 32
6.0	Busan clay, korea (N_{kt})	Hong et al.,2010	7 - 20
7.0		Almeida et al., 2010	4 - 16
8.0	Busan Clay, Korea (N_{kc})	Hong et al.,2010	3 - 18
9.0	Busan Clay, Korea (N_{Au})		4 - 9
10.0	Alluvial clays, Malaysia	Abdel Rahman ,2007	12 - 19
11.0	Alluvial clay and silt soils, Sudan	Hassan, 2004	34 - 62
12.0		Gebreselassie, 2003	7.6 - 28.4 8 - 29 89.3
13.0	Klang Clay, Indonesia	Chen, 2001	5 - 12
14.0		Karlsrud, 1996	6 - 15
15.0	Stiff fissured clays (general)	Terzaghi et al., 1996	11 - 30
16.0	Norway and one site in UK	Karlsrud, 1996	2 - 10
17.0		Bowles, 1995	Up to 70
18.0		Powell & Quaterman, 1988	10 - 20
19.0		La Rochelle et al., 1988	11 - 18
20.0		Rad & Lunne, 1988	8 - 29
21.0	Clay and silts, Sudan	Ismail & Zein ,1987	32 - 39
22.0		Aas et al., 1986	8 - 16

Table 2: Recommended values for numerous soil types			
S/No	Soil Types	Reference	N_{kt} Values
23.0		Lunne et al., 1985	1 - 13
24.0		Senneset et al., 1982	6 - 12
25.0		Lunne & Kleven 1981; Jorss, 1998	15 - 20
26.0	Various soil types	Sanglerat, 1972	5 - 70
27.0		Bowles, 1995	5 - 70

Figure 10 (a) ~ (d) shows a comparison of numerous cone factors with various studies and the values obtained $N_{\Delta u}$, N_{kt} and N_{ke} from Akbar Cheshomi, 2016 were slightly higher than those determined in previous studies.

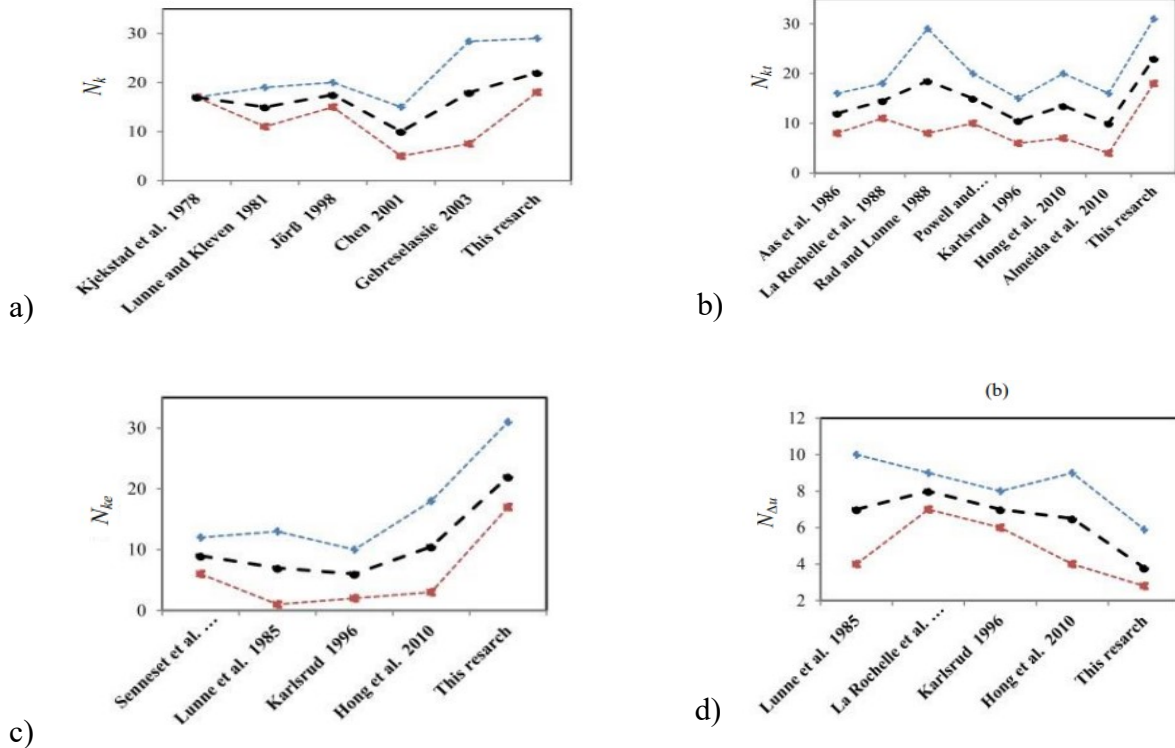


Figure 10: Akbar Cheshomi, 2016 N_{kt} versus previous studies (a-d).

The reasons for the differences in the cone factor values were may be due to different reference tests (Triaxial, Field Vane, and CPTU), soil disturbance, soil sampling methodologies, and

material properties, and however there were significant and acceptable correlations between the variables such as S_u (Akbar Cheshomi, 2016).

In silty soils, the most frequently applied in situ testing methods included vane tests (VT) and cone penetration tests probing (CPTU) (Katarzyna, 2015). Based on the results of cone penetration tests the value of S_u were calculated from equation 7, which most typically referred to shear strength from the vane test / direct shear test and it was determined using the net cone resistance value (q_{net}).

$$S_u = \frac{q_n}{N_{kt}} \quad (7)$$

Where N_{kt} – empirical cone factor.

During testing when u_1, u_2 , and u_3 measurements were encountered equations (2-6) were used (Senneset et al., 1982), and the N_{kt} was dependant on laboratory S_u to simulate subsoil loading conditions however determination was dependent on the procedure to reconstruct changes in the stress state of the subsoil. In the case of VT in soft soils, it was recommended to apply correction coefficients because the changes depended on the type of test, type of soil, and time factor (Katarzyna, 2015).

2.3 Empirical correlations

Over the years, various theoretical and empirical correlations have been formulated to obtain S_u for fine-grained soils by use of; pore pressure cone tip resistance (q_t) in terrestrial clay, (Mesri, 2001) ; pore pressure ratio and q_t using u_2 (Li et al., 2019) ; artificial neural network (Xie et al., 2019); CPT, VST and u_2 in eastern Canada (La Rochelle et al., 1988); q_t and high-quality triaxial tests for clay in bridge foundations (Tong et al., 2011); combined CPTU and indoor tests of

Fujian clay (Ni et al., 2019); in situ soil state parameters based on CPTU field test results (Duan et al., 2021); CPTU, q_t and maximum super porous pressure method in over-consolidated clay (Liu et al., 2021); combined bearing-capacity theory, direct shear modes of failure at CPTU tip and sleeve resistances, and u_2 to develop a set of analytical models (Eslami & Mohammadi, 2016); corresponding q_t , field CPTU and laboratory triaxial tests on marine clay in the Lianyungang area (Cai et al., 2006, Cai et al., 2010, Duan et al., 2021), laboratory data, CPTU data and SHANSEP parameters of clay (Yang et al., 2019); indoor mini-ball penetration tests, in-situ tests, to study the influence of temperature of marine clay (Gu et al., 2022) and introduction in initial design of offshore wind energy projects (Liu et al., 2020; He et al., 2021; Wang et al., 2022). Although these studies were carried out and conducted there was still a lack of calibration methods and combining CPTU data with soil parameters is very important (Wu et al., 2023). Then Karlsrud et al., (2005) grouped N_{kt} factors based on S_t : $S_t < 15$ and $S_t > 15$ to be compared with PI, OCR, $N_{\Delta u}$, B_q and in Sweden, Larsson et al., (2007) for normally to slightly over-consolidated clays compared both N_{kt} , $N_{\Delta u}$ with LL, however, there were no clear correlations when, Low et al., (2010) correlated onshore as well as offshore clays N_{kt} factors database with PI, S_t , strength anisotropy, and rigidity index.

So Leroueil et al., 1995; Mayne, 1986; Mayne, 2001; Powell, 2005 proposed correlations between σ'_p and OCR thus OCR increased when Q_t increased on the other side when σ'_p increased also q_{net} increased, but were related by a factor k which is clay or site-specific (see Figure 11 (Priscilla et al., 2019)).

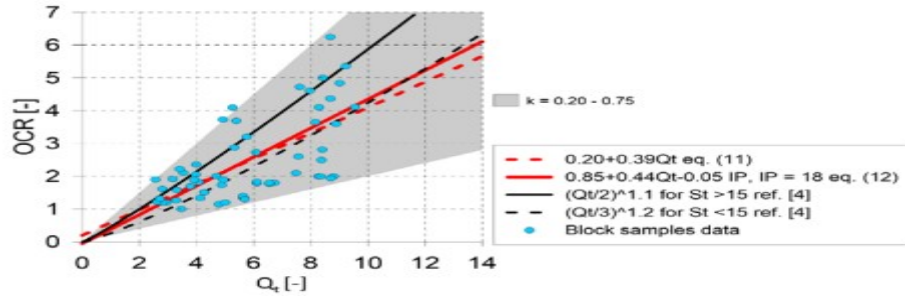


Figure 11: OCR against Q_t .

The current practice suggested that for sensitive clay, when determining S_u profile, the strain-softening behavior and time effect be taken into account when the data has been extracted from CPTU correlations, and a 15% reduction of S_u should be emphasized, thus this reduction may be included in a calculation program such as Geo-Suite Toolbox. Then during the selection of S_u profiles, Eurocode 7, Chapters 2.4.3 and 2.4.5.2 recommended that the results should be obtained from correlations/theory/empirical, and measured values must be reconciled with empirical data to make sure that the quantity falls within the expected range of the values.

S_u values vary sometimes due to the direction of loading, soil anisotropy, strain rate, and OCR, and these values used in the analysis depend on the design problem, on the other side there is a need to calibrate the laboratory tests because S_u cannot be precisely determined by the use of the CPT moreover with the aid of the empirical correlations S_u can be derived thus in Equation 4 is a relationship formulated by Lunne et al., 1997 (Robertson & Cabal, 2010).

2.4 Chapter Summary

Tropical Soil terminology is usually confusing (Vaughan et al., 1988), and there are no agreements on the boundary of the tropical soils because of different perspectives as per grades that constitute these soils (Fookes, 1997), on the other side residual soils geotechnical characteristics quantification is important for an economical and safe design, but more difficult

to predict their engineering behavior mathematically. So due to their unsaturated conditions, their engineering behavior is more complicated thus the S_u characteristics are still not well understood (Rahardjo et al., 1995).

The literature review is comprised of the definition of shear strength, drained and undrained conditions, how stability is controlled, and different names of undrained and drained shear strength then however, there are different assumptions as per analyses (Charles, 1991).

Furthermore, it is also comprised of the Development of soil shear strength models done by different authors for example coulomb in 1773, Hvorslev, Skempton, Terzaghi' and although equation deduced from Hvorslev was universally accepted, soft clays S_u remained a concern. However, these tests tend to be expensive when many tests are conducted, thus various empirical correlations between S_u and soil properties have been formulated with the aid of index tests (Vikas, 2016). Work done from the late 1960s showed that some clays displayed normalized behavior (James, 2005), however there is a difference in the degree of cementation. (Karlsrud et al., 2005; Priscilla et al., 2019; Larsson et al., 2007; D'Ignazio et al., 2016; Chung et al., 2002; Watabe et al., 2002; Bo et al., 2003; Moses et al., 2003; Steiger & Leung, 1991). So, it would be of great value if the use of SHANSEP knowledge could be transferred to tropical soils (Gutierrez et al., 2008). It was stated that the soil mechanics classical concepts and OCR were not almost universally applicable to residual soils although in sedimentary soils the behavior of the soils depends on the OCR (Blight & Leong, 2012; Vaughan, 1985; Wesley, 2010). However, there is a belief that the control of soil strength by μ is merely a relationship and it is sometimes called upsilon. (Fellenius & Altaee, 1994; Lommler, 2012; Michael, 2021) so it was suggested than an

upper value for a more conservative estimate but for a deposit where there is experience suggested values must be adjusted to reflect the experience.

In case there is the availability of high-quality in-situ and lab data site-specific correlations must be formulated accordingly based on the reliable value of S_u (Robertson & Cabal, 2010). Due to the CPTU applications and developments, valuable information on the soil characteristics across various countries has been gathered leading to the formulation of various empirical formulas in the determination of numerous soil parameters to be used in the foundation designs of structures of high-raised buildings in most cases by use of CPT databases (Abdul, 2017), and additional tests result into a successful investigation to obtain appropriate parameters for the residual soils designs (Santos et al., 2015).

The N_{kt} used to determine S_u based on q_t should be related to the reference values from the triaxial test and values differ highly significantly depending on the degree of subsoil over consolidation and cementation. It was pointed out that there is still a lack of calibration methods based on high-quality laboratory testing for analyzing soil parameters such as S_u . Additionally, combining CPTU data with soil parameters is a valuable research endeavor (Wu et al., 2023). Therefore there is a need to calibrate the laboratory tests because S_u cannot be precisely determined by the use of the CPT moreover with the aid of empirical correlations S_u can be derived. Low et al., (2010) attempted to correlate, based on a database of onshore as well as offshore clays from different sites around the world, cone factors to soil parameters such as IP , S_t , strength anisotropy, and rigidity index but showed no clear correlations.

CHAPTER THREE : RESEARCH METHODOLOGY

3.1 Introduction

This Chapter focused on research methods which discussed and explained how and why the particular research methods were chosen then it described in detail the techniques employed within the research. It further elaborated the following; test pit excavation, data collection of CPTU points from the western and central regions of Uganda, in situ tests namely cone penetrometer; laboratory work namely particle size distribution, oedometer, atterberg limits, and CU triaxial test, etc., and interpretation of results.

3.2 Research strategy

To accomplish the research, 32 CPTU points were conducted in the field, Soil Samples were taken to the laboratory for particle size distribution, carrying out Atterberg Limits Tests, and Oedometer Tests materials. Within this research there were two methods related to earlier literature SHANSEP s and m constants, N_{kt} cone factors equations related with Atterberg limits parameters were compiled into which numerical values or earlier equations were substituted.

For the case of SHANSEP constants, OCR was determined by the relationship of the ratio of pre-consolidation pressure to present effective vertical pressure then the pre-consolidation pressure was determined by the correlation formulated by Stas & Kulhawy in 1984 after which OCR values obtained from the relationship of OCR were substituted into SHANSEP formulae by Ladd & Foot, (1994) with the earlier literature s and m constants to obtain an estimated S_u close to the laboratory triaxial values and from these values obtained the s and m constants were adjusted to obtain an S_u for a similar literature lightly consolidated and over consolidated clays to obtain the s and m constants to be used in the current study.

Then for the case of the cone factors, N_{kt} literature equations, Atterberg limits and plasticity Index numerical values were substituted into them to obtain various cone factors, N_{kt} which were also furthermore inserted into an expression stated by (Schertmann, 1978; Lunne et al., 1985; Lunne et al., 1997; Ye et al., 1998; Su et al., 2002; KG 2005; Hong et al., 2009) to obtain S_u . From those cone factors, N_{kt} values obtained were adjusted to obtain a S_u for similar literature lightly consolidated and over-consolidated clays to obtain cone factors, N_{kt} values to be used in the current study.

3.3 Data collection

This was conducted by case studies with the aid of direct observation, documents, archival records, and participant observation as sources of information. The CPTU tests were conducted on two (02) sites namely Ngwendo sub-county in Buliisa district (site 2) and Buloba in Wakiso district (site 1) and too laboratory tests were conducted.

3.3.1 Sampling

This was done with the aid of direct soil sampling methods such as pits then undisturbed and disturbed samples were collected from where the CPTU reference points were marked as per the selected existing sites so that the samples were transported to the laboratory for testing and in this study we analyzed a total of eighty-one (81) samples such that twenty-eight (28) samples were for liquid limit tests, twenty-eight (28) samples for plastic limits, twelve (12) samples for consolidation and thirteen (13) samples for undrained shear strength using triaxial testing.

3.4 SHANSEP Procedure

SHANSEP by Ladd and Foot, (1994) was used to determine the S_u based on the relevant measurements and experience data but in various cases, it is a weighted mean of the available

data then the values vary greatly according to the depth so one should be careful while taking measurements of the S_u . Often the following assumptions were made for a simple shear strength path based on results presented by Ladd, (1991) for practices where we cannot run the laboratory tests.

$$s = 0.20 \text{ to } 0.25 \text{ (0.2 for low Plasticity and 0.25 for high plasticity soils)}$$

$$m = 0.8$$

The pre-consolidation pressure was determined by the correlation formulated by Stas and Kulhawy, (1984) expressed as shown in equation 8;

$$\frac{\sigma'_c}{p_a} = 10^{(1.11 - 1.62LI)} \quad (8)$$

Where;

$$p_a = \text{Atmospheric Pressure}$$

$$LI = \text{Liquidity Index}$$

Then the Over Consolidation ratio (OCR) for soil was determined with the relationship expressed as in equation (09);

$$OCR = \frac{\sigma'_c}{\sigma'_{vo}} \quad (9)$$

Where; σ'_c = Preconsolidation pressure of a specimen

$$\sigma'_{vo} = \text{Present effective vertical pressure}$$

3.5 Laboratory Tests

3.5.1 Moisture Content

This was taken to be the amount of water, and the necessary equipment included a desiccator, a metal container, and a Drying Oven with a temperature from 105°C to 110°C. Additionally, the process was as follows: once the container was cleaned, dried, and weighed to the nearest 0.1g (ml), a representative sample was crushed and placed loosely inside the container. The sample container was immediately weighed in square meters (m²) and put in the oven to dry at 105 ° C for at least 12 hours. once it dried, the container and its content were weighed Following BS 1377: Part 2: 1990 then the moisture content of the soil specimen, w, as a percentage of the dry soil mass to the nearest 0.1% was the moisture content for the soil sample and below the equation (10) was used;

$$W = \left(\frac{m_2 - m_3}{m_3 - m_1} \right) \times 100 (\%) \quad (10)$$

3.5.2 Atterberg Limit (cone penetrometer method)

The Atterberg limit included LL, PL, and SL values. In the first step of the LL test, the soil sample was air-dried and then passed through a 425-micron SI sieve, and 150g of sieved soil was mixed thoroughly with distilled water to form a uniform paste. A brass cup of 50mm internal diameter and 50mm height was filled so that there was no air entrapped within the cup by leveling. Then the cone was gradually lowered to just touch the surface of the soil as a Graduated scale reading was noted as the initial reading. Then the author started the timer and pressed the push button so that the cone was released to be allowed to penetrate the soil for 5 seconds. After the 5 seconds, readings from the graduated scale were taken as the final readings.

So, the depth up to the cone penetrated the soil sample was taken and the penetration to the nearest millimeter was noted say P_1 mm. Some soil was scooped off from the cup and its water content was determined by use of the water content determination methods. The remaining soil was removed from the cup and cleaned for another sample to be filled.

The author added more water to the soil and again made a uniform paste. Then the experiment was repeated and the values of P_2 , P_3 , P_4 , and corresponding water moisture contents W_2 , W_3 , and W_4 were noted. So by use of the above results liquid limit of the soils was determined by drawing a graph having penetration on the x-axis and Water moisture content on the y-axis then a best-fitting line was drawn through the experimental points. From the graph, the water moisture content value which corresponds to 20mm penetration was read and it was the value taken as the liquid limit of the soil.

Then in the case of the Plastic limit test, a thoroughly mixed portion of a 20-gm soil was passed through a 425-micron I.S. sieve and then mixed thoroughly with distilled water in an evaporating dish so that the soil was plastic enough to be easily molded within the fingers. The soil sample prepared was allowed for 24 hours for the water to permeate through the soil mass. 8 gm of the plastic soil mass was rolled between the fingers and glass plate into a thread of uniform diameter throughout its length. This rolling was continued till the thread was 3mm in diameter. The soil sample was again kneaded together to a uniform mass and re-rolled then rolling was continued until the thread crumbled when the diameter was 3mm. The pieces of the crumbled thread were collected and then fixed within an air-tight container for moisture content determination. This above was repeated at least 3 times and an average of the results was calculated to the nearest whole number.

3.6 Cone factor

Earlier published equations 11, 12, 13, 14, 15, and 16 were used to obtain N_{kt} and then substituted into equation 2-4 to estimate S_u for the sites under study. The N_{kt} values were supplemented with already published data from the literature as shown in Table 2-2

$$N_{kt} = 7.95 + 0.13PI \quad (11)$$

$$N_{kt} = 0.285PI + 7.636 \quad (12)$$

$$N_{kt} = 13.4 + 6.65 * LL \quad (13)$$

$$N_{kt} = 27. - \frac{3.6LL}{PL} \quad (14)$$

$$N_{kt} = 1.11x \left(\frac{21 + PL^2}{LL} + \frac{20}{\ln(LL)} \right) - 1.79 \quad (15)$$

$$N_{kt} = 4PI - 48 \quad (16)$$

After having determined the S_u from the above two methods, the values of S_u were compared with the S_u from the laboratory.

3.7 Empirical Relationship Creation

Due to extreme values, and small sample size, assumptions and conditions of the parametric statistical procedures are not met thus a normal distribution could be followed so nonparametric tests were used (Huma & Mubashir , 2017). Therefore the empirical creation was checked by use of CPT-pro software, Microsoft Excel capable of calculating: σ_{vo} , σ'_{vo} , q_t , f_t , R_f , Q_t , F_r , B_q

CHAPTER FOUR : ANALYSIS, DISCUSSION OF RESULTS

4.1 Introduction

This Chapter is comprised of the site characterization or results, formulation of the proposed model for estimating the S_u , and proposed correlations.

4.2 Site characterization and results

The general soil characterization of the two sites is shown in Table 3 and named according to the USCS system.

Table 3: Classifications for sites 1 and 2

Site 1		Site 2	
Depth, m	USCS Name	Depth, m	USCS name
1.25	CL	10.5	CL
1.75	CH	12.25	CL
2	CL	12.75	CL
2.4	CL	15.75	CL
2.6	CL	16.75	CL
	CH	19.25	CL
5.4	CL	21.15	CL
8.75	CL	23.15	CL
8.9	SM	26.5	CL
9.5	CL	39.975	CH
13	CL	41	CL
17.5	CL	45	SC
18.9	CL	49.25	CL
20.5	CL	57.5	CL

Generally, at Site 1, fine content ranged from 50% to 78%, natural moisture content ranged from 11.6% to 32.9% within a depth of 26.0-30.0 while the lowest was within a depth of 20.0 – 30.0m as shown in Figure 12. The Liquid Limit ranged from 36.5% to

55.8%, Plastic Limit from 20.6% to 26.7%, Plasticity Index from 14.6% to 29.5% and Linear Shrinkage from 0.7% to 15.0% as shown in Figure 13. The CU Triaxial laboratory S_u ranged from 30kPa to 68 kPa, and internal friction ϕ ranged from 0.03° to 15.6° as shown in Figure 15 and Figure 14.

At site 2 the fine content ranged from 46.4% to 98%, and natural moisture content ranged from 8.8% to 27.0% with the highest within a depth of 15.0-15.3 while the lowest was within a depth of 12.0 –12.3m as shown in Figure 12. The Liquid Limit ranged from 28.9% to 53.3%, Plastic Limit from 15.6% to 24.2%, Plasticity Index from 13.0 % to 29.1% and Linear Shrinkage from 0.4% to 13.6% as shown in Figure 13. Open and filled symbols are for Buloba and Buliisa respectively.

The CU Triaxial laboratory S_u ranged between 80 kPa to 158 kPa, the internal friction ϕ ranged from 8.5 to 15.7 and cohesive values from 8.7 to 24.5 as shown in Figure 15 and Figure 14 with the open and filled symbols for Buloba and Buliisa respectively.

The change curves for the q_t , friction ratio, u_1, u_2, u_3 , SBT Index, and SBT for sites 1 and 2 are presented in Figure 16 and Figure 17.

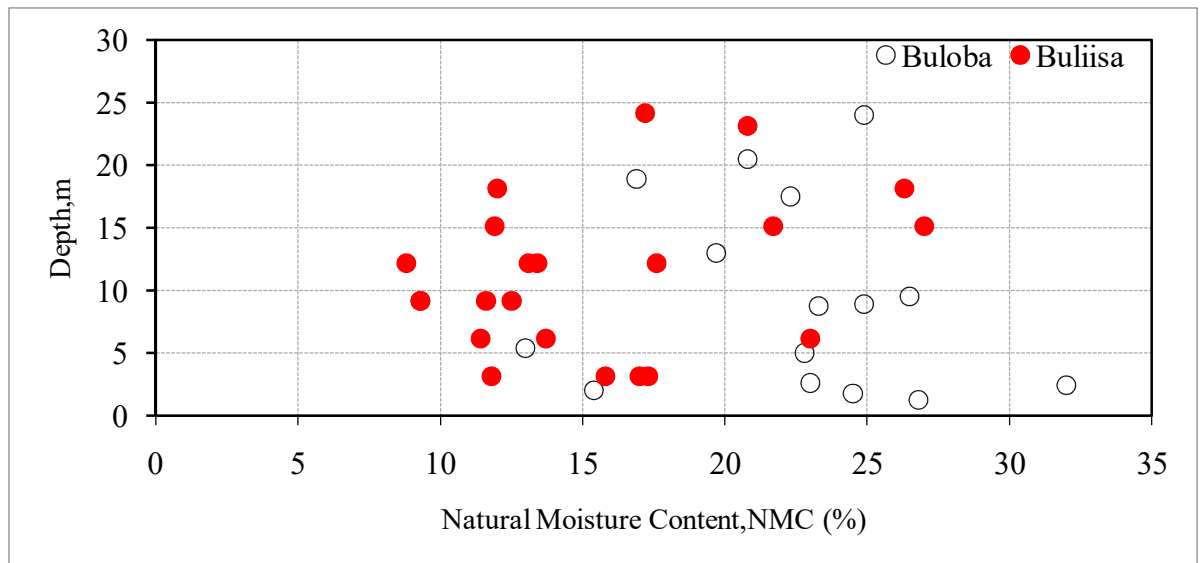


Figure 12: Variation of NMC with depth.

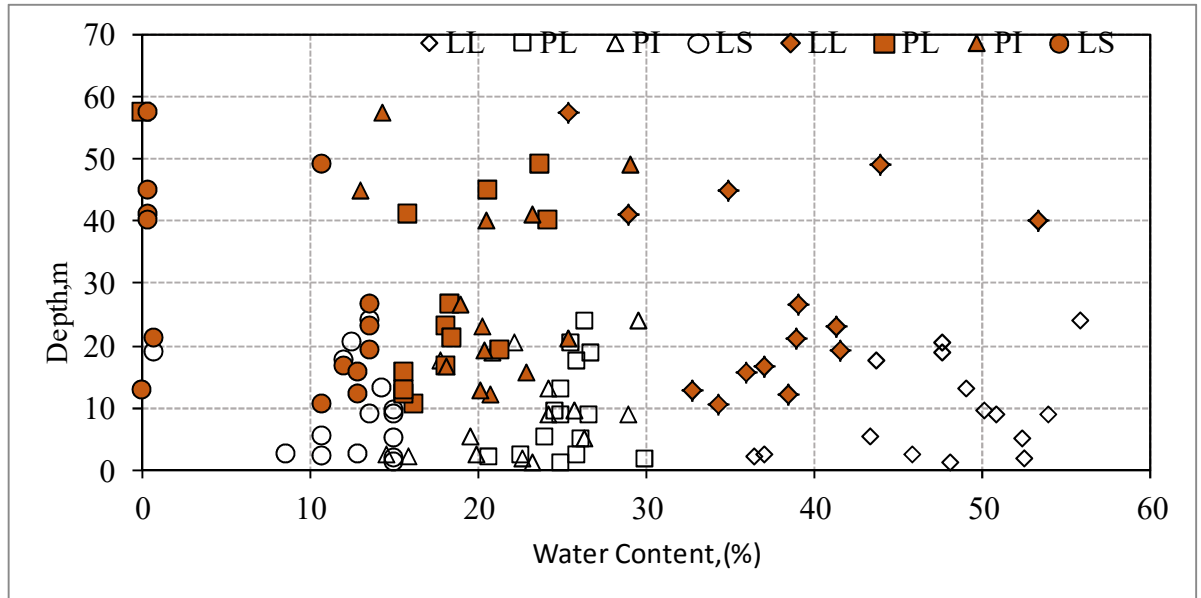


Figure 13: Variation of Atterberg limits with depth.

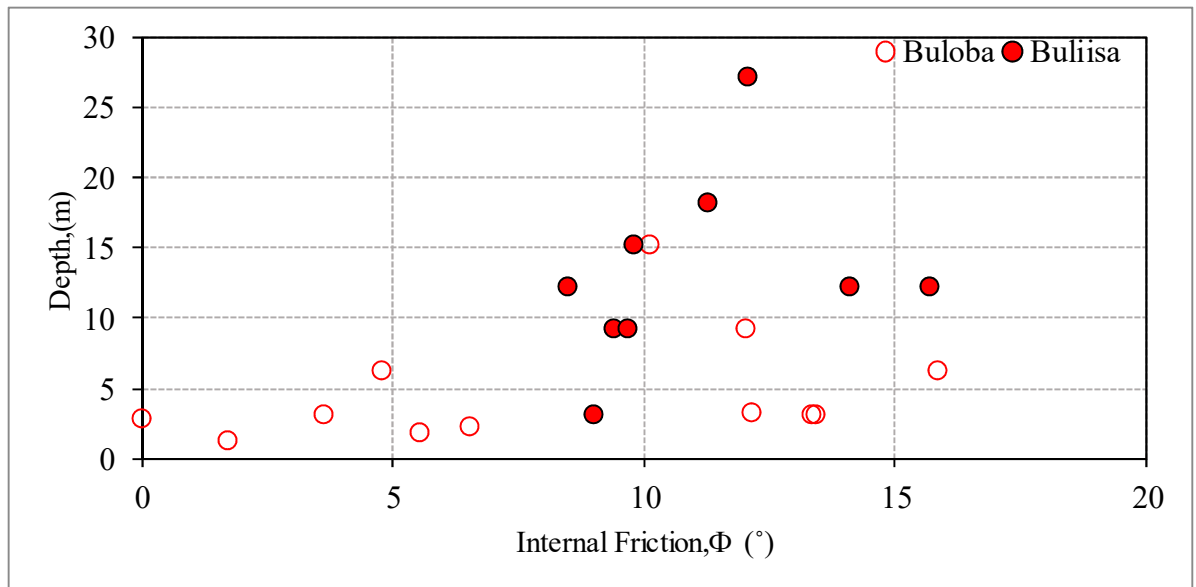


Figure 14: Variation of internal friction with depth.

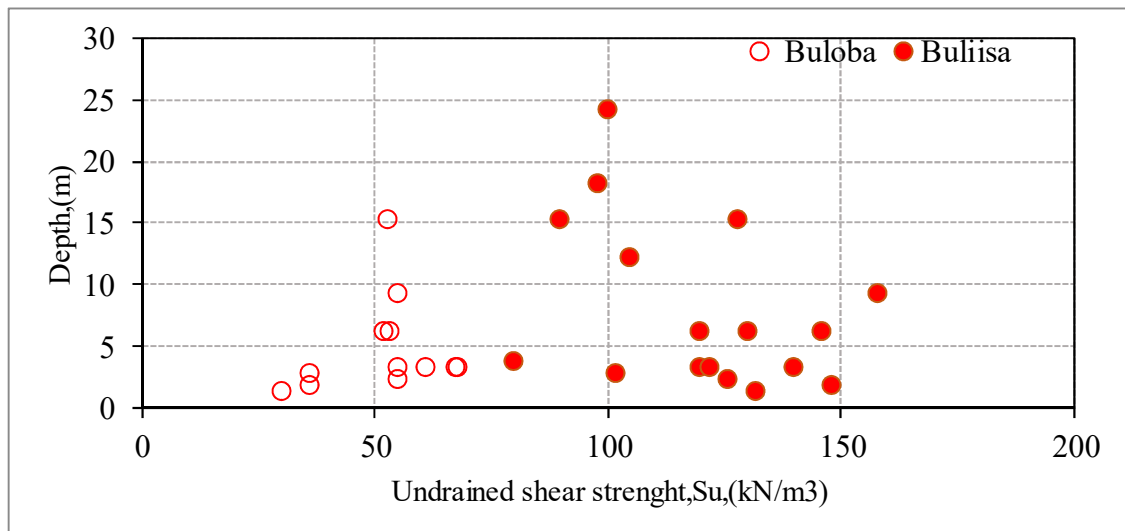
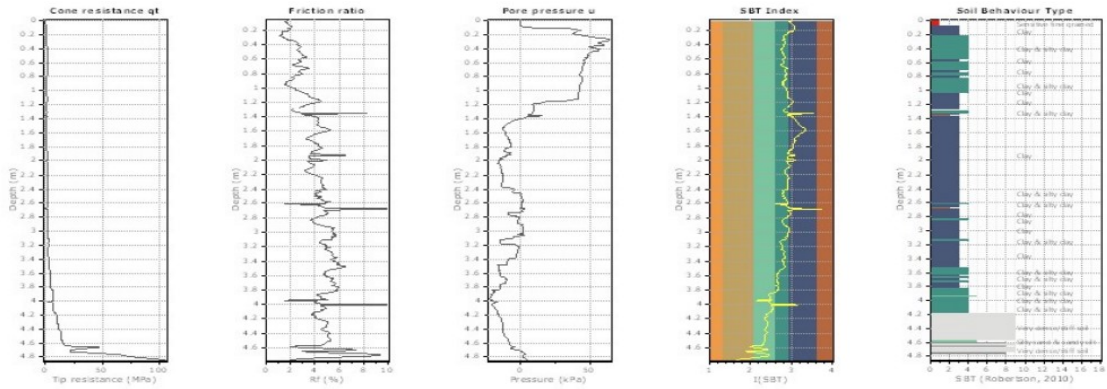


Figure 15: Variation of S_u with depth.



SBT legend

- | | | |
|---------------------------|------------------------------|-----------------------------------|
| 1. Sensitive fine grained | 4. Clayey silt to silty clay | 7. Gravely sand to sand |
| 2. Organic material | 5. Silty sand to sandy silt | 8. Very stiff sand to clayey sand |
| 3. Clay to silty clay | 6. Clean sand to silty sand | 9. Very stiff fine grained |

Figure 16: CPTU Profile Site 1 borehole 1.

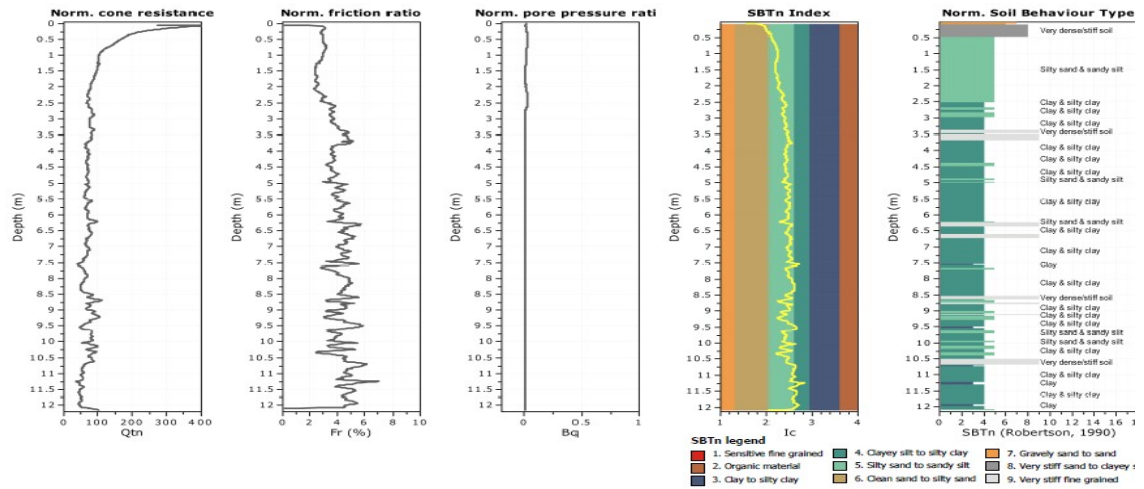


Figure 17: CPTU Profile Site 2 borehole 1.

Results from the laboratory tests are presented below in Table 4.

Table 4: Laboratory S_u for sites 1 and 2

Site 1		Site 2	
Depth, m	Lab TXT S_u (kPa)	Depth, m	Lab TXT S_u (kPa)
2.5	30.0	3.15	140
7.5	36.0	6.15	146
10.0	55.0	12.15	105
16.0	36.0	15.15	90
19.0	67.5	18.15	98
22.0	61.0	21.15	100
26.0	52.0	24.15	80
30.0	53.0	27.15	130

It can be observed that the laboratory S_u increased with depth to a maximum of about 67.5 kPa, and 90 kPa and started decreasing with the increase in depth. This observation is similar to results reported by studies conducted by (Stefaniak, 2015). S_u decreases as Moisture content increases with depth and when moisture content is low the S_u will be higher leading to a higher internal friction.

4.3 Formulation of the proposed model for estimating the S_u

The formulation involved two approaches, the use of SHANSEP where the OCR was estimated using existing equations from the literature, and the use of cone factor, N_{kt} estimated from existing equations from the literature. These estimated S_u values were then compared with the laboratory S_u results to come up with an appropriate model.

4.3.1 Determination of the constants for the SHANSEP approach.

The constants within this study were determined by the SHANSEP principle formulated according to Ladd & Foott, (1974) expressed as equation 3 an empirical relationship widely used in Norway. Then the empirical relationship to predict the pre-consolidation pressure proposed by (Stas & Kulhawy, 1984) presented as Equation 8 was used and the relationship may change depending on the soil type. S_u is a characteristic profile, which refers to the active S_u profile usually based from experience or measurements but it changes with depth. Often the following assumptions were made for a simple shear strength path based on results presented by Ladd, (1991) for practices where laboratory tests cannot be conducted.

$$s = 0.20 \text{ to } 0.25 \text{ (0.2 for low Plasticity and 0.25 for high plasticity soils)}$$

$$m = 0.8$$

4.3.2 Determination of the cone factor N_{kt} from the existing equations.

The study employed earlier published equations 11 – 16 to obtain N_{kt} and then substituted the N_{kt} values into equation 4 to estimate undrained shear strength for the sites under study.

Changes in S_u with depth were determined based on changes in q_t and calculated from equation 4 using N_{kt} , the empirical cone factor derived from equations 11 – 16.

4.3.3 Estimation of S_u using SHANSEP approach

The over-consolidation ratio obtained by substitution of Equation 8 into OCR of Equation 9 was used in this method to estimate the S_u of the soil. The constants s and m were chosen from the lowest, median, and highest values recorded from the literature (as seen in Tables 8 to Table 14) then the s constant was adjusted and optimized to fit the laboratory S_u as shown in Table 5.

Table 5: Variation of the constants s and m

s	m	depth,m	γ ,(kN/m ³)	σ'_{vo} (kPa)	OCR	SHANSEP S _u (kPa)	Lab TXT S _u (kPa)
Lowest s and m constants							
0.21	0.45	2.5	18	45	21.099	37.27	30
0.21	0.45	7.5	18	135	15.234	96.56	36
0.21	0.45	10.0	18	180	8.79	100.53	55
0.21	0.45	16.0	18	288	9.967	170.20	36
0.21	0.45	19.0	18	342	8.002	183.10	67.5
0.21	0.45	22.0	18	396	7.165	201.73	61.0
0.21	0.45	26.0	18	468	3.284	167.82	52.0
0.21	0.45	30.0	18	540	0.4519	79.32	53.0
Median s and m constants							
0.49	0.65	2.5	18	45	21.099	160.02	30
0.49	0.65	7.5	18	135	15.234	388.47	36
0.49	0.65	10.0	18	180	8.79	362.29	55
0.49	0.65	16.0	18	288	9.967	629.01	36
0.49	0.65	19.0	18	342	8.002	647.59	67.5
0.49	0.65	22.0	18	396	7.165	697.88	61.0
0.49	0.65	26.0	18	468	3.284	496.71	52.0
0.49	0.65	30.0	18	540	0.4519	157.89	53.0
Highest s and m constants							
0.73	0.78	2.5	18	45	21.099	354.37	30
0.73	0.78	7.5	18	135	15.234	824.62	36
0.73	0.78	10.0	18	180	8.79	715.99	55
0.73	0.78	16.0	18	288	9.967	1,263.56	36
0.73	0.78	19.0	18	342	8.002	1,264.28	67.5
0.73	0.78	22.0	18	396	7.165	1,343.03	61.0
0.73	0.78	26.0	18	468	3.284	863.70	52.0
0.73	0.78	30.0	18	540	0.4519	212.15	53.0
Adjusted s and m constants							
0.07	0.45	2.5	18	45	21.099	12.42	30
0.07	0.45	7.5	18	135	15.234	32.19	36
0.07	0.45	10.0	18	180	8.79	33.51	55
0.07	0.45	16.0	18	288	9.967	56.73	36
0.07	0.45	19.0	18	342	8.002	61.03	67.5
0.07	0.45	22.0	18	396	7.165	67.24	61.0
0.07	0.45	26.0	18	468	3.284	55.94	52.0
0.07	0.45	30.0	18	540	0.4519	26.44	53.0

It was observed from Table 5 that the lowest S_u determined ranged from 37.27kPa to 201.73 kPa (when $s = 0.21$, $m = 0.45$), the median ranged from 157.89 kPa to 697.88kPa (when $s = 0.49$, $m = 0.65$), the highest ranged from 212.15 kPa to 1,343.03 kPa (when $s = 0.73$, $m = 0.78$) then when s and m constants adjusted (when $s = 0.07$, $m = 0.45$) S_u determined ranged from 30 kPa to 67.5 kPa. It is also further observed that the correlations between SHANSEP, S_u , and laboratory S_u at the lowest s and m gave an $R^2 = 0.59$; median gave $R^2 = 0.49$; highest s and m gave $R^2 = 0.37$; and the adjusted s and m constants gave $R^2 = 0.79$.

A comparison of the S_u values obtained by the use of the minimum, maximum, median, and adjusted s and m constants is shown in Figure 18. It can be observed that constants of $s = 0.07$ and $m = 0.45$ gave a better fit of the estimation with the laboratory results. This could be due to NMC change which results in excess u_1, u_2, u_3 and any rise in u_1, u_2, u_3 reduces soil S_u as shown in Table 4 and Table 5 S_u decreases down the depth for values of S_u obtained by use of the minimum, maximum, median, adjusted s and m constants.

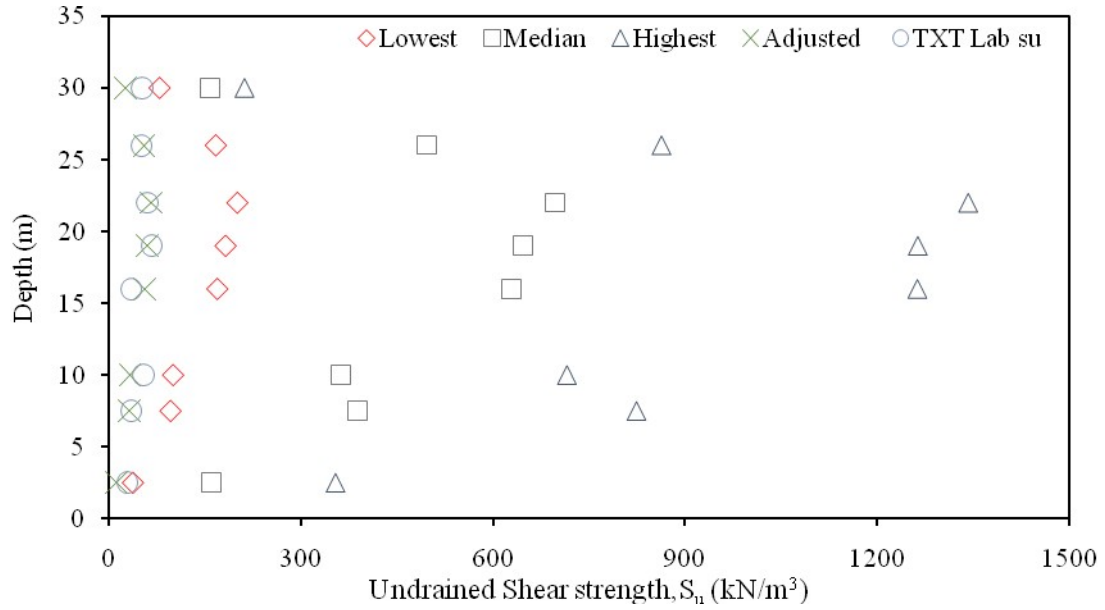


Figure 18: SHANSEP S_u versus laboratory results.

4.3.4 Estimation of S_u using cone factor, N_{kt}

After the substitution of Atterberg limit values into equations 11 – 16 as seen in the Tables 15 to Table 52, the minimum and maximum N_{kt} values obtained for each equations are presented in Table 6 below.

Table 6: N_{kt} values obtained from Equations 11 –16

Equation Number	N_{kt} Values
Equation 11	9.85 - 11.79
Equation 12	11.79 - 16.04
Equation 13	256.12 - 384.47
Equation 14	19.50 - 21.36
Equation 15	29.19 - 35.36
Equation 16	10.40 - 70.00

The N_{kt} values in Table 6 were used together with equation 4 to estimate the S_u and details documented within Table 7, and the minimum N_{kt} was 9.85, the median 19.5, and the Maximum was 384.47. On site 1, the undrained shear strength ranged from 2.94 kPa (for the maximum values of N_{kt}) to 197.25 kPa (for the minimum values of N_{kt}). At Site 2, the undrained shear strength ranged from 40.48 kPa (for the maximum values of N_{kt}) to 2,369.85 kPa (for the minimum values of N_{kt}) as shown in Table 7. Figure 19 illustrated the relation for both sites comprised of the lower, middle, and upper S_u determined by method 2 against TXT Lab S_u tested on both sites.

Table 7: S_u values determined by use of equations from 11 to 16

	N_{kt} Values	Site 1		Site 2	
		Lower	Upper	Lower	Upper
Minimum values recorded	9.85	114.94	197.21	1,767.08	2,369.37
	11.8	95.94	164.62	877.05	1,622.23
	11.8	58.06	99.62	877.05	1,175.73
	19.5	58.06	99.62	596.21	799.26
	29.2	38.77	66.52	67.98	91.13
	256.1	4.42	7.58	1,767.08	2,369.37
Maximum values recorded	16.00	70.76	121.41	1,088.09	1,458.64
	21.00	52.90	90.77	491.79	894.50
	35.40	31.98	54.87	491.79	659.27
	70.00	16.17	27.75	248.71	333.40
	384.5	2.94	5.05	45.28	60.70
Median values recorded	10.40	108.86	186.78	1,673.99	2,244.06
	19.50	58.06	99.62	892.79	1,196.83
	21.4	52.90	90.77	813.33	1,090.57
	29.2	38.77	66.52	596.21	799.26
	35.4	31.98	54.87	491.79	659.27
	70.0	16.17	27.75	248.71	333.40

Figure 19 is a comparison of S_u values obtained from laboratory consolidated undrained Triaxial test against those obtained from equation 4 after having substituted cone factors, N_{kt} values determined from the earlier formulas equation 11 – 16 in Table 6 at a depth

of 3.54m. Whereas there was some degree of agreement with the samples from the Buloba site, the results from Buliisa minimum and median N_{kt} values used showed a big disparity. When the maximum N_{kt} values were used, the laboratory triaxial results showed comparable results compared to the median and maximum values on N_{kt} of the Buloba site.

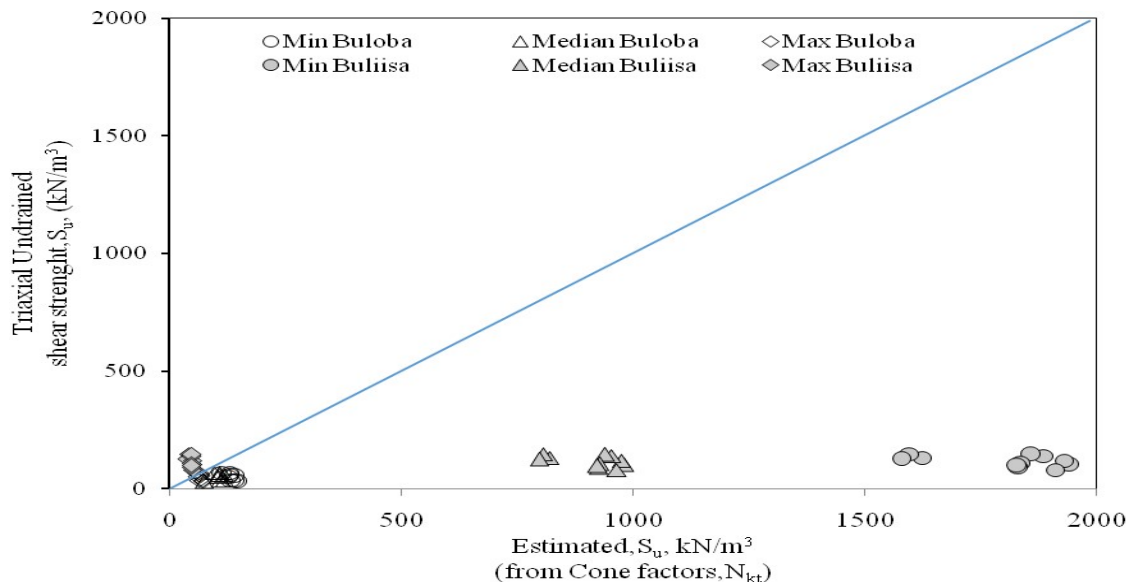


Figure 19: Various S_u from N_{kt} values versus S_u TXT.

S_u values determined from N_{kt} values 28 to 39 values as shown in Table 2 reported by (Ismail, 1987; Hassan, 2004; Gebreselassie B, n.d.; Otoko, Fubara et al., 2016; Rad & Lunne, 1988; Rémai, 2013; Terzaghi et al., 1996; Zein, 2017) agreed with the Laboratory S_u CU compression for site 1 while for site 2 there were no any of the cone factors N_{kt} to be substituted into equation 4 from the literature review which gave S_u values in agreement with that from the Lab TXT S_u CU compression.

Generally, the N_{kt} values for site 2 were higher as compared to those in some other research papers reported by (Joseph, 1997; Jorss, 1998; Lunne & Kleven, 1981; Senneset et al., 1982; Lunne et al., 1985; Aas et al., 1986; Rad & Lunne, 1988; Ismail, 1987; La Rochelle et al., 1988; Powell & Quarterman, 1988; Bowles, 1995; Karlsrud et al., 1997; Terzaghi et al., 1996; Chen, 2001; Hassan, 2004; Rahman, 2007; Almeida et al., 2010; Hong et al., 2010; Rémai, 2013; Stefaniak, 2015), and the higher N_{kt} were due to various reasons such as differences in the nature, testing techniques, and geological history, and in-situ conditions prevailing during testing.

The various values determined by use numerous different techniques may be due to various factors such as different assumptions used, type of soils, different precisions, etc. and it is essential to consider these factors when interpreting data and making conclusions. For example, Stefaniak, (2015) reports that for silty soils, the S_u estimated from the Vane shear test were identical to the laboratory triaxial result, however, this was not observed with results at site 1 but agreed with results at site 2 because the soils included both clay and silts soils.

For the case of the S_u estimated from SHANSEP, the m and s constants used were different as compared to those obtained by (Yang et al., 2019) when using a direct method of SHANSEP. The cause of this could be because the study by (Yang et al., 2019) contained specifically clay, and the soils were quite different.

4.4 Proposed correlations.

As seen in Figure 20, after having offset S_u obtained by SHANSEP parameters and N_{kt} factors in the present study close to the S_u obtained in the (Thakur et al., 2016) and (White et al., 2019) studies for lightly consolidated clays and heavily consolidated clays soils thus equation 13 was modified to equation 18 and equation 15 was modified to equation 17.

$$N_{kt} = 1.9x \left(\frac{21 + PL^2}{LL} + \frac{23}{In(LL)} \right) - 6.0 \dots\dots\dots (17)$$

$$N_{kt} = 34 + 4.76LL \dots\dots\dots (18)$$

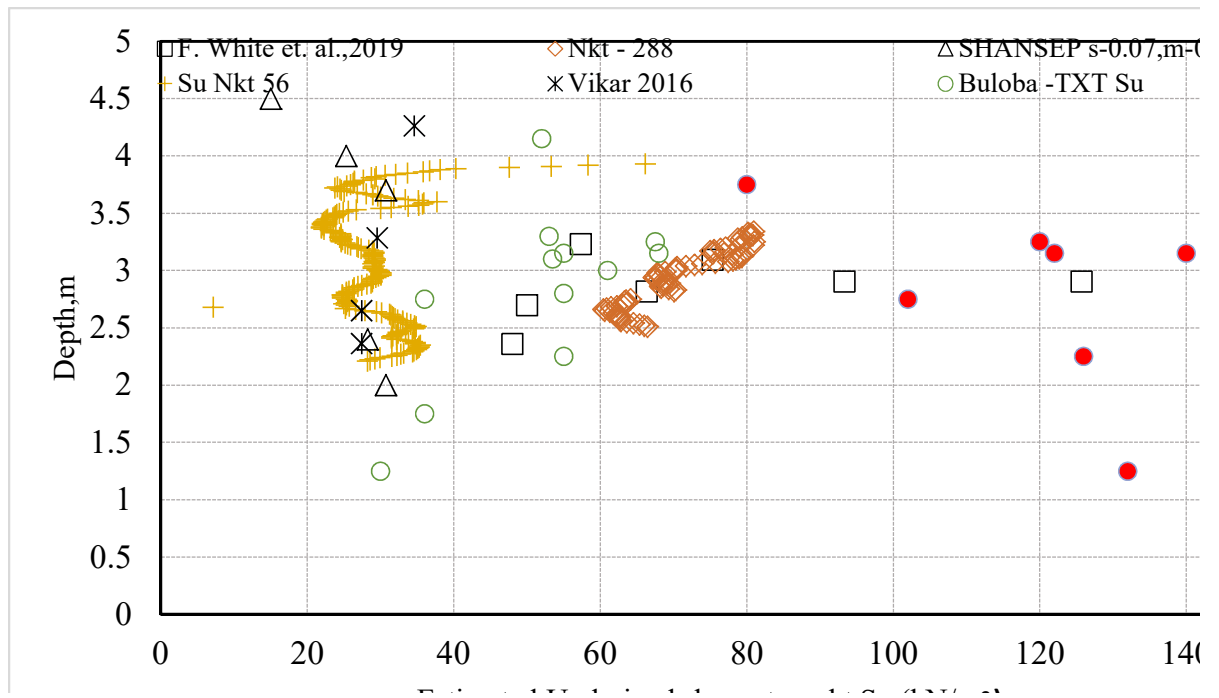


Figure 20: Current S_u values versus previous literature TXT lab S_u .

CHAPTER FIVE : CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this study, the empirical relationships of residual soil parameters based on piezocone and laboratory tests for tropical soils to determine field S_u were assessed.

It was observed that N_{kt} value of 56 is proposed for slightly consolidated residual soils while $N_{kt} = 288$ should be used for heavily consolidated residual soils during the estimation of S_u . Furthermore, the study concludes that SHANSEP constants of $s = 0.07$ and $m = 0.82$ should be appropriate for estimating the S_u of residual soils, and

5.2 Recommendations

It is important to use the appropriate correlation for a specific soil type and site conditions and to be aware of the uncertainties associated with the empirical relationships.

REFERENCES

- AAS, G., LACASSE, S., LUNNE, T. & HØEG, K. (1986). Use of in situ tests for foundation design on clay. *In Proceedings ASCE Specialty Conference in Situ 86*, 1-30.
DOI:10.1016/0148-9062(88)92781-7, Corpus ID: 113868845
- AAS, G. (1965). Study of the Effect of Vane Shape and Rate of Strain on Measured Values of In Situ Shear Strength of Clays. *Proc. 6th International Conference on Soil Mechanical Foundation Engineering, Montreal*, 1, 141–145.
- ALMEIDA M. MARQUES M, B. M. (2010). Geotechnical Parameters of very soft clays from CPTu. *2nd International Symposium on Cone Penetration Testing, CPT' 10*, 2–46.
- ALTAE, A., & FELLENIUS, B. H. (1994). 153 Physical Modeling. *In Canadian Geotechnical Journal* (Vol. 31, pp. 420–431).
- BELL A L. (1915). Lateral pressure and resistance of clay and the supporting power of clay foundations. *Proc. Institute for Civil Engineers.*, 149, 233.
- BEN HE A, SHAOLI YANG B, K. H. A. B. (2021). Soil parameters for offshore wind farm foundation design: A case study of Zhuanghe wind farm. *Engineering Geology*, Volume 285, article id. 106055.
- BENNETT, H. H. & R. J. ALLISON, (1928). soils of Cuba. Washgton. *American Journal of Agricultural Economics*, vol. 10, issue 4, 558-559
- BERRE, T. 1992. Geotechnical properties of clay-shales. *Norwegian Geotechnical*

Institute, Report No. 541082-3.

BISHOP A. W. (1966). The recent development of testing techniques on soft soils have agreed with the σ' envelope as non-cohesive soils. *Rankine Lecture, Geotechnique*, 2(16), 91 – 130.

BJERRUM, L. (1961). The effective shear strength parameters of sensitive clays. ISSMGE, 5 Paris, 1961, *Proceedings*, 1(NGI pub 45), 23–28.

BLIGHT G E AND LEONG E C. (2012). Mechanics of residual soils. *CRC Press*.

BOWLES, J. E. (1995). Foundation Analysis and Design (5th Edition). *McGraw-Hill Science/Engineering/Mat*.

BRAND, E. W; PHILLIPSON, H. B. (1985). Sampling and testing of residual soils. Southeast Asian Geotechnical Society, Société internationale de mécanique des sols des travaux de fondation Technical Committee, *A review of international practice*, Scorpion Press, Hong Kong.

BUJANG, M. A., GHANI, P. A., SOELAR, S. A., & ZULKIFLI, N. A. (2012). Sample size guideline for exploratory factor analysis when using small sample: Taking into considerations of different measurement scales. *ICSSBE 2012 - Proceedings, 2012 International Conference on Statistics in Science, Business and Engineering: “Empowering Decision Making with Statistical Sciences,”* DOI:10.1109/ICSSBE.2012.6396605, 447–451. <https://doi.org/10.1109/ICSSBE.2012.6396605>

BURINGH, P. (1979). Introduction to the study of soils in tropical & subtropical regions. *Centre for agricultural publishing and documentation: Wageningen, the Netherlands*. Price Dfl.25.00. ISBN 90 220 0691 3, 3RD edition, 124 pp, 7 figs.

BWAMBALE, B., BAGAMPADDE, U., GIDUDU, A., & MARTINI, F. (2015). Seismic Hazard Analysis for the Albertine Region, Uganda – a Probabilistic Approach. *South African Journal of Geology*, 118(4), 411–424. <https://doi.org/10.2113/gssajg.118.4.411>

CAI, G. J., LIU, S. Y., TONG, L. Y., & DU, G. Y. (2010). Field evaluation of undrained shear strength from piezocone penetration tests in soft marine clay. *Marine Georesources and Geotechnology*, 28 (2), 143–153. <https://doi.org/10.1080/10641191003780906>

CHANG, M.F., and GOH, A. T. . (1988). Behaviour of bored piles in residual soils and weathered rocks of Singapore. *Research Report CSE/1988/17, Nanyang Technological Institute, Singapore*.

CHEN C. (2001). Evaluating undrained shear strength of Klang Clay from Cone Penetration test. *Proceedings of the International Conference on in Situ Measurement of Soil Properties and Case Histories*, 141-148.

CHESHOMI, A. (2018). Empirical relationships of CPTu results and undrained shear strength. *Journal of GeoEngineering*, 13 (2), 49–57. [https://doi.org/10.6310/jog.20180613\(2\).1](https://doi.org/10.6310/jog.20180613(2).1)

CLINE, M. G. (1955). Soil survey of the territory of Hawaii. *US SOIL SURVEY SERIES, 1939*, 25.

COOLIDGE, C. W. (2015). Use and Application of Piezocone Penetration Testing in Presumpscot Formation. 1–13.

DAS, B. M. & SOBHAN, K. (2010). Principles of Geotechnical Engineering. 8th edition. Stamford: *Cengage Learning*.

DE CARVALHO, J. C., & GITIRANA, G. DE F. N. (2021). Unsaturated soils in the context of tropical soils. *Soils and Rocks*, 44(3), 1–25. <https://doi.org/10.28927/SR.2021.068121>

DEERE, D.U., AND F. D. P. (1971). Slope Stability in Residual Soils. *In Proc., Fourth Pan American Conference on Soil Mechanics and Foundation Engineering, San Juan, Puerto Rico, American Society of Civil Engineers, New York*, 1, 87–170.

DIXIT, M., & PATIL, K. (2016). Study of effect of different parameters on bearing. *Government College of Engineering, Aurangabad (M.S.)*–431 005, India. 682-685

DUAN, WEI; CONGRESS, SURYA SARAT CHANDRA; CAI, GUOJUN; PUPPALA, ANAND J.; DONG, XIAOQIANG; DU, Y. (2021). Empirical correlations of soil parameters based on piezocone penetration tests (CPTU) for Hong Kong - Zhuhai-MACAU BRIDGE (HZMB) project. *Transportation Geotechnics*, 30 (100605).

ERDI MYFTARAGA OLSI KORETA. (2013). Selection of Characteristic Values from

Cone Penetration Test. *Proceedings of the 5th International Young Geotechnical Engineers' Conference*, 2(978-1-61499-296-7), 375–378.

ESLAMI, A., & MOHAMMADI, A. (2016). Drained soil shear strength parameters from CPTu data for marine deposits by analytical model. *Ships and Offshore Structures*, 11(8), 913–925. <https://doi.org/10.1080/17445302.2015.1131082>

ESLAMI, A., MOSHFEGHI, S., MOSHFEGHI, S., & ESLAMI, M. M. (2019). Piezocone and cone penetration test (CPTu and CPT) applications in foundation engineering. <https://doi.org/10.1016/C2017-0-04195-2>

FELLENIOUS W. (1922). Statens Jarnvagens Geoteknisk Kommission, Stockholm.

FOOKES, P. G. (1997a). Geology for Engineers: the Geological Model, Prediction and Performance. *Quarterly Journal of Engineering Geology*, 30, 293–424.

FOOKES, P. G. (1997b). Tropical Residual Soils. *A Geological Society Engineering Group*, (163)-178.

Ladd, C. C., & Foott, R. (1974). New design procedures for stability of soft clays. *Journal of the Geotechnical Engineering Division, American Society of Civil Engineers*, Serial URL: <http://ojps.aip.org/gto>, ISSN: 1090-0241, GT7, Volume 100, 763-786.

GEBRESELASSIE B. (2003). Experimental, analytical and numerical investigations of excavations in normally consolidated soft soils,. PhD thesis, *University of Kassel*.

Engineering, Geology.

GU, Z., GUO, X., JIAO, H., JIA, Y., & NIAN, T. (2022). Effect of Low Temperature on the Undrained Shear Strength of Deep-Sea Clay by Mini-Ball Penetration Tests. *Marine Science and Engineering*.

GUTIERREZ, M., NYGÅRD, R., HØEG, K., & BERRE, T. (2008). Normalized undrained shear strength of clay shales. 99, 31–39. <https://doi.org/10.1016/j.enggeo.2008.02.002>

H, TODO AND M. M. PAUZI. (1989). Geotechnical engineering properties of residual soils originated from granite in Malaysia and Singapore. *Proc. of the International Conference in Tropical Terrains, UKM Bangi, Malaysia*, 160–169.

HONG S, LEE M, KIM J, L. W. (2010). Evaluation undrained shear strength of Busan clay using CPT. *2nd International Symposium on Cone Penetration Testing, CPT' 10*, 2–23.

HUAT, B. B. K., TOLL, D. G., & PRASAD, A. (2012). Handbook of tropical residual soils engineering. <https://doi.org/10.1201/b12302>

ISMAIL HA, Z. A. (1987). Prediction of undrained shear strength and SPT using the static CPT data. *Proceedings 9th Regional African Conference on SMFE, L*, 185–192.

JANBU, N. (1967). Settlement calculation based on the tangent modulus concept. *Soil Mechanics and Foundation Engineering, The Technical University of*

Norway.,Trondheim.

KARAKAN, E. (2023). Flow index-liquid limit relationship by fall-cone tests in clay-sand mixtures. *Engineering Science and Technology, an International Journal*,. <https://doi.org/10.1016/j.jestch.2023.101405>

KARLSRUD, K., LUNNE, T., & BRATTLIEN, K. (1997). Improved CPTU interpretations based on block samples. *Publikasjon - Norges Geotekniske Institute*, 195–201.

KARLSRUD, K., LUNNE, T., & STRANDVIK, S. O. (2005). CPTU correlations for clays.16th *International Conference on Soil Mechanics and Geotechnical Engineering (Osaka)*,2:693-702

LA ROCHELLE, P. ZEBDI, M., LEROUAIL, S., TAVENAS, F., & V. (1988). Piezocone tests in sensitive clays of eastern Canada. *Geology*, DOI:10.1016/0148-9062(90)91259-a, Corpus ID: 133485775

LACASSE, S., GUTTORMSEN, T., NADIM, F., RAHIM, A. & LUNNE, T. (2007). Use of statistical methods for selecting design soil parameters. *Proceedings of the 6th International Conference on Offshore Site Investigation and Geotechnics, London*London: Society for Underwater Technology., 11–13.

LADD, C. C. (1992). Stability evaluation during staged construction. *In Journal of Geotechnical Engineering* (Vol. 118, Issue 8). [https://doi.org/10.1061/\(ASCE\)0733-](https://doi.org/10.1061/(ASCE)0733-)

9410(1992)118:8(1288.2)

LAMBE, T.W., WHITMAN, R.V. (1969). Soil Mechanics. John Wiley & Sons.

LAMBE T W. (1960). A mechanistic picture of shear strength in clay. *ASCE Research Conference on Shear Strength of Cohesive Soils*, 555–580.

LARSSON, R. (2008). Information 1:: Jords egenskaper. Linköping.

LI, XUEPENG ; CAI, GUOJUN ; LIU, SONGYU ; PUPPALA, ANAND J. ; ZHENG, JINHUO ; JIANG, T. (2019). Undrained Shear Strength and Pore Pressure Changes Due to Prestress Concrete Pile Installation in Soft Clay. *International Journal of Civil Engineering*, 17(10.1007/s40999-017-0200–0), 193–203.

LIU, C. N., HUANG, W. W., HO, Y. H., & LIN, B. H. (2021). Finite Element Analyses of Geosynthetic-Reinforced Soil Ground Under Surcharge and Probabilistic Estimation of the Bearing Capacity. *Journal of GeoEngineering*, 16(3), 99–109. [https://doi.org/10.6310/jog.202109_16\(3\).3](https://doi.org/10.6310/jog.202109_16(3).3)

LOMMLER, J. C. (2012). Geotechnical Problem Solving. *In Geotechnical Problem Solving*. <https://doi.org/10.1002/9781119968429>

M GIDIGASU, M. G. (2012). Laterite Soil Engineering Pedogenesis and Engineering Principles. *Elsevier Scientific Publishing Company, Amsterdam*, ISBN: 9780444601230

Hassan M. (2004). Evaluation of undrained shear strength from CPT for local fine grained soils. *Unpublished M.Sc. Thesis, BRRI, University of Khartoum, Khartoum.*

MARSDEN, J.R., HOLT, R.M., NAKKEN, S.J., AND RAAEN, A. M. (1992). Mechanical and petrophysical characterization of highly stressed mudstones. *In Proceedings of Eurock 92 Conference. Balkema, Rotterdam*, 51–56.

MAYNE, P. W. (2007). In-situ test calibrations for evaluating soil parameters. *Characterisation and Engineering Properties of Natural Soils*, 3–4, 1601–1652. <https://doi.org/10.1201/noe0415426916.ch2>

MAYNE, P. W., COOP, M. R., SPRINGMAN, S., HUANG, A.-B., & ZORNBERG, J. (2009). State-of-the-Art Paper (SOA-1): GeoMaterial Behavior and Testing. *Proc. 17th Intl. Conf. Soil Mechanics & Geotechnical Engineering*, 2777–2872.

MAYNE, P. W., & PEUCHEN, J. (2018). Evaluation of CPTU N_{kt} cone factor for undrained strength of clays. *Cone Penetration Testing 2018 - Proceedings of the 4th International Symposium on Cone Penetration Testing, CPT 2018*, 423–429.

MESRI, G. (2001). Undrained shear strength of soft clays from push cone penetration test. *Geotechnique*, 51(2), 167–168. <https://doi.org/10.1680/geot.2001.51.2.167>

MICHAEL, A., & STUDENT, B. (2021). 45th Annual Michael Bozozuk Student Forum For abstracts of presentations and student participants ' information ,*Carleton University*
Candidate : Ms . Narges Gheisari , PhD student Title : Settlement analysis in soft clay.

Mohr, E. C. J. & F. A. van Baren. (1954). *Tropical Soils*. Hague.

MUTEBI, S., OZUMBA, B. M., & ADEIGBE, O. C. (2019). An Aspect of Palyno Stratigraphy of “XM” Field Located in Semliki Basin South Western Uganda. *Journal of Petroleum & Environmental Biotechnology*, 10(1). <https://doi.org/10.35248/2157-7463.19.10.388>

NI, T., YANG, Y., GU, C., LIU, J., CHEN, J., & LOU, X. (2019). Early-Age Tensile Basic Creep Behavioral Characteristics of High-Strength Concrete Containing Admixtures. *Advances in Civil Engineering*, 24–26. <https://doi.org/10.1155/2019/9495231>

Nyakairu, G. W. A., Kurzweil, H., & Koeberl, C. (2002). Mineralogical, geochemical, and sedimentological characteristics of clay deposits from central Uganda and their applications. www.elsevier.com/locate/jafrearsci, *Journal of African Earth Sciences*, (1)123-134

OTOKO, G. R., FUBARA-MANUEL, I., IGWAGU, M., & EDOH, C. (2016). Empirical cone factor for estimation of undrained shear strength. *Electronic Journal of Geotechnical Engineering*, 21(18), 6069–6076.

PANIAGUA, P., D’IGNAZIO, M., L’HEUREUX, J.-S., LUNNE, T., & KARLSRUD, K. (2019). CPTU correlations for Norwegian clays: an update. *AIMS Geosciences*, 5(2), 82–103. <https://doi.org/10.3934/geosci.2019.2.82>

PEUCHEN, J., PLASMAN, S. J., VAN STEVENINCK, R., & ENGINEERS, F. (1996).

Line sensor: ion: es: inc in I jo sica.

POH, K.B., CHUAH, H.L., AND TAN, S. . (1985). Residual granite soil of Singapore.

Proceedings of the 8th Southeast Asian Geotechnical Conference, Kuala Lumpur, 1, 3.1-3.9.

RAD, N.S. & LUNNE, T. . (1988). Direct correlations between piezocone test results and undrained shear strength of clay. *Proceedings of Penetration Testing 1988, ISOPT-1*;, 911–917.

RAHARDJO, H., LIM, T. T., CHANG, M. F., & FREDLUND, D. G. (1995). Shear-strength characteristics of a residual soil. *Canadian Geotechnical Journal*, 32(1), 60–77.
<https://doi.org/10.1139/t95-005>

RAHMAN, A. (2007). Correlation of cone resistance with undrained shear strength for clay soils. *Report for Partial Fulfillment of M.Sc. in Geotechnics, Civil Engineering, UTM, Skudai*, 306.

RÉMAI, Z. (2013). Correlation of undrained shear strength and CPT resistance. *Periodica Polytechnica Civil Engineering*, 57 (1), 39–44. <https://doi.org/10.3311/PPci.2140>

ROBERTS, R.C. (1942). Soil survey of Puerto Rico. *Soil Survey Series, 1936, Washington*, No. 8.

Robertson, P. & Cabal, K. (2023). CONE PENETRATION TESTING GUIDE TO. A Summary Guide to the Cone Penetration Test (CPT)

ROCHA, B. P., & GIACHETI, H. L. (2018). Site characterization of a tropical soil by in situ tests. *DYNA (Colombia)*, 85 (206), 211–219. <https://doi.org/10.15446/dyna.v85n206.67891>

SANGLERAT, G. (1972). The penetration and soil exploration. *Elsevier Sci-Entific Publishing*, 52–80.

SENNESET, K., JANBU, N. & SVANO, G. (1982). Strength and deformation parameters from cone penetration tests. *Proc. 2nd European Symposium on Penetration Testing, Amsterdam*, 2, 863–870.

SKEMPTON, A. W. (1948). The rate of softening in stiff fissured clays, with special reference to London Clay. *Proceedings of the 2nd International Conference on Soil Mechanics and Foundation Engineering*, 2, 50–53.

STAS, C.V., AND KULHAWY, F. H. (1984). Critical evaluation of design methods for foundations under axial uplift and compression loading. *Report EL-3771. Electric Power Research Institute, Palo Alto, Calif.*

STEFANIAK, K. (2015a). Assessment of Shear Strength in Silty Soils. *Studia Geotechnica et Mechanica*, 37(2), 51–55. <https://doi.org/10.1515/sgem-2015-0020>

STEFANIAK, K. (2015b). Assessment of Shear Strength in Silty Soils. *Studia*

Geotechnica et Mechanica, 37(2), 51–55. <https://doi.org/10.1515/sgem-2015-0020>

STEIGER, R.P., & LEUNG, P. K. (1991). Critical state shale mechanics. *In Proceedings of the 32nd US Symposium on Rock.*, 293–302.

STUDY, T. D., (2003). The Development Study on Water Resources Development and Management for Lake Kyoga Basin Final Report -Main Report- Chapter 2 Natural Conditions 2.3.2. 1.

TAVENAS, F. & S. L. (1987). State-of-the-art Of, on laboratory and in-situ stress-strain-time behavior Clays., Soft. *Proceedings of the International Symposium on Geotechnical Engineering of Soft Soils, Mexico City*, 1–46.

TERGAZHI K. (1943). Theoretical Soil Mechanics. *John Wiley, New York*.

TERZAGHI, K., PECK, R. B., & MESRI, G. (1996). Soil Mechanics in Engineering Practice.pdf. *In John wiley & sons* (p. 534).

THAKUR, V., FAUSKERUD, O. A., & GJELSVIK, V. (2016). A procedure for the assessment of the undrained shear strength profile of soft clays. *Proceedings of the 17th Nordic Geotechnical Meeting*, 2, 534–546.

THAKUR, V., FAUSKERUD, O. A., GJELSVIK, V., CHRISTENSEN, S., OSET, F., NORDAL, S., VIKLUND, M., & STRAND, S.-A. (2016). A procedure for the assessment of the undrained shear strength profile of soft clays, *17th Nordic Geotechnical Meeting (NGM-2016)*

TONG, LIYUAN, Q. WANG, GUANHENG DU, S. L. (2011). Determination of undrained shear strength using piezocone penetration test in clayey soil for bridge foundation. *Journal of Southeast University*, 27(2), 201–205.

TUMWESIGE, R., GIDUDU, A., BAGAMPADDE, U., & RYAN, C. (2014). An investigation of the relationship between standard penetration test and shear wave velocity for unsaturated soils (a Case Study of the Earthquake Prone Area of the Albertine Graben). *Second European Conference on Earthquake Engineering and Seismology, August*, 1–12.

TWESIGYE-OMWE, M. N., KAWEESA, P., & KYAKULA, M. (2009). A Study of the Use of Ground Investigation Reports during Foundation Design in Kampala. *Second International Conference on Advances in Engineering and Technology, February*, 443–449.

VARGAS, M. (1974). Engineering Properties of Residual Soils from the South-Central Region of Brazil. In *Proc., Second International Congress of the International Association of Engineering Geology, Sao Paulo, Brazil, Associação Brasileira de Geologia de Engenharia*, 1.

VAUGHAN P.R., M. M. & M. S. M. (1988). Indexing the engineering properties of residual soil. *Quarterly Journal of Engineering Geology*, 21, 61–84.

WEI DUAN A B, SURYA SARAT CHANDRA CONGRESS C, GUOJUN CAI B, ANAND J. PUPPALA C, XIAOQIANG DONG D, Y. D. E. (2021). Empirical

correlations of soil parameters based on piezocone penetration tests (CPTU) for Hong Kong-Zhuhai-Macau Bridge (HZMB) project, *Transportation Geotechnics*, Volume 30, article id. 100605., 10.1016/j.trgeo.2021.100605,

WESLEY, L D. (2010). Geotechnical Engineering in Residual Soils. *John Wiley & Sons, Inc, New Jersey*, 259.

WESTERHOF, A. B., HÄRMÄ, P., ISABIRYE, E., KATTO, E., KOISTINEN, T., KUOSMANEN, E., LEHTO, T., LEHTONEN, M., MÄKITIE, H., MANNINNEN, T., MÄNTTÄRI, I., PEKKALA, Y., POKKI, J., SAALMANN, K., & VIRRANSALO, P. (2014). Geology and Geodynamic Development of Uganda with Explanation of the 1:1,000,000 Scale Geological Map. In Geological Survey of Finland, *Special Paper 55*.

WHITE, F., P. INGRAM, D. NICHOLSON, M. S., & BETRU, M. (2019). An update of the SPT-CU relationship proposed by M. Stroud in 1974. *Proc. XVII ECSMGE-2019*, 1–8. <https://doi.org/10.32075/17ECSMGE-2019-0500>

WORL DATLAS, O. (2017). Uganda Geography. 1–4. <https://www.worldatlas.com>

WU QI A, ZHU ENCI A, LI HAO A, LI YUANXI B, WANG HUAAN B, C. G. (2023). A new empirical model for the undrained shear strength of undisturbed marine fine-grained soil based on piezocone penetration tests. *Applied Ocean Research*.

XIE WENQIANG, CAI GUOJUN, R. W. AND J. M. Z. (2019). Prediction of the undrained shear strength of clay from CPTu data using artificial neural network.

YANG, S. L., LUNNE, T., ANDERSEN, K. H., D'LGNAZIO, M., & YETGINER, G. (2019). Undrained shear strength of marine clays based on CPTU data and SHANSEP parameters. 17th European Conference on Soil Mechanics and Geotechnical Engineering, *ECSMGE 2019 - Proceedings, 2019-Septe*. <https://doi.org/10.32075/17ECSMGE-2019-0048>

YANG, S. L., LUNNE, T., ANDERSEN, K. H., D, M., & YETGINER, G. (2019). Undrained shear strength of marine clays based on CPTU data and SHANSEP parameters. 1996, 1–8. <https://doi.org/10.32075/17ECSMGE-2019-0048>

YUSOF, N. Q. A. M., & ZABIDI, H. (2018). Reliability of Using Standard Penetration Test (SPT) in Predicting Properties of Soil. *Journal of Physics: Conference Series*, 1082(1). <https://doi.org/10.1088/1742-6596/1082/1/012094>

ZEIN, A. K. M. (2017a). Estimation of undrained shear strength of fine grained soils from cone penetration resistance. *International Journal of Geo-Engineering*, 8(1). <https://doi.org/10.1186/s40703-017-0046-y>

ZEIN, A. K. M. (2017b). Estimation of undrained shear strength of fine grained soils from cone penetration resistance. *International Journal of Geo-Engineering*, 8(1). <https://doi.org/10.1186/s40703-017-0046-y>

ZENG, X., LI, Y., LIU, X., YAO, J., & LIN, Z. (2020). Relationship between the Shear Strength and the Depth of Cone Penetration in Fall Cone Tests. *Advances in Civil Engineering*, 2020. <https://doi.org/10.1155/2020/8850430>

APPENDICES

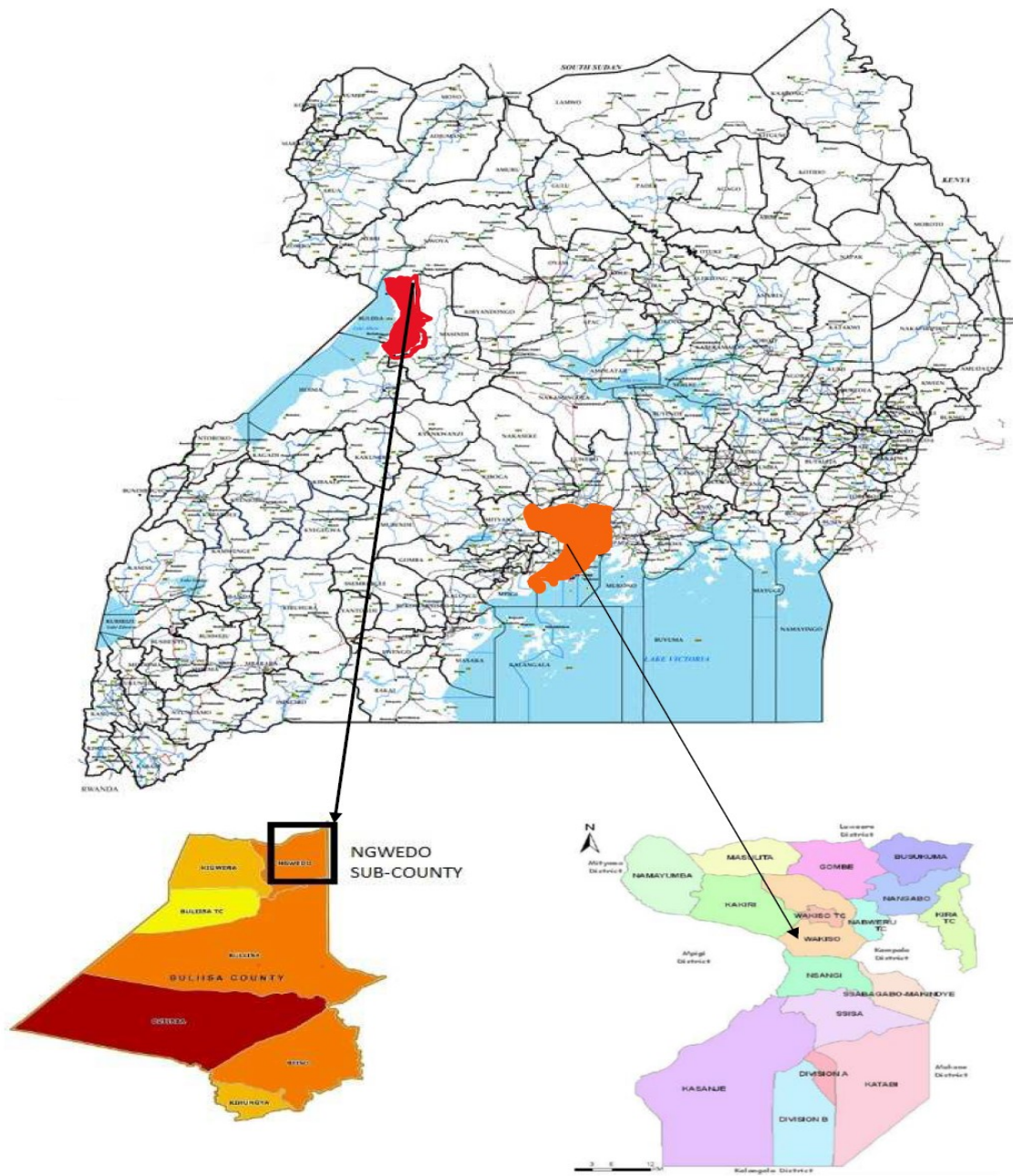


Figure 21: Location of the sites under study.

Table 8: SHANSEP S_u measured by substituting $s=0.26, 0.40, 0.49, 0.55$

s	m	depth, m	γ (kN/m ³)	σ'_{vo} (kPa)	OCR	S_u (kPa)	Min	Max
0.26	0.63	2.5	18	45	21.099	79.89		
0.26	0.63	7.5	18	135	15.234	195.20		
0.26	0.63	10.0	18	180	8.79	184.06		
0.26	0.63	16.0	18	288	9.967	318.76		
0.26	0.63	19.0	18	342	8.002	329.62		
0.26	0.63	22.0	18	396	7.165	356.00		
0.26	0.63	26.0	18	468	3.284	257.37		
0.26	0.63	30.0	18	540	0.4519	85.12		
							79.89	356.00
0.4	0.91	2.5	18	45	21.099	288.64		
0.4	0.91	7.5	18	135	15.234	643.81		
0.4	0.91	10.0	18	180	8.79	520.43		
0.4	0.91	16.0	18	288	9.967	933.57		
0.4	0.91	19.0	18	342	8.002	907.81		
0.4	0.91	22.0	18	396	7.165	950.61		
0.4	0.91	26.0	18	468	3.284	552.37		
0.4	0.91	30.0	18	540	0.4519	104.84		
							104.84	950.61
0.49	0.65	2.5	18	45	21.099	160.02		
0.49	0.65	7.5	18	135	15.234	388.47		
0.49	0.65	10.0	18	180	8.79	362.29		
0.49	0.65	16.0	18	288	9.967	629.01		
0.49	0.65	19.0	18	342	8.002	647.59		
0.49	0.65	22.0	18	396	7.165	697.88		
0.49	0.65	26.0	18	468	3.284	496.71		
0.49	0.65	30.0	18	540	0.4519	157.89		
							157.89	697.88
0.55	0.57	2.5	18	45	21.099	140.74		
0.55	0.57	7.5	18	135	15.234	350.67		
0.55	0.57	10.0	18	180	8.79	341.75		
0.55	0.57	16.0	18	288	9.967	587.40		
0.55	0.57	19.0	18	342	8.002	615.48		
0.55	0.57	22.0	18	396	7.165	669.16		
0.55	0.57	26.0	18	468	3.284	506.94		
0.55	0.57	30.0	18	540	0.4519	188.86		
							140.74	669.16

Table 9: SHANSEP S_u measured by substituting $s=0.38, 0.41, 0.70, 0.53$

s	m	depth, m	γ (kN/m ³)	σ'_{vo} (kPa)	OCR	S_u (kPa)	Min	Max
0.38	0.94	2.5	18	45	21.099	300.47		
0.38	0.94	7.5	18	135	15.234	663.69		
0.38	0.94	10.0	18	180	8.79	527.72		
0.38	0.94	16.0	18	288	9.967	950.23		
0.38	0.94	19.0	18	342	8.002	917.94		
0.38	0.94	22.0	18	396	7.165	958.04		
0.38	0.94	26.0	18	468	3.284	543.81		
0.38	0.94	30.0	18	540	0.4519	97.26		
							97.26	958.04
0.41	0.72	2.5	18	45	21.099	165.75		
0.41	0.72	7.5	18	135	15.234	393.32		
0.41	0.72	10.0	18	180	8.79	352.96		
0.41	0.72	16.0	18	288	9.967	618.22		
0.41	0.72	19.0	18	342	8.002	626.78		
0.41	0.72	22.0	18	396	7.165	670.25		
0.41	0.72	26.0	18	468	3.284	451.69		
0.41	0.72	30.0	18	540	0.4519	124.97	124.97	670.25
0.7	0.7	2.5	18	45	21.099	266.25		
0.7	0.7	7.5	18	135	15.234	635.92		
0.7	0.7	10.0	18	180	8.79	576.98		
0.7	0.7	16.0	18	288	9.967	1,008.06		
0.7	0.7	19.0	18	342	8.002	1,026.51		
0.7	0.7	22.0	18	396	7.165	1,100.13		
0.7	0.7	26.0	18	468	3.284	753.05		
0.7	0.7	30.0	18	540	0.4519	216.78	216.78	1,100.13
0.53	0.62	2.5	18	45	21.099	157.95		
0.53	0.62	7.5	18	135	15.234	387.22		
0.53	0.62	10.0	18	180	8.79	367.13		
0.53	0.62	16.0	18	288	9.967	635.01		
0.53	0.62	19.0	18	342	8.002	658.09		
0.53	0.62	22.0	18	396	7.165	711.55		
0.53	0.62	26.0	18	468	3.284	518.43		
0.53	0.62	30.0	18	540	0.4519	174.90		
							157.95	711.55

Table 10: SHANSEP S_u measured by substituting $s=0.60, 0.60, 0.24, 0.47$.

s	m	depth, m	γ (kN/m ³)	σ'_{vo} (kPa)	OCR	S_u (kPa)	Min	Max
0.60	0.60	2.5	18	45	21.099	168.24		
0.60	0.60	7.5	18	135	15.234	415.12		
0.60	0.60	10.0	18	180	8.79	397.94		
0.60	0.60	16.0	18	288	9.967	686.57		
0.60	0.60	19.0	18	342	8.002	714.66		
0.60	0.60	22.0	18	396	7.165	774.42		
0.60	0.60	26.0	18	468	3.284	573.11		
0.60	0.60	30.0	18	540	0.4519	201.17		
							168.24	774.42
0.60	0.64	2.5	18	45	21.099	190.06		
0.60	0.64	7.5	18	135	15.234	462.90		
0.60	0.64	10.0	18	180	8.79	434.09		
0.60	0.64	16.0	18	288	9.967	752.71		
0.60	0.64	19.0	18	342	8.002	776.65		
0.60	0.64	22.0	18	396	7.165	837.89		
0.60	0.64	26.0	18	468	3.284	601.03		
0.60	0.64	30.0	18	540	0.4519	194.88		
							190.06	837.89
0.24	0.73	2.5	18	45	21.099	100.03		
0.24	0.73	7.5	18	135	15.234	236.59		
0.24	0.73	10.0	18	180	8.79	211.15		
0.24	0.73	16.0	18	288	9.967	370.30		
0.24	0.73	19.0	18	342	8.002	374.60		
0.24	0.73	22.0	18	396	7.165	400.14		
0.24	0.73	26.0	18	468	3.284	267.57		
0.24	0.73	30.0	18	540	0.4519	72.57	72.57	400.14
0.47	0.66	2.5	18	45	21.099	158.24	72.57	400.14
0.47	0.66	7.5	18	135	15.234	382.90		
0.47	0.66	10.0	18	180	8.79	355.14		
0.47	0.66	16.0	18	288	9.967	617.37		
0.47	0.66	19.0	18	342	8.002	634.21		
0.47	0.66	22.0	18	396	7.165	682.71		
0.47	0.66	26.0	18	468	3.284	482.14		
0.47	0.66	30.0	18	540	0.4519	150.25		

Table 11: SHANSEP S_u measured by substituting $s=0.37, 0.28, 0.39$.

s	m	depth, m	γ (kN/m ³)	σ'_{vo} (kPa)	OCR	S_u (kPa)	Min	Max
0.37	0.79	2.5	18	45	21.099	185.17		
0.37	0.79	7.5	18	135	15.234	429.50		
0.37	0.79	10.0	18	180	8.79	370.87		
0.37	0.79	16.0	18	288	9.967	655.33		
0.37	0.79	19.0	18	342	8.002	654.27		
0.37	0.79	22.0	18	396	7.165	694.25		
0.37	0.79	26.0	18	468	3.284	443.00		
0.37	0.79	30.0	18	540	0.4519	106.68		
0.28	0.91	2.5	18	45	21.099	202.05	150.25	682.71
0.28	0.91	7.5	18	135	15.234	450.66		
0.28	0.91	10.0	18	180	8.79	364.30		
0.28	0.91	16.0	18	288	9.967	653.50		
0.28	0.91	19.0	18	342	8.002	635.47		
0.28	0.91	22.0	18	396	7.165	665.43		
0.28	0.91	26.0	18	468	3.284	386.66		
0.28	0.91	30.0	18	540	0.4519	73.39		
0.39	0.81	2.5	18	45	21.099	207.46	73.39	665.43
0.39	0.81	7.5	18	135	15.234	478.05		
0.39	0.81	10.0	18	180	8.79	408.29		
0.39	0.81	16.0	18	288	9.967	723.26		
0.39	0.81	19.0	18	342	8.002	718.92		
0.39	0.81	22.0	18	396	7.165	761.18		
0.39	0.81	26.0	18	468	3.284	478.19		
0.39	0.81	30.0	18	540	0.4519	110.67		

Table 12: SHANSEP S_u measured by substituting $s=0.69, 0.53, 0.45$.

s	m	depth, m	γ (kN/m ³)	σ'_{vo} (kPa)	OCR	S_u (kPa)	Min	Max
0.69	0.58	2.5	18	45	21.099	182.03		
0.69	0.58	7.5	18	135	15.234	452.08		
0.69	0.58	10.0	18	180	8.79	438.16		
0.69	0.58	16.0	18	288	9.967	754.07		
0.69	0.58	19.0	18	342	8.002	788.37		
0.69	0.58	22.0	18	396	7.165	856.19		
0.69	0.58	26.0	18	468	3.284	643.59		
0.69	0.58	30.0	18	540	0.4519	235.05		
							106.68	694.25
0.53	0.78	2.5	18	45	21.099	257.28		
0.53	0.78	7.5	18	135	15.234	598.69		
0.53	0.78	10.0	18	180	8.79	519.83		
0.53	0.78	16.0	18	288	9.967	917.38		
0.53	0.78	19.0	18	342	8.002	917.90		
0.53	0.78	22.0	18	396	7.165	975.08		
0.53	0.78	26.0	18	468	3.284	627.07		
0.53	0.78	30.0	18	540	0.4519	154.03		
							154.03	975.08
0.45	0.6	2.5	18	45	21.099	126.18		
0.45	0.6	7.5	18	135	15.234	311.34		
0.45	0.6	10.0	18	180	8.79	298.45		
0.45	0.6	16.0	18	288	9.967	514.92		
0.45	0.6	19.0	18	342	8.002	535.99		
0.45	0.6	22.0	18	396	7.165	580.81		
0.45	0.6	26.0	18	468	3.284	429.83		
0.45	0.6	30.0	18	540	0.4519	150.88		
							126.18	580.81

Table 13: SHANSEP S_u measured by substituting $s=0.65, 0.63, 0.41$

s	m	depth, m	γ (kN/m ³)	σ'_{vo} (kPa)	OCR	S_u (kPa)	Min	Max
0.65	0.89	2.5	18	45	21.099	441.28		
0.65	0.89	7.5	18	135	15.234	990.72		
0.65	0.89	10.0	18	180	8.79	809.72		
0.65	0.89	16.0	18	288	9.967	1,448.87		
0.65	0.89	19.0	18	342	8.002	1,415.10		
0.65	0.89	22.0	18	396	7.165	1,485.08		
0.65	0.89	26.0	18	468	3.284	876.51		
0.65	0.89	30.0	18	540	0.4519	173.10	173.10	1,485.08
0.63	0.83	2.5	18	45	21.099	356.20		
0.63	0.83	7.5	18	135	15.234	815.47		
0.63	0.83	10.0	18	180	8.79	688.85		
0.63	0.83	16.0	18	288	9.967	1,223.32		
0.63	0.83	19.0	18	342	8.002	1,210.66		
0.63	0.83	22.0	18	396	7.165	1,278.98		
0.63	0.83	26.0	18	468	3.284	791.04		
0.63	0.83	30.0	18	540	0.4519	175.96		
							175.96	1,278.98
0.41	0.88	2.5	18	45	21.099	269.99		
0.41	0.88	7.5	18	135	15.234	608.13		
0.41	0.88	10.0	18	180	8.79	499.77		
0.41	0.88	16.0	18	288	9.967	893.13		
0.41	0.88	19.0	18	342	8.002	874.23		
0.41	0.88	22.0	18	396	7.165	918.48		
0.41	0.88	26.0	18	468	3.284	546.34		
0.41	0.88	30.0	18	540	0.4519	110.06		
							110.06	918.48

Table 14: SHANSEP S_u measured by substituting $s=0.73, 0.21, 0.53, 0.49$.

s	m	depth, m	γ (kN/m ³)	σ'_{vo} (kPa)	OCR	S_u (kPa)	Min	Max
0.73	0.78	2.5	18	45	21.099	354.37		
0.73	0.78	7.5	18	135	15.234	824.62		
0.73	0.78	10.0	18	180	8.79	715.99		
0.73	0.78	16.0	18	288	9.967	1,263.56		
0.73	0.78	19.0	18	342	8.002	1,264.28		
0.73	0.78	22.0	18	396	7.165	1,343.03		
0.73	0.78	26.0	18	468	3.284	863.70		
0.73	0.78	30.0	18	540	0.4519	212.15		
							212.15	1,343.03
0.21	0.45	2.5	18	45	21.099	37.27		
0.21	0.45	7.5	18	135	15.234	96.56		
0.21	0.45	10.0	18	180	8.79	100.53		
0.21	0.45	16.0	18	288	9.967	170.20		
0.21	0.45	19.0	18	342	8.002	183.10		
0.21	0.45	22.0	18	396	7.165	201.73		
0.21	0.45	26.0	18	468	3.284	167.82		
0.21	0.45	30.0	18	540	0.4519	79.32		
							37.27	201.73
0.53	0.94	2.5	18	45	21.099	419.08		
0.53	0.94	7.5	18	135	15.234	925.67		
0.53	0.94	10.0	18	180	8.79	736.03		
0.53	0.94	16.0	18	288	9.967	1,325.31		
0.53	0.94	19.0	18	342	8.002	1,280.29		
0.53	0.94	22.0	18	396	7.165	1,336.21		
0.53	0.94	26.0	18	468	3.284	758.47		
0.53	0.94	30.0	18	540	0.4519	135.65		
							135.65	1,336.21
0.49	0.47	2.5	18	45	21.099	92.43		
0.49	0.47	7.5	18	135	15.234	237.93		
0.49	0.47	10.0	18	180	8.79	244.99		
0.49	0.47	16.0	18	288	9.967	415.83		
0.49	0.47	19.0	18	342	8.002	445.37		
0.49	0.47	22.0	18	396	7.165	489.60		
0.49	0.47	26.0	18	468	3.284	401.01		
0.49	0.47	30.0	18	540	0.4519	182.16		
							92.43	489.60

Table 15: S_u determined for site 1 from Equation 11

Depth, m	q_t (MPa)	q_t (kPa)	σ_v (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} - 9.85$)	S_u , ($N_{kt} - 11.79$)
0.85	1.47	1470	16.15	9.85	11.79	147.63	123.36
0.86	1.41	1410	16.34	9.85	11.79	141.52	118.26
0.87	1.41	1410	16.53	9.85	11.79	141.50	118.24
0.88	1.34	1340	16.72	9.85	11.79	134.37	112.29
0.89	1.29	1290	16.91	9.85	11.79	129.27	108.03
0.9	1.29	1290	17.1	9.85	11.79	129.25	108.01
0.91	1.27	1270	17.29	9.85	11.79	127.20	106.30
0.92	1.22	1220	17.48	9.85	11.79	122.11	102.04
0.93	1.15	1150	17.67	9.85	11.79	114.98	96.08
0.94	1.15	1150	17.86	9.85	11.79	114.96	96.07
2.41	1.81	1810	45.79	9.85	11.79	179.14	149.70
2.42	1.81	1810	45.98	9.85	11.79	179.12	149.68
2.43	1.82	1820	46.17	9.85	11.79	180.12	150.52
2.44	1.85	1850	46.36	9.85	11.79	183.15	153.05
2.45	1.86	1860	46.55	9.85	11.79	184.14	153.88
2.46	1.86	1860	46.74	9.85	11.79	184.12	153.86
2.47	1.88	1880	46.93	9.85	11.79	186.14	155.54
2.48	1.92	1920	47.12	9.85	11.79	190.18	158.92
2.49	1.98	1980	47.31	9.85	11.79	196.25	164.00
2.5	1.99	1990	47.5	9.85	11.79	197.25	164.83
3.7	1.45	1450	70.3	9.85	11.79	140.10	117.07
3.71	1.44	1440	70.49	9.85	11.79	139.06	116.21
3.72	1.4	1400	70.68	9.85	11.79	134.98	112.80
3.73	1.42	1420	70.87	9.85	11.79	137.00	114.48
3.74	1.49	1490	71.06	9.85	11.79	144.08	120.40
3.75	1.52	1520	71.25	9.85	11.79	147.11	122.93
3.76	1.54	1540	71.44	9.85	11.79	149.12	124.61
3.77	1.55	1550	71.63	9.85	11.79	150.12	125.45
3.78	1.55	1550	71.82	9.85	11.79	150.10	125.43
3.79	1.62	1620	72.01	9.85	11.79	157.19	131.35

Table 16: S_u determined for site 1 from Equation 12

Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v, \nu}$ (kPa)	Minimum N_{kt}	Maximum N_{kt}	Undrained shear strength, kPa ($N_{kt} - 11.8$)	Undrained shear strength, kPa ($N_{kt} - 16.04$)
0.85	1.47	1470	16.15	11.80	16.04	123.24	90.62
0.86	1.41	1410	16.34	11.80	16.04	118.14	86.86
0.87	1.41	1410	16.53	11.80	16.04	118.12	86.85
0.88	1.34	1340	16.72	11.80	16.04	112.17	82.48
0.89	1.29	1290	16.91	11.80	16.04	107.92	79.35
0.9	1.29	1290	17.1	11.80	16.04	107.90	79.34
0.91	1.27	1270	17.29	11.80	16.04	106.19	78.08
0.92	1.22	1220	17.48	11.80	16.04	101.93	74.95
0.93	1.15	1150	17.67	11.80	16.04	95.98	70.58
0.94	1.15	1150	17.86	11.80	16.04	95.97	70.56
2.41	1.81	1810	45.79	11.80	16.04	149.55	109.96
2.42	1.81	1810	45.98	11.80	16.04	149.53	109.95
2.43	1.82	1820	46.17	11.80	16.04	150.36	110.56
2.44	1.85	1850	46.36	11.80	16.04	152.89	112.42
2.45	1.86	1860	46.55	11.80	16.04	153.72	113.03
2.46	1.86	1860	46.74	11.80	16.04	153.71	113.02
2.47	1.88	1880	46.93	11.80	16.04	155.38	114.25
2.48	1.92	1920	47.12	11.80	16.04	158.76	116.73
2.49	1.98	1980	47.31	11.80	16.04	163.83	120.46
2.5	1.99	1990	47.5	11.80	16.04	164.66	121.07
3.7	1.45	1450	70.3	11.80	16.04	116.95	85.99
3.71	1.44	1440	70.49	11.80	16.04	116.09	85.36
3.72	1.4	1400	70.68	11.80	16.04	112.68	82.85
3.73	1.42	1420	70.87	11.80	16.04	114.36	84.09
3.74	1.49	1490	71.06	11.80	16.04	120.28	88.44
3.75	1.52	1520	71.25	11.80	16.04	122.81	90.30
3.76	1.54	1540	71.44	11.80	16.04	124.49	91.53
3.77	1.55	1550	71.63	11.80	16.04	125.32	92.14
3.78	1.55	1550	71.82	11.80	16.04	125.30	92.13
3.79	1.62	1620	72.01	11.80	16.04	131.22	96.48

Table 17: S_u determined for site 1 from Equation 13

Depth, m	q_t (MPa)	q_t (kPa)	σ_v (kPa)	Minimum N_{kt}	Maximum N_{kt}	Undrained shear strength (N_{kt} -256.13)	Undrained shear strength (N_{kt} -384.47)
0.85	1.47	1470	16.15	256.13	384.47	5.68	3.78
0.86	1.41	1410	16.34	256.13	384.47	5.44	3.62
0.87	1.41	1410	16.53	256.13	384.47	5.44	3.62
0.88	1.34	1340	16.72	256.13	384.47	5.17	3.44
0.89	1.29	1290	16.91	256.13	384.47	4.97	3.31
0.9	1.29	1290	17.1	256.13	384.47	4.97	3.31
0.91	1.27	1270	17.29	256.13	384.47	4.89	3.26
0.92	1.22	1220	17.48	256.13	384.47	4.70	3.13
0.93	1.15	1150	17.67	256.13	384.47	4.42	2.95
0.94	1.15	1150	17.86	256.13	384.47	4.42	2.94
2.41	1.81	1810	45.79	256.13	384.47	6.89	4.59
2.42	1.81	1810	45.98	256.13	384.47	6.89	4.59
2.43	1.82	1820	46.17	256.13	384.47	6.93	4.61
2.44	1.85	1850	46.36	256.13	384.47	7.04	4.69
2.45	1.86	1860	46.55	256.13	384.47	7.08	4.72
2.46	1.86	1860	46.74	256.13	384.47	7.08	4.72
2.47	1.88	1880	46.93	256.13	384.47	7.16	4.77
2.48	1.92	1920	47.12	256.13	384.47	7.31	4.87
2.49	1.98	1980	47.31	256.13	384.47	7.55	5.03
2.5	1.99	1990	47.5	256.13	384.47	7.58	5.05
3.7	1.45	1450	70.3	256.13	384.47	5.39	3.59
3.71	1.44	1440	70.49	256.13	384.47	5.35	3.56
3.72	1.4	1400	70.68	256.13	384.47	5.19	3.46
3.73	1.42	1420	70.87	256.13	384.47	5.27	3.51
3.74	1.49	1490	71.06	256.13	384.47	5.54	3.69
3.75	1.52	1520	71.25	256.13	384.47	5.66	3.77
3.76	1.54	1540	71.44	256.13	384.47	5.73	3.82
3.77	1.55	1550	71.63	256.13	384.47	5.77	3.85
3.78	1.55	1550	71.82	256.13	384.47	5.77	3.84
3.79	1.62	1620	72.01	256.13	384.47	6.04	4.03

Table 18: S_u determined for site 1 from Equation 14

Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,}$ (kPa)	Minimum N_{kt}	Maximum N_{kt}	Undrained shear strength, kPa ($N_{kt} - 19.51$)	Undrained shear strength, kPa ($N_{kt} - 20.36$)
0.85	1.47	1470	16.15	19.51	21.36	74.53	68.05
0.86	1.41	1410	16.34	19.51	21.36	71.44	65.23
0.87	1.41	1410	16.53	19.51	21.36	71.43	65.23
0.88	1.34	1340	16.72	19.51	21.36	67.84	61.94
0.89	1.29	1290	16.91	19.51	21.36	65.26	59.59
0.9	1.29	1290	17.1	19.51	21.36	65.25	59.58
0.91	1.27	1270	17.29	19.51	21.36	64.22	58.64
0.92	1.22	1220	17.48	19.51	21.36	61.65	56.29
0.93	1.15	1150	17.67	19.51	21.36	58.05	53.00
0.94	1.15	1150	17.86	19.51	21.36	58.04	52.99
2.41	1.81	1810	45.79	19.51	21.36	90.44	82.58
2.42	1.81	1810	45.98	19.51	21.36	90.43	82.57
2.43	1.82	1820	46.17	19.51	21.36	90.93	83.03
2.44	1.85	1850	46.36	19.51	21.36	92.46	84.42
2.45	1.86	1860	46.55	19.51	21.36	92.96	84.88
2.46	1.86	1860	46.74	19.51	21.36	92.95	84.87
2.47	1.88	1880	46.93	19.51	21.36	93.97	85.80
2.48	1.92	1920	47.12	19.51	21.36	96.01	87.67
2.49	1.98	1980	47.31	19.51	21.36	99.08	90.46
2.5	1.99	1990	47.5	19.51	21.36	99.58	90.92
3.7	1.45	1450	70.3	19.51	21.36	70.73	64.58
3.71	1.44	1440	70.49	19.51	21.36	70.21	64.10
3.72	1.4	1400	70.68	19.51	21.36	68.15	62.22
3.73	1.42	1420	70.87	19.51	21.36	69.16	63.15
3.74	1.49	1490	71.06	19.51	21.36	72.74	66.42
3.75	1.52	1520	71.25	19.51	21.36	74.27	67.81
3.76	1.54	1540	71.44	19.51	21.36	75.28	68.74
3.77	1.55	1550	71.63	19.51	21.36	75.79	69.20
3.78	1.55	1550	71.82	19.51	21.36	75.78	69.19
3.79	1.62	1620	72.01	19.51	21.36	79.36	72.46

Table 19: S_u determined for site 1 from Equation 15

Depth, m	q_t (MPa)	q_t (kPa)	σ_v (kPa)	Minimum N_{kt}	Maximum N_{kt}	Undrained shear strength, kPa ($N_{kt} - 19.51$)	Undrained shear strength, kPa ($N_{kt} - 20.36$)
0.85	1.47	1470	16.15	29.19	35.36	49.81	41.12
0.86	1.41	1410	16.34	29.19	35.36	47.75	39.41
0.87	1.41	1410	16.53	29.19	35.36	47.75	39.41
0.88	1.34	1340	16.72	29.19	35.36	45.34	37.42
0.89	1.29	1290	16.91	29.19	35.36	43.62	36.00
0.9	1.29	1290	17.1	29.19	35.36	43.61	36.00
0.91	1.27	1270	17.29	29.19	35.36	42.92	35.43
0.92	1.22	1220	17.48	29.19	35.36	41.20	34.01
0.93	1.15	1150	17.67	29.19	35.36	38.80	32.02
0.94	1.15	1150	17.86	29.19	35.36	38.79	32.02
2.41	1.81	1810	45.79	29.19	35.36	60.45	49.89
2.42	1.81	1810	45.98	29.19	35.36	60.44	49.89
2.43	1.82	1820	46.17	29.19	35.36	60.78	50.16
2.44	1.85	1850	46.36	29.19	35.36	61.80	51.01
2.45	1.86	1860	46.55	29.19	35.36	62.14	51.29
2.46	1.86	1860	46.74	29.19	35.36	62.13	51.28
2.47	1.88	1880	46.93	29.19	35.36	62.81	51.84
2.48	1.92	1920	47.12	29.19	35.36	64.17	52.97
2.49	1.98	1980	47.31	29.19	35.36	66.22	54.66
2.5	1.99	1990	47.5	29.19	35.36	66.56	54.93
3.7	1.45	1450	70.3	29.19	35.36	47.27	39.02
3.71	1.44	1440	70.49	29.19	35.36	46.93	38.73
3.72	1.4	1400	70.68	29.19	35.36	45.55	37.59
3.73	1.42	1420	70.87	29.19	35.36	46.23	38.15
3.74	1.49	1490	71.06	29.19	35.36	48.62	40.13
3.75	1.52	1520	71.25	29.19	35.36	49.64	40.97
3.76	1.54	1540	71.44	29.19	35.36	50.32	41.53
3.77	1.55	1550	71.63	29.19	35.36	50.66	41.81
3.78	1.55	1550	71.82	29.19	35.36	50.65	41.80
3.79	1.62	1620	72.01	29.19	35.36	53.04	43.78

Table 20: S_u determined for site 1 from Equation 16

Depth, m	q_t (MPa)	q_t (kPa)	σ_v (kPa)	Minimum N_{kt}	Maximum N_{kt}	Undrained shear strength, kPa ($N_{kt} - 10.41$)	Undrained shear strength, kPa ($N_{kt} - 70$)
0.85	1.47	1470	16.15	10.40	70.00	139.79	20.77
0.86	1.41	1410	16.34	10.40	70.00	134.01	19.91
0.87	1.41	1410	16.53	10.40	70.00	133.99	19.91
0.88	1.34	1340	16.72	10.40	70.00	127.24	18.90
0.89	1.29	1290	16.91	10.40	70.00	122.41	18.19
0.9	1.29	1290	17.1	10.40	70.00	122.39	18.18
0.91	1.27	1270	17.29	10.40	70.00	120.45	17.90
0.92	1.22	1220	17.48	10.40	70.00	115.63	17.18
0.93	1.15	1150	17.67	10.40	70.00	108.88	16.18
0.94	1.15	1150	17.86	10.40	70.00	108.86	16.17
2.41	1.81	1810	45.79	10.40	70.00	169.64	25.20
2.42	1.81	1810	45.98	10.40	70.00	169.62	25.20
2.43	1.82	1820	46.17	10.40	70.00	170.56	25.34
2.44	1.85	1850	46.36	10.40	70.00	173.43	25.77
2.45	1.86	1860	46.55	10.40	70.00	174.37	25.91
2.46	1.86	1860	46.74	10.40	70.00	174.35	25.90
2.47	1.88	1880	46.93	10.40	70.00	176.26	26.19
2.48	1.92	1920	47.12	10.40	70.00	180.08	26.76
2.49	1.98	1980	47.31	10.40	70.00	185.84	27.61
2.5	1.99	1990	47.5	10.40	70.00	186.78	27.75
3.7	1.45	1450	70.3	10.40	70.00	132.66	19.71
3.71	1.44	1440	70.49	10.40	70.00	131.68	19.56
3.72	1.4	1400	70.68	10.40	70.00	127.82	18.99
3.73	1.42	1420	70.87	10.40	70.00	129.72	19.27
3.74	1.49	1490	71.06	10.40	70.00	136.44	20.27
3.75	1.52	1520	71.25	10.40	70.00	139.30	20.70
3.76	1.54	1540	71.44	10.40	70.00	141.21	20.98
3.77	1.55	1550	71.63	10.40	70.00	142.15	21.12
3.78	1.55	1550	71.82	10.40	70.00	142.13	21.12
3.79	1.62	1620	72.01	10.40	70.00	148.85	22.11

Table 21: S_u determined for site 2 from Equation 11

Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,}$ (kPa)	Minimum N_{kt}	Maximum N_{kt}	Undrained shear strength, kPa ($N_{kt} - 9.64$)	Undrained shear strength, kPa ($N_{kt} - 11.73$)
2.48	16.04	16040	47.12	9.64	11.73	1659.01	1363.42
2.49	15.78	15780	47.31	9.64	11.73	1632.02	1341.24
2.5	15.61	15610	47.5	9.64	11.73	1614.37	1326.73
2.51	19.19	19190	47.69	9.64	11.73	1985.72	1631.91
2.52	19.06	19060	47.88	9.64	11.73	1972.21	1620.81
2.53	18.87	18870	48.07	9.64	11.73	1952.48	1604.60
2.54	18.64	18640	48.26	9.64	11.73	1928.60	1584.97
2.55	18.37	18370	48.45	9.64	11.73	1900.58	1561.94
2.56	18.15	18150	48.64	9.64	11.73	1877.73	1543.17
2.57	18.09	18090	48.83	9.64	11.73	1871.49	1538.04
2.58	18.07	18070	49.02	9.64	11.73	1869.40	1536.32
2.59	18.09	18090	49.21	9.64	11.73	1871.45	1538.00
2.6	18.07	18070	49.4	9.64	11.73	1869.36	1536.28
2.61	18.01	18010	49.59	9.64	11.73	1863.11	1531.15
2.62	17.98	17980	49.78	9.64	11.73	1859.98	1528.58
3.2	22.27	22270	60.8	9.64	11.73	2303.86	1893.37
3.21	22.78	22780	60.99	9.64	11.73	2356.74	1936.83
3.22	23.36	23360	61.18	9.64	11.73	2416.89	1986.26
3.25	23.4	23400	61.75	9.64	11.73	2420.98	1989.62
3.26	23.09	23090	61.94	9.64	11.73	2388.80	1963.18
3.27	22.86	22860	62.13	9.64	11.73	2364.92	1943.55
3.28	22.75	22750	62.32	9.64	11.73	2353.49	1934.16
3.29	22.92	22920	62.51	9.64	11.73	2371.11	1948.64
3.3	23.23	23230	62.7	9.64	11.73	2403.25	1975.05
3.31	23.34	23340	62.89	9.64	11.73	2414.64	1984.41
3.32	23.23	23230	63.08	9.64	11.73	2403.21	1975.01
3.33	23.15	23150	63.27	9.64	11.73	2394.89	1968.18
3.34	23.38	23380	63.46	9.64	11.73	2418.73	1987.77
3.53	21	21000	67.07	9.64	11.73	2171.47	1784.56
3.54	20.28	20280	67.26	9.64	11.73	2096.76	1723.17

Table 22: S_u determined for site 2 from Equation 12

Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,}$ (kPa)	Minimum N_{kt}	Maximum N_{kt}	Undrained shear strength, kPa ($N_{kt} - 11.34$)	Undrained shear strength, kPa ($N_{kt} - 15.93$)
2.48	16.04	16040	47.12	11.34	15.93	1410.18	1003.95
2.49	15.78	15780	47.31	11.34	15.93	1387.24	987.61
2.5	15.61	15610	47.5	11.34	15.93	1372.23	976.93
2.51	19.19	19190	47.69	11.34	15.93	1687.89	1201.65
2.52	19.06	19060	47.88	11.34	15.93	1676.41	1193.48
2.53	18.87	18870	48.07	11.34	15.93	1659.64	1181.54
2.54	18.64	18640	48.26	11.34	15.93	1639.34	1167.09
2.55	18.37	18370	48.45	11.34	15.93	1615.51	1150.13
2.56	18.15	18150	48.64	11.34	15.93	1596.10	1136.31
2.57	18.09	18090	48.83	11.34	15.93	1590.79	1132.53
2.58	18.07	18070	49.02	11.34	15.93	1589.01	1131.26
2.59	18.09	18090	49.21	11.34	15.93	1590.76	1132.50
2.6	18.07	18070	49.4	11.34	15.93	1588.98	1131.24
2.61	18.01	18010	49.59	11.34	15.93	1583.67	1127.46
2.62	17.98	17980	49.78	11.34	15.93	1581.01	1125.56
3.2	22.27	22270	60.8	11.34	15.93	1958.31	1394.17
3.21	22.78	22780	60.99	11.34	15.93	2003.26	1426.18
3.22	23.36	23360	61.18	11.34	15.93	2054.39	1462.58
3.25	23.4	23400	61.75	11.34	15.93	2057.87	1465.05
3.26	23.09	23090	61.94	11.34	15.93	2030.51	1445.58
3.27	22.86	22860	62.13	11.34	15.93	2010.22	1431.13
3.28	22.75	22750	62.32	11.34	15.93	2000.50	1424.21
3.29	22.92	22920	62.51	11.34	15.93	2015.47	1434.87
3.3	23.23	23230	62.7	11.34	15.93	2042.79	1454.32
3.31	23.34	23340	62.89	11.34	15.93	2052.47	1461.21
3.32	23.23	23230	63.08	11.34	15.93	2042.76	1454.30
3.33	23.15	23150	63.27	11.34	15.93	2035.69	1449.26
3.34	23.38	23380	63.46	11.34	15.93	2055.95	1463.69
3.53	21	21000	67.07	11.34	15.93	1845.77	1314.06
3.54	20.28	20280	67.26	11.34	15.93	1782.27	1268.85

Table 23: S_u determined for site 2 from Equation 13

Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,}$ (kPa)	Minimum N_{kt}	Maximum N_{kt}	Undrained shear strength, kPa ($N_{kt} - 182.31$)	Undrained shear strength, kPa ($N_{kt} - 367.85$)
2.48	16.04	16040	47.12	182.31	367.85	87.72	43.48
2.49	15.78	15780	47.31	182.31	367.85	86.30	42.77
2.5	15.61	15610	47.5	182.31	367.85	85.36	42.31
2.51	19.19	19190	47.69	182.31	367.85	105.00	52.04
2.52	19.06	19060	47.88	182.31	367.85	104.28	51.69
2.53	18.87	18870	48.07	182.31	367.85	103.24	51.17
2.54	18.64	18640	48.26	182.31	367.85	101.98	50.54
2.55	18.37	18370	48.45	182.31	367.85	100.50	49.81
2.56	18.15	18150	48.64	182.31	367.85	99.29	49.21
2.57	18.09	18090	48.83	182.31	367.85	98.96	49.05
2.58	18.07	18070	49.02	182.31	367.85	98.85	48.99
2.59	18.09	18090	49.21	182.31	367.85	98.96	49.04
2.6	18.07	18070	49.4	182.31	367.85	98.85	48.99
2.61	18.01	18010	49.59	182.31	367.85	98.52	48.83
2.62	17.98	17980	49.78	182.31	367.85	98.35	48.74
3.2	22.27	22270	60.8	182.31	367.85	121.82	60.38
3.21	22.78	22780	60.99	182.31	367.85	124.62	61.76
3.22	23.36	23360	61.18	182.31	367.85	127.80	63.34
3.25	23.4	23400	61.75	182.31	367.85	128.01	63.45
3.26	23.09	23090	61.94	182.31	367.85	126.31	62.60
3.27	22.86	22860	62.13	182.31	367.85	125.05	61.98
3.28	22.75	22750	62.32	182.31	367.85	124.45	61.68
3.29	22.92	22920	62.51	182.31	367.85	125.38	62.14
3.3	23.23	23230	62.7	182.31	367.85	127.08	62.98
3.31	23.34	23340	62.89	182.31	367.85	127.68	63.28
3.32	23.23	23230	63.08	182.31	367.85	127.07	62.98
3.33	23.15	23150	63.27	182.31	367.85	126.63	62.76
3.34	23.38	23380	63.46	182.31	367.85	127.90	63.39
3.53	21	21000	67.07	182.31	367.85	114.82	56.91
3.54	20.28	20280	67.26	182.31	367.85	110.87	54.95

Table 24: S_u determined for site 2 from Equation 14

Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,}$ (kPa)	Minimum N_{kt}	Maximum N_{kt}	Undrained shear strength, kPa (N_{kt} -18)	Undrained shear strength, kPa (N_{kt} -21)
2.48	16.04	16040	47.12	18	21	888.49	761.57
2.49	15.78	15780	47.31	18	21	874.04	749.18
2.5	15.61	15610	47.5	18	21	864.58	741.07
2.51	19.19	19190	47.69	18	21	1063.46	911.54
2.52	19.06	19060	47.88	18	21	1056.23	905.34
2.53	18.87	18870	48.07	18	21	1045.66	896.28
2.54	18.64	18640	48.26	18	21	1032.87	885.32
2.55	18.37	18370	48.45	18	21	1017.86	872.45
2.56	18.15	18150	48.64	18	21	1005.63	861.97
2.57	18.09	18090	48.83	18	21	1002.29	859.10
2.58	18.07	18070	49.02	18	21	1001.17	858.14
2.59	18.09	18090	49.21	18	21	1002.27	859.09
2.6	18.07	18070	49.4	18	21	1001.14	858.12
2.61	18.01	18010	49.59	18	21	997.80	855.26
2.62	17.98	17980	49.78	18	21	996.12	853.82
3.2	22.27	22270	60.8	18	21	1233.84	1057.58
3.21	22.78	22780	60.99	18	21	1262.17	1081.86
3.22	23.36	23360	61.18	18	21	1294.38	1109.47
3.25	23.4	23400	61.75	18	21	1296.57	1111.35
3.26	23.09	23090	61.94	18	21	1279.34	1096.57
3.27	22.86	22860	62.13	18	21	1266.55	1085.61
3.28	22.75	22750	62.32	18	21	1260.43	1080.37
3.29	22.92	22920	62.51	18	21	1269.86	1088.45
3.3	23.23	23230	62.7	18	21	1287.07	1103.20
3.31	23.34	23340	62.89	18	21	1293.17	1108.43
3.32	23.23	23230	63.08	18	21	1287.05	1103.19
3.33	23.15	23150	63.27	18	21	1282.60	1099.37
3.34	23.38	23380	63.46	18	21	1295.36	1110.31
3.53	21	21000	67.07	18	21	1162.94	996.81
3.54	20.28	20280	67.26	18	21	1122.93	962.51

Table 25: S_u determined for site 2 from Equation 15

Depth , m	q_t (MPa)	q_t (kPa)	σ_{sv} (kPa)	Minimum N_{kt}	Maximum N_{kt}	S_u , kPa ($N_{kt} - 23.61$)	S_u , kPa ($N_{kt} - 30.96$)
2.48	16.04	16040	47.12	29.19	35.36	547.98	452.29
2.49	15.78	15780	47.31	29.19	35.36	539.07	444.93
2.5	15.61	15610	47.5	29.19	35.36	533.24	440.12
2.51	19.19	19190	47.69	29.19	35.36	655.90	541.35
2.52	19.06	19060	47.88	29.19	35.36	651.43	537.67
2.53	18.87	18870	48.07	29.19	35.36	644.92	532.29
2.54	18.64	18640	48.26	29.19	35.36	637.03	525.78
2.55	18.37	18370	48.45	29.19	35.36	627.77	518.14
2.56	18.15	18150	48.64	29.19	35.36	620.23	511.92
2.57	18.09	18090	48.83	29.19	35.36	618.17	510.21
2.58	18.07	18070	49.02	29.19	35.36	617.47	509.64
2.59	18.09	18090	49.21	29.19	35.36	618.15	510.20
2.6	18.07	18070	49.4	29.19	35.36	617.46	509.63
2.61	18.01	18010	49.59	29.19	35.36	615.40	507.93
2.62	17.98	17980	49.78	29.19	35.36	614.36	507.08
3.2	22.27	22270	60.8	29.19	35.36	760.98	628.09
3.21	22.78	22780	60.99	29.19	35.36	778.45	642.51
3.22	23.36	23360	61.18	29.19	35.36	798.31	658.90
3.25	23.4	23400	61.75	29.19	35.36	799.67	660.02
3.26	23.09	23090	61.94	29.19	35.36	789.04	651.25
3.27	22.86	22860	62.13	29.19	35.36	781.15	644.74
3.28	22.75	22750	62.32	29.19	35.36	777.37	641.62
3.29	22.92	22920	62.51	29.19	35.36	783.19	646.42
3.3	23.23	23230	62.7	29.19	35.36	793.81	655.18
3.31	23.34	23340	62.89	29.19	35.36	797.57	658.29
3.32	23.23	23230	63.08	29.19	35.36	793.80	655.17
3.33	23.15	23150	63.27	29.19	35.36	791.05	652.91
3.34	23.38	23380	63.46	29.19	35.36	798.92	659.40
3.53	21	21000	67.07	29.19	35.36	717.25	591.99
3.54	20.28	20280	67.26	29.19	35.36	692.57	571.63

Table 26: S_u determined for site 2 from Equation 16

Depth, m	q_t (MPa)	q_t (kPa)	σ_{sv} (kPa)	Minimum N_{kt}	Maximum N_{kt}	Undrained shear strength, kPa ($N_{kt}-4$)	Undrained shear strength, kPa ($N_{kt}-68.4$)
2.48	16.04	16040	47.12	4.00	68.40	3998.22	233.81
2.49	15.78	15780	47.31	4.00	68.40	3933.17	230.01
2.5	15.61	15610	47.5	4.00	68.40	3890.63	227.52
2.51	19.19	19190	47.69	4.00	68.40	4785.58	279.86
2.52	19.06	19060	47.88	4.00	68.40	4753.03	277.95
2.53	18.87	18870	48.07	4.00	68.40	4705.48	275.17
2.54	18.64	18640	48.26	4.00	68.40	4647.94	271.81
2.55	18.37	18370	48.45	4.00	68.40	4580.39	267.86
2.56	18.15	18150	48.64	4.00	68.40	4525.34	264.64
2.57	18.09	18090	48.83	4.00	68.40	4510.29	263.76
2.58	18.07	18070	49.02	4.00	68.40	4505.25	263.46
2.59	18.09	18090	49.21	4.00	68.40	4510.20	263.75
2.6	18.07	18070	49.4	4.00	68.40	4505.15	263.46
2.61	18.01	18010	49.59	4.00	68.40	4490.10	262.58
2.62	17.98	17980	49.78	4.00	68.40	4482.56	262.14
3.2	22.27	22270	60.8	4.00	68.40	5552.30	324.70
3.21	22.78	22780	60.99	4.00	68.40	5679.75	332.15
3.22	23.36	23360	61.18	4.00	68.40	5824.71	340.63
3.25	23.4	23400	61.75	4.00	68.40	5834.56	341.20
3.26	23.09	23090	61.94	4.00	68.40	5757.02	336.67
3.27	22.86	22860	62.13	4.00	68.40	5699.47	333.30
3.28	22.75	22750	62.32	4.00	68.40	5671.92	331.69
3.29	22.92	22920	62.51	4.00	68.40	5714.37	334.17
3.3	23.23	23230	62.7	4.00	68.40	5791.83	338.70
3.31	23.34	23340	62.89	4.00	68.40	5819.28	340.31
3.32	23.23	23230	63.08	4.00	68.40	5791.73	338.70
3.33	23.15	23150	63.27	4.00	68.40	5771.68	337.53
3.34	23.38	23380	63.46	4.00	68.40	5829.14	340.89
3.53	21	21000	67.07	4.00	68.40	5233.23	306.04
3.54	20.28	20280	67.26	4.00	68.40	5053.19	295.51

Table 27: S_u determined for site 1 from Akbar Cheshomi, 2016 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	σ_v (kPa)	Minimum N_{kt}	Maximum N_{kt}	Undrained shear strength, kPa ($N_{kt}-22$)	Undrained shear strength, kPa ($N_{kt}-23$)
0.85	1.5	1470	16.2	22	23	66.08	63.21
0.86	1.4	1410	16.3	22	23	63.35	60.59
0.87	1.4	1410	16.5	22	23	63.34	60.59
0.88	1.3	1340	16.7	22	23	60.15	57.53
0.89	1.3	1290	16.9	22	23	57.87	55.35
0.9	1.3	1290	17.1	22	23	57.86	55.34
0.91	1.3	1270	17.3	22	23	56.94	54.47
0.92	1.2	1220	17.5	22	23	54.66	52.28
0.93	1.2	1150	17.7	22	23	51.47	49.23
0.94	1.2	1150	17.9	22	23	51.46	49.22
2.41	1.8	1810	45.8	22	23	80.19	76.70
2.42	1.8	1810	46	22	23	80.18	76.70
2.43	1.8	1820	46.2	22	23	80.63	77.12
2.44	1.9	1850	46.4	22	23	81.98	78.42
2.45	1.9	1860	46.6	22	23	82.43	78.85
2.46	1.9	1860	46.7	22	23	82.42	78.84
2.47	1.9	1880	46.9	22	23	83.32	79.70
2.48	1.9	1920	47.1	22	23	85.13	81.43
2.49	2	1980	47.3	22	23	87.85	84.03
2.5	2	1990	47.5	22	23	88.30	84.46
3.7	1.5	1450	70.3	22	23	62.71	59.99
3.71	1.4	1440	70.5	22	23	62.25	59.54
3.72	1.4	1400	70.7	22	23	60.42	57.80
3.73	1.4	1420	70.9	22	23	61.32	58.66
3.74	1.5	1490	71.1	22	23	64.50	61.69
3.75	1.5	1520	71.3	22	23	65.85	62.99
3.76	1.5	1540	71.4	22	23	66.75	63.85
3.77	1.6	1550	71.6	22	23	67.20	64.28
3.78	1.6	1550	71.8	22	23	67.19	64.27
3.79	1.6	1620	72	22	23	70.36	67.30

Table 28: Site 1 S_u obtained from Otoko et al., 2016 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	σ_{sv} (kPa)	Minimum N_{kt}	Maximum N_{kt}	Undrained shear strength, kPa ($N_{kt} - 34.2$)	Undrained shear strength, kPa ($N_{kt} - 57.2$)
0.85	1.5	1470	16.15	7	10	207.69	145.39
0.86	1.4	1410	16.34	7	10	199.09	139.37
0.87	1.4	1410	16.53	7	10	199.07	139.35
0.88	1.3	1340	16.72	7	10	189.04	132.33
0.89	1.3	1290	16.91	7	10	181.87	127.31
0.9	1.3	1290	17.1	7	10	181.84	127.29
0.91	1.3	1270	17.29	7	10	178.96	125.27
0.92	1.2	1220	17.48	7	10	171.79	120.25
0.93	1.2	1150	17.67	7	10	161.76	113.23
0.94	1.2	1150	17.86	7	10	161.73	113.21
2.41	1.8	1810	45.79	7	10	252.03	176.42
2.42	1.8	1810	45.98	7	10	252.00	176.40
2.43	1.8	1820	46.17	7	10	253.40	177.38
2.44	1.9	1850	46.36	7	10	257.66	180.36
2.45	1.9	1860	46.55	7	10	259.06	181.35
2.46	1.9	1860	46.74	7	10	259.04	181.33
2.47	1.9	1880	46.93	7	10	261.87	183.31
2.48	1.9	1920	47.12	7	10	267.55	187.29
2.49	2	1980	47.31	7	10	276.10	193.27
2.5	2	1990	47.5	7	10	277.50	194.25
3.7	1.5	1450	70.3	7	10	197.10	137.97
3.71	1.4	1440	70.49	7	10	195.64	136.95
3.72	1.4	1400	70.68	7	10	189.90	132.93
3.73	1.4	1420	70.87	7	10	192.73	134.91
3.74	1.5	1490	71.06	7	10	202.71	141.89
3.75	1.5	1520	71.25	7	10	206.96	144.88
3.76	1.5	1540	71.44	7	10	209.79	146.86
3.77	1.6	1550	71.63	7	10	211.20	147.84
3.78	1.6	1550	71.82	7	10	211.17	147.82
3.79	1.6	1620	72.01	7	10	221.14	154.80

Table 29: Site 1 S_u obtained from Stefanik 2015 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	σ_v (kPa)	Minimum N_{kt}	Undrained shear strength, kPa ($N_{kt} - 15.5$)
0.85	1.47	1470	16.15	16	93.80
0.86	1.41	1410	16.34	16	89.91
0.87	1.41	1410	16.53	16	89.90
0.88	1.34	1340	16.72	16	85.37
0.89	1.29	1290	16.91	16	82.13
0.9	1.29	1290	17.1	16	82.12
0.91	1.27	1270	17.29	16	80.82
0.92	1.22	1220	17.48	16	77.58
0.93	1.15	1150	17.67	16	73.05
0.94	1.15	1150	17.86	16	73.04
2.41	1.81	1810	45.79	16	113.82
2.42	1.81	1810	45.98	16	113.81
2.43	1.82	1820	46.17	16	114.44
2.44	1.85	1850	46.36	16	116.36
2.45	1.86	1860	46.55	16	117.00
2.46	1.86	1860	46.74	16	116.98
2.47	1.88	1880	46.93	16	118.26
2.48	1.92	1920	47.12	16	120.83
2.49	1.98	1980	47.31	16	124.69
2.5	1.99	1990	47.5	16	125.32
3.7	1.45	1450	70.3	16	89.01
3.71	1.44	1440	70.49	16	88.36
3.72	1.4	1400	70.68	16	85.76
3.73	1.42	1420	70.87	16	87.04
3.74	1.49	1490	71.06	16	91.54
3.75	1.52	1520	71.25	16	93.47
3.76	1.54	1540	71.44	16	94.75
3.77	1.55	1550	71.63	16	95.38
3.78	1.55	1550	71.82	16	95.37
3.79	1.62	1620	72.01	16	99.87

Table 30: Site 1 S_u obtained from Remai 2013 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,}$ (kPa)	Minimum N_{kt}	Maximum N_{kt}	S_u , kPa ($N_{kt} - 12$)	S_u , kPa ($N_{kt} - 32$)
0.9	1.47	1470	16.15	12	32	121.15	45.43
0.9	1.41	1410	16.34	12	32	116.14	43.55
0.9	1.41	1410	16.53	12	32	116.12	43.55
0.9	1.34	1340	16.72	12	32	110.27	41.35
0.9	1.29	1290	16.91	12	32	106.09	39.78
0.9	1.29	1290	17.1	12	32	106.08	39.78
0.9	1.27	1270	17.29	12	32	104.39	39.15
0.9	1.22	1220	17.48	12	32	100.21	37.58
0.9	1.15	1150	17.67	12	32	94.36	35.39
0.9	1.15	1150	17.86	12	32	94.35	35.38
2.4	1.81	1810	45.79	12	32	147.02	55.13
2.4	1.81	1810	45.98	12	32	147.00	55.13
2.4	1.82	1820	46.17	12	32	147.82	55.43
2.4	1.85	1850	46.36	12	32	150.30	56.36
2.5	1.86	1860	46.55	12	32	151.12	56.67
2.5	1.86	1860	46.74	12	32	151.11	56.66
2.5	1.88	1880	46.93	12	32	152.76	57.28
2.5	1.92	1920	47.12	12	32	156.07	58.53
2.5	1.98	1980	47.31	12	32	161.06	60.40
2.5	1.99	1990	47.5	12	32	161.88	60.70
3.7	1.45	1450	70.3	12	32	114.98	43.12
3.7	1.44	1440	70.49	12	32	114.13	42.80
3.7	1.4	1400	70.68	12	32	110.78	41.54
3.7	1.42	1420	70.87	12	32	112.43	42.16
3.7	1.49	1490	71.06	12	32	118.25	44.34
3.8	1.52	1520	71.25	12	32	120.73	45.27
3.8	1.54	1540	71.44	12	32	122.38	45.89
3.8	1.55	1550	71.63	12	32	123.20	46.20
3.8	1.55	1550	71.82	12	32	123.18	46.19
3.8	1.62	1620	72.01	12	32	129.00	48.37

Table 31: Site 1 S_u obtained from Hong et al.,2010 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	σ_v (kPa)	Minimum N_{kt}	Maximum N_{kt}	Undrained shear strength, kPa ($N_{kt} - 7$)	Undrained shear strength, kPa ($N_{kt} - 20$)
0.85	1.5	1470	16.2	7	20	207.69	72.69
0.86	1.4	1410	16.3	7	20	199.09	69.68
0.87	1.4	1410	16.5	7	20	199.07	69.67
0.88	1.3	1340	16.7	7	20	189.04	66.16
0.89	1.3	1290	16.9	7	20	181.87	63.65
0.9	1.3	1290	17.1	7	20	181.84	63.65
0.91	1.3	1270	17.3	7	20	178.96	62.64
0.92	1.2	1220	17.5	7	20	171.79	60.13
0.93	1.2	1150	17.7	7	20	161.76	56.62
0.94	1.2	1150	17.9	7	20	161.73	56.61
2.41	1.8	1810	45.8	7	20	252.03	88.21
2.42	1.8	1810	46	7	20	252.00	88.20
2.43	1.8	1820	46.2	7	20	253.40	88.69
2.44	1.9	1850	46.4	7	20	257.66	90.18
2.45	1.9	1860	46.6	7	20	259.06	90.67
2.46	1.9	1860	46.7	7	20	259.04	90.66
2.47	1.9	1880	46.9	7	20	261.87	91.65
2.48	1.9	1920	47.1	7	20	267.55	93.64
2.49	2	1980	47.3	7	20	276.10	96.63
2.5	2	1990	47.5	7	20	277.50	97.13
3.7	1.5	1450	70.3	7	20	197.10	68.99
3.71	1.4	1440	70.5	7	20	195.64	68.48
3.72	1.4	1400	70.7	7	20	189.90	66.47
3.73	1.4	1420	70.9	7	20	192.73	67.46
3.74	1.5	1490	71.1	7	20	202.71	70.95
3.75	1.5	1520	71.3	7	20	206.96	72.44
3.76	1.5	1540	71.4	7	20	209.79	73.43
3.77	1.6	1550	71.6	7	20	211.20	73.92
3.78	1.6	1550	71.8	7	20	211.17	73.91
3.79	1.6	1620	72	7	20	221.14	77.40

Table 32: Site 1 S_u obtained from Almeida et al., 2010 N_{kt} values

Depth, m	qt (MPa)	qt (kPa)	σ_v (kPa)	Min. Nkt	Max. Nkt	S_u ,kPa ($N_{kt}-4$)	S_u ,kPa ($N_{kt}-16$)	Depth, m	qt (MPa)	qt (kPa)	σ_v (kPa)	Min. Nkt	Max. Nkt	S_u , kPa ($N_{kt}-4$)	S_u ,kPa ($N_{kt}-9$)	Depth, m	qt (MPa)	qt (kPa)	σ_v (kPa)	Min. Nkt	Max. Nkt	S_u ,kPa ($N_{kt}-12$)	S_u ,kPa ($N_{kt}-19$)
0.85	1.47	1470	16.2	15	20	96.92	72.69	0.85	1.47	1470	16.15	35	56	41.42	26.15	0.85	1.47	1470	16.15	12	19	121.15	76.52
0.86	1.41	1410	16.3	15	20	92.91	69.68	0.86	1.41	1410	16.34	35	56	39.71	25.07	0.86	1.41	1410	16.34	12	19	116.14	73.35
0.87	1.41	1410	16.5	15	20	92.90	69.67	0.87	1.41	1410	16.53	35	56	39.70	25.06	0.87	1.41	1410	16.53	12	19	116.12	73.34
0.88	1.34	1340	16.7	15	20	88.22	66.16	0.88	1.34	1340	16.72	35	56	37.70	23.80	0.88	1.34	1340	16.72	12	19	110.27	69.65
0.89	1.29	1290	16.9	15	20	84.87	63.65	0.89	1.29	1290	16.91	35	56	36.27	22.90	0.89	1.29	1290	16.91	12	19	106.09	67.00
0.9	1.29	1290	17.1	15	20	84.86	63.65	0.9	1.29	1290	17.1	35	56	36.26	22.89	0.9	1.29	1290	17.1	12	19	106.08	66.99
0.91	1.27	1270	17.3	15	20	83.51	62.64	0.91	1.27	1270	17.29	35	56	35.69	22.53	0.91	1.27	1270	17.29	12	19	104.39	65.93
0.92	1.22	1220	17.5	15	20	80.17	60.13	0.92	1.22	1220	17.48	35	56	34.26	21.63	0.92	1.22	1220	17.48	12	19	100.21	63.29
0.93	1.15	1150	17.7	15	20	75.49	56.62	0.93	1.15	1150	17.67	35	56	32.26	20.37	0.93	1.15	1150	17.67	12	19	94.36	59.60
0.94	1.15	1150	17.9	15	20	75.48	56.61	0.94	1.15	1150	17.86	35	56	32.25	20.36	0.94	1.15	1150	17.86	12	19	94.35	59.59
2.41	1.81	1810	45.8	15	20	117.61	88.21	2.41	1.81	1810	45.79	35	56	50.26	31.73	2.41	1.81	1810	45.79	12	19	147.02	92.85
2.42	1.81	1810	46	15	20	117.60	88.20	2.42	1.81	1810	45.98	35	56	50.26	31.73	2.42	1.81	1810	45.98	12	19	147.00	92.84
2.43	1.82	1820	46.2	15	20	118.26	88.69	2.43	1.82	1820	46.17	35	56	50.54	31.90	2.43	1.82	1820	46.17	12	19	147.82	93.36
2.44	1.85	1850	46.4	15	20	120.24	90.18	2.44	1.85	1850	46.36	35	56	51.39	32.44	2.44	1.85	1850	46.36	12	19	150.30	94.93
2.45	1.86	1860	46.6	15	20	120.90	90.67	2.45	1.86	1860	46.55	35	56	51.67	32.62	2.45	1.86	1860	46.55	12	19	151.12	95.44
2.46	1.86	1860	46.7	15	20	120.88	90.66	2.46	1.86	1860	46.74	35	56	51.66	32.61	2.46	1.86	1860	46.74	12	19	151.11	95.43
2.47	1.88	1880	46.9	15	20	122.20	91.65	2.47	1.88	1880	46.93	35	56	52.22	32.97	2.47	1.88	1880	46.93	12	19	152.76	96.48
2.48	1.92	1920	47.1	15	20	124.86	93.64	2.48	1.92	1920	47.12	35	56	53.36	33.68	2.48	1.92	1920	47.12	12	19	156.07	98.57
2.49	1.98	1980	47.3	15	20	128.85	96.63	2.49	1.98	1980	47.31	35	56	55.06	34.76	2.49	1.98	1980	47.31	12	19	161.06	101.72
2.5	1.99	1990	47.5	15	20	129.50	97.13	2.5	1.99	1990	47.5	35	56	55.34	34.94	2.5	1.99	1990	47.5	12	19	161.88	102.24
3.7	1.45	1450	70.3	15	20	91.98	68.99	3.7	1.45	1450	70.3	35	56	39.31	24.81	3.7	1.45	1450	70.3	12	19	114.98	72.62
3.71	1.44	1440	70.5	15	20	91.30	68.48	3.71	1.44	1440	70.49	35	56	39.02	24.63	3.71	1.44	1440	70.49	12	19	114.13	72.08

Table 33: Site 1 S_u obtained from Hassan 2004 N_{kt} values

Depth, m	qt (MPa)	qt (kPa)	σ_v (kPa)	Min. Nkt	Max. Nkt	S_u ,kPa (Nkt - 34)	S_u ,kPa (Nkt - 62)	Depth ,m	qt (MPa)	qt (kPa)	σ_v (kPa)	Min. Nkt	Max. Nkt	S_u ,kPa (Nkt - 8)	S_u ,kPa (Nkt -28)	Depth, m	qt (MPa)	qt (kPa)	σ_v (kPa)	Min. Nkt	Max. Nkt	S_u ,kPa (Nkt - 8)	S_u ,kPa (Nkt - 28)
0.85	1.47	1470	16.15	34	62	42.76	23.45	0.85	1.47	1470	16.15	8	28	191.30	51.19	0.85	1.47	1470	16.15	8	29	191.30	50.13
0.86	1.41	1410	16.34	34	62	40.99	22.48	0.86	1.41	1410	16.34	8	28	183.38	49.07	0.86	1.41	1410	16.34	8	29	183.38	48.06
0.87	1.41	1410	16.53	34	62	40.98	22.48	0.87	1.41	1410	16.53	8	28	183.35	49.07	0.87	1.41	1410	16.53	8	29	183.35	48.05
0.88	1.34	1340	16.72	34	62	38.92	21.34	0.88	1.34	1340	16.72	8	28	174.12	46.59	0.88	1.34	1340	16.72	8	29	174.12	45.63
0.89	1.29	1290	16.91	34	62	37.44	20.53	0.89	1.29	1290	16.91	8	28	167.51	44.83	0.89	1.29	1290	16.91	8	29	167.51	43.90
0.9	1.29	1290	17.1	34	62	37.44	20.53	0.9	1.29	1290	17.1	8	28	167.49	44.82	0.9	1.29	1290	17.1	8	29	167.49	43.89
0.91	1.27	1270	17.29	34	62	36.84	20.21	0.91	1.27	1270	17.29	8	28	164.83	44.11	0.91	1.27	1270	17.29	8	29	164.83	43.20
0.92	1.22	1220	17.48	34	62	35.37	19.40	0.92	1.22	1220	17.48	8	28	158.23	42.34	0.92	1.22	1220	17.48	8	29	158.23	41.47
0.93	1.15	1150	17.67	34	62	33.30	18.26	0.93	1.15	1150	17.67	8	28	148.99	39.87	0.93	1.15	1150	17.67	8	29	148.99	39.05
0.94	1.15	1150	17.86	34	62	33.30	18.26	0.94	1.15	1150	17.86	8	28	148.97	39.86	0.94	1.15	1150	17.86	8	29	148.97	39.04
2.41	1.81	1810	45.79	34	62	51.89	28.46	2.41	1.81	1810	45.79	8	28	232.13	62.12	2.41	1.81	1810	45.79	8	29	232.13	60.83
2.42	1.81	1810	45.98	34	62	51.88	28.45	2.42	1.81	1810	45.98	8	28	232.11	62.11	2.42	1.81	1810	45.98	8	29	232.11	60.83
2.43	1.82	1820	46.17	34	62	52.17	28.61	2.43	1.82	1820	46.17	8	28	233.40	62.46	2.43	1.82	1820	46.17	8	29	233.40	61.17
2.44	1.85	1850	46.36	34	62	53.05	29.09	2.44	1.85	1850	46.36	8	28	237.32	63.51	2.44	1.85	1850	46.36	8	29	237.32	62.19
2.45	1.86	1860	46.55	34	62	53.34	29.25	2.45	1.86	1860	46.55	8	28	238.61	63.85	2.45	1.86	1860	46.55	8	29	238.61	62.53
2.46	1.86	1860	46.74	34	62	53.33	29.25	2.46	1.86	1860	46.74	8	28	238.59	63.85	2.46	1.86	1860	46.74	8	29	238.59	62.53
2.47	1.88	1880	46.93	34	62	53.91	29.57	2.47	1.88	1880	46.93	8	28	241.19	64.54	2.47	1.88	1880	46.93	8	29	241.19	63.21
2.48	1.92	1920	47.12	34	62	55.08	30.21	2.48	1.92	1920	47.12	8	28	246.43	65.95	2.48	1.92	1920	47.12	8	29	246.43	64.58
2.49	1.98	1980	47.31	34	62	56.84	31.17	2.49	1.98	1980	47.31	8	28	254.30	68.05	2.49	1.98	1980	47.31	8	29	254.30	66.64

Table 34: Site 1 S_u obtained from Ismail & Zein 1987 N_{kt} values

Depth, m	qt (MPa)	qt (kPa)	σ_v (kPa)	Min. Nkt	Max. Nkt	S_u , kPa (Nkt - 32)	S_u ,kPa (Nkt - 39)	Depth, m	qt (MPa)	qt (kPa)	σ_v (kPa)	Min. Nkt	Max. Nkt	S_u ,kPa (Nkt - 8)	S_u ,kPa (Nkt - 16)	Depth, m	qt (MPa)	qt (kPa)	σ_v (kPa)	Min. Nkt	Max. Nkt	S_u , kPa (Nkt -1)	S_u , kPa (Nkt - 13)
0.85	1.47	1470	16.15	32	39	45.43	37.28	0.85	1.47	1470	16.15	8	16	181.73	90.87	0.85	1.47	1470	16.15	1	13	1453.85	111.83
0.86	1.41	1410	16.34	32	39	43.55	35.73	0.86	1.41	1410	16.34	8	16	174.21	87.10	0.86	1.41	1410	16.34	1	13	1393.66	107.20
0.87	1.41	1410	16.53	32	39	43.55	35.73	0.87	1.41	1410	16.53	8	16	174.18	87.09	0.87	1.41	1410	16.53	1	13	1393.47	107.19
0.88	1.34	1340	16.72	32	39	41.35	33.93	0.88	1.34	1340	16.72	8	16	165.41	82.71	0.88	1.34	1340	16.72	1	13	1323.28	101.79
0.89	1.29	1290	16.91	32	39	39.78	32.64	0.89	1.29	1290	16.91	8	16	159.14	79.57	0.89	1.29	1290	16.91	1	13	1273.09	97.93
0.9	1.29	1290	17.1	32	39	39.78	32.64	0.9	1.29	1290	17.1	8	16	159.11	79.56	0.9	1.29	1290	17.1	1	13	1272.90	97.92
0.91	1.27	1270	17.29	32	39	39.15	32.12	0.91	1.27	1270	17.29	8	16	156.59	78.29	0.91	1.27	1270	17.29	1	13	1252.71	96.36
0.92	1.22	1220	17.48	32	39	37.58	30.83	0.92	1.22	1220	17.48	8	16	150.32	75.16	0.92	1.22	1220	17.48	1	13	1202.52	92.50
0.93	1.15	1150	17.67	32	39	35.39	29.03	0.93	1.15	1150	17.67	8	16	141.54	70.77	0.93	1.15	1150	17.67	1	13	1132.33	87.10
0.94	1.15	1150	17.86	32	39	35.38	29.03	0.94	1.15	1150	17.86	8	16	141.52	70.76	0.94	1.15	1150	17.86	1	13	1132.14	87.09
2.41	1.81	1810	45.79	32	39	55.13	45.24	2.41	1.81	1810	45.79	8	16	220.53	110.26	2.41	1.81	1810	45.79	1	13	1764.21	135.71
2.42	1.81	1810	45.98	32	39	55.13	45.23	2.42	1.81	1810	45.98	8	16	220.50	110.25	2.42	1.81	1810	45.98	1	13	1764.02	135.69
2.43	1.82	1820	46.17	32	39	55.43	45.48	2.43	1.82	1820	46.17	8	16	221.73	110.86	2.43	1.82	1820	46.17	1	13	1773.83	136.45
2.44	1.85	1850	46.36	32	39	56.36	46.25	2.44	1.85	1850	46.36	8	16	225.46	112.73	2.44	1.85	1850	46.36	1	13	1803.64	138.74
2.45	1.86	1860	46.55	32	39	56.67	46.50	2.45	1.86	1860	46.55	8	16	226.68	113.34	2.45	1.86	1860	46.55	1	13	1813.45	139.50
2.46	1.86	1860	46.74	32	39	56.66	46.49	2.46	1.86	1860	46.74	8	16	226.66	113.33	2.46	1.86	1860	46.74	1	13	1813.26	139.48
2.47	1.88	1880	46.93	32	39	57.28	47.00	2.47	1.88	1880	46.93	8	16	229.13	114.57	2.47	1.88	1880	46.93	1	13	1833.07	141.01
2.48	1.92	1920	47.12	32	39	58.53	48.02	2.48	1.92	1920	47.12	8	16	234.11	117.06	2.48	1.92	1920	47.12	1	13	1872.88	144.07
2.49	1.98	1980	47.31	32	39	60.40	49.56	2.49	1.98	1980	47.31	8	16	241.59	120.79	2.49	1.98	1980	47.31	1	13	1932.69	148.67
2.5	1.99	1990	47.5	32	39	60.70	49.81	2.5	1.99	1990	47.5	8	16	242.81	121.41	2.5	1.99	1990	47.5	1	13	1942.50	149.42
3.7	1.45	1450	70.3	32	39	43.12	35.38	3.7	1.45	1450	70.3	8	16	172.46	86.23	3.7	1.45	1450	70.3	1	13	1379.70	106.13
3.71	1.44	1440	70.49	32	39	42.80	35.12	3.71	1.44	1440	70.49	8	16	171.19	85.59	3.71	1.44	1440	70.49	1	13	1369.51	105.35
3.72	1.4	1400	70.68	32	39	41.54	34.09	3.72	1.4	1400	70.68	8	16	166.17	83.08	3.72	1.4	1400	70.68	1	13	1329.32	102.26
3.73	1.42	1420	70.87	32	39	42.16	34.59	3.73	1.42	1420	70.87	8	16	168.64	84.32	3.73	1.42	1420	70.87	1	13	1349.13	103.78

Table 35: Site 1 S_u obtained from Senneset et al., 1982 N_{kt} values

Depth, m	qt (MPa)	qt (kPa)	σ_v (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} - 6$)	S_u , kPa ($N_{kt} - 12$)	Depth, m	qt (MPa)	qt (kPa)	σ_v (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} - 15$)	S_u , kPa ($N_{kt} - 20$)	Depth, m	qt (MPa)	qt (kPa)	σ_v (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} - 5$)	S_u , kPa ($N_{kt} - 70$)
0.85	1.47	1470	16.15	6	12	242.31	121.15	0.85	1.47	1470	16.15	15	20	96.92	72.69	0.85	1.47	1470	16.15	5	70	290.77	20.77
0.86	1.41	1410	16.34	6	12	232.28	116.14	0.86	1.41	1410	16.34	15	20	92.91	69.68	0.86	1.41	1410	16.34	5	70	278.73	19.91
0.87	1.41	1410	16.53	6	12	232.25	116.12	0.87	1.41	1410	16.53	15	20	92.90	69.67	0.87	1.41	1410	16.53	5	70	278.69	19.91
0.88	1.34	1340	16.72	6	12	220.55	110.27	0.88	1.34	1340	16.72	15	20	88.22	66.16	0.88	1.34	1340	16.72	5	70	264.66	18.90
0.89	1.29	1290	16.91	6	12	212.18	106.09	0.89	1.29	1290	16.91	15	20	84.87	63.65	0.89	1.29	1290	16.91	5	70	254.62	18.19
0.9	1.29	1290	17.1	6	12	212.15	106.08	0.9	1.29	1290	17.1	15	20	84.86	63.65	0.9	1.29	1290	17.1	5	70	254.58	18.18
0.91	1.27	1270	17.29	6	12	208.79	104.39	0.91	1.27	1270	17.29	15	20	83.51	62.64	0.91	1.27	1270	17.29	5	70	250.54	17.90
0.92	1.22	1220	17.48	6	12	200.42	100.21	0.92	1.22	1220	17.48	15	20	80.17	60.13	0.92	1.22	1220	17.48	5	70	240.50	17.18
0.93	1.15	1150	17.67	6	12	188.72	94.36	0.93	1.15	1150	17.67	15	20	75.49	56.62	0.93	1.15	1150	17.67	5	70	226.47	16.18
0.94	1.15	1150	17.86	6	12	188.69	94.35	0.94	1.15	1150	17.86	15	20	75.48	56.61	0.94	1.15	1150	17.86	5	70	226.43	16.17
2.41	1.81	1810	45.79	6	12	294.04	147.02	2.41	1.81	1810	45.79	15	20	117.61	88.21	2.41	1.81	1810	45.79	5	70	352.84	25.20
2.42	1.81	1810	45.98	6	12	294.00	147.00	2.42	1.81	1810	45.98	15	20	117.60	88.20	2.42	1.81	1810	45.98	5	70	352.80	25.20
2.43	1.82	1820	46.17	6	12	295.64	147.82	2.43	1.82	1820	46.17	15	20	118.26	88.69	2.43	1.82	1820	46.17	5	70	354.77	25.34
2.44	1.85	1850	46.36	6	12	300.61	150.30	2.44	1.85	1850	46.36	15	20	120.24	90.18	2.44	1.85	1850	46.36	5	70	360.73	25.77
2.45	1.86	1860	46.55	6	12	302.24	151.12	2.45	1.86	1860	46.55	15	20	120.90	90.67	2.45	1.86	1860	46.55	5	70	362.69	25.91
2.46	1.86	1860	46.74	6	12	302.21	151.11	2.46	1.86	1860	46.74	15	20	120.88	90.66	2.46	1.86	1860	46.74	5	70	362.65	25.90
2.47	1.88	1880	46.93	6	12	305.51	152.76	2.47	1.88	1880	46.93	15	20	122.20	91.65	2.47	1.88	1880	46.93	5	70	366.61	26.19
2.48	1.92	1920	47.12	6	12	312.15	156.07	2.48	1.92	1920	47.12	15	20	124.86	93.64	2.48	1.92	1920	47.12	5	70	374.58	26.76
2.49	1.98	1980	47.31	6	12	322.12	161.06	2.49	1.98	1980	47.31	15	20	128.85	96.63	2.49	1.98	1980	47.31	5	70	386.54	27.61
2.5	1.99	1990	47.5	6	12	323.75	161.88	2.5	1.99	1990	47.5	15	20	129.50	97.13	2.5	1.99	1990	47.5	5	70	388.50	27.75
3.7	1.45	1450	70.3	6	12	229.95	114.98	3.7	1.45	1450	70.3	15	20	91.98	68.99	3.7	1.45	1450	70.3	5	70	275.94	19.71
3.71	1.44	1440	70.49	6	12	228.25	114.13	3.71	1.44	1440	70.49	15	20	91.30	68.48	3.71	1.44	1440	70.49	5	70	273.90	19.56
3.72	1.4	1400	70.68	6	12	221.55	110.78	3.72	1.4	1400	70.68	15	20	88.62	66.47	3.72	1.4	1400	70.68	5	70	265.86	18.99
3.73	1.42	1420	70.87	6	12	224.86	112.43	3.73	1.42	1420	70.87	15	20	89.94	67.46	3.73	1.42	1420	70.87	5	70	269.83	19.27

Table 36: Site 1 S_u obtained from Bowles 1995 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,}$ (kPa)	Min. Nkt	$S_{u,}$ kPa ($N_{kt} - 70$)	Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,}$ (kPa)	Min. Nkt	$S_{u,}$ kPa ($N_{kt} - 70$)
0.85	1.47	1470	16.15	17	85.52	0.85	1.47	1470	16.15	13.5	107.69
0.86	1.41	1410	16.34	17	81.98	0.86	1.41	1410	16.34	13.5	103.23
0.87	1.41	1410	16.53	17	81.97	0.87	1.41	1410	16.53	13.5	103.22
0.88	1.34	1340	16.72	17	77.84	0.88	1.34	1340	16.72	13.5	98.02
0.89	1.29	1290	16.91	17	74.89	0.89	1.29	1290	16.91	13.5	94.30
0.9	1.29	1290	17.1	17	74.88	0.9	1.29	1290	17.1	13.5	94.29
0.91	1.27	1270	17.29	17	73.69	0.91	1.27	1270	17.29	13.5	92.79
0.92	1.22	1220	17.48	17	70.74	0.92	1.22	1220	17.48	13.5	89.08
0.93	1.15	1150	17.67	17	66.61	0.93	1.15	1150	17.67	13.5	83.88
0.94	1.15	1150	17.86	17	66.60	0.94	1.15	1150	17.86	13.5	83.86
2.41	1.81	1810	45.79	17	103.78	2.41	1.81	1810	45.79	13.5	130.68
2.42	1.81	1810	45.98	17	103.77	2.42	1.81	1810	45.98	13.5	130.67
2.43	1.82	1820	46.17	17	104.34	2.43	1.82	1820	46.17	13.5	131.39
2.44	1.85	1850	46.36	17	106.10	2.44	1.85	1850	46.36	13.5	133.60
2.45	1.86	1860	46.55	17	106.67	2.45	1.86	1860	46.55	13.5	134.33
2.46	1.86	1860	46.74	17	106.66	2.46	1.86	1860	46.74	13.5	134.32
2.47	1.88	1880	46.93	17	107.83	2.47	1.88	1880	46.93	13.5	135.78
2.48	1.92	1920	47.12	17	110.17	2.48	1.92	1920	47.12	13.5	138.73
2.49	1.98	1980	47.31	17	113.69	2.49	1.98	1980	47.31	13.5	143.16
2.5	1.99	1990	47.5	17	114.26	2.5	1.99	1990	47.5	13.5	143.89
3.7	1.45	1450	70.3	17	81.16	3.7	1.45	1450	70.3	13.5	102.20
3.71	1.44	1440	70.49	17	80.56	3.71	1.44	1440	70.49	13.5	101.45
3.72	1.4	1400	70.68	17	78.20	3.72	1.4	1400	70.68	13.5	98.47
3.73	1.42	1420	70.87	17	79.36	3.73	1.42	1420	70.87	13.5	99.94
3.74	1.49	1490	71.06	17	83.47	3.74	1.49	1490	71.06	13.5	105.11

Table 37: Site 2 S_u obtained from Akbar Cheshomi, 2016 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	σ_v (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa (N_{kt} -22)	S_u , kPa (N_{kt} -22)	Depth, m	q_t (MPa)	q_t (kPa)	σ_v (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa (N_{kt} -34.2)	S_u , kPa (N_{kt} -57.2)
2.48	16.04	16040	47.12	22	23	726.95	695.34	2.48	16.04	16040	47.12	34	57	467.63	279.60
2.49	15.78	15780	47.31	22	23	715.12	684.03	2.49	15.78	15780	47.31	34	57	460.02	275.05
2.5	15.61	15610	47.5	22	23	707.39	676.63	2.5	15.61	15610	47.5	34	57	455.04	272.07
2.51	19.19	19190	47.69	22	23	870.11	832.27	2.51	19.19	19190	47.69	34	57	559.72	334.66
2.52	19.06	19060	47.88	22	23	864.19	826.61	2.52	19.06	19060	47.88	34	57	555.91	332.38
2.53	18.87	18870	48.07	22	23	855.54	818.34	2.53	18.87	18870	48.07	34	57	550.35	329.05
2.54	18.64	18640	48.26	22	23	845.08	808.34	2.54	18.64	18640	48.26	34	57	543.62	325.03
2.55	18.37	18370	48.45	22	23	832.80	796.59	2.55	18.37	18370	48.45	34.20	57.20	535.72	320.31
2.56	18.15	18150	48.64	22	23	822.79	787.02	2.56	18.15	18150	48.64	34.20	57.20	529.28	316.46
2.57	18.09	18090	48.83	22	23	820.05	784.40	2.57	18.09	18090	48.83	34.20	57.20	527.52	315.41
2.58	18.07	18070	49.02	22	23	819.14	783.52	2.58	18.07	18070	49.02	34.20	57.20	526.93	315.05
2.59	18.09	18090	49.21	22	23	820.04	784.38	2.59	18.09	18090	49.21	34.20	57.20	527.51	315.40
2.6	18.07	18070	49.4	22	23	819.12	783.50	2.6	18.07	18070	49.4	34.20	57.20	526.92	315.05
2.61	18.01	18010	49.59	22	23	816.38	780.89	2.61	18.01	18010	49.59	34.20	57.20	525.16	313.99
2.62	17.98	17980	49.78	22	23	815.01	779.57	2.62	17.98	17980	49.78	34.20	57.20	524.28	313.47
3.2	22.27	22270	60.8	22	23	1009.51	965.62	3.2	22.27	22270	60.8	34.20	57.20	649.39	388.27
3.21	22.78	22780	60.99	22	23	1032.68	987.78	3.21	22.78	22780	60.99	34.20	57.20	664.30	397.19
3.22	23.36	23360	61.18	22	23	1059.04	1012.99	3.22	23.36	23360	61.18	34.20	57.20	681.25	407.32
3.25	23.4	23400	61.75	22	23	1060.83	1014.71	3.25	23.4	23400	61.75	34.20	57.20	682.40	408.01
3.26	23.09	23090	61.94	22	23	1046.73	1001.22	3.26	23.09	23090	61.94	34.20	57.20	673.34	402.59
3.27	22.86	22860	62.13	22	23	1036.27	991.21	3.27	22.86	22860	62.13	34.20	57.20	666.60	398.56
3.28	22.75	22750	62.32	22	23	1031.26	986.42	3.28	22.75	22750	62.32	34.20	57.20	663.38	396.64

Table 38: Site 2 S_u obtained from Otoko et al., 2016 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,v}$ (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} - 34.2$)	S_u , kPa ($N_{kt} - 57.2$)	Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,v}$ (kPa)	Min. N_{kt}	S_u , kPa ($N_{kt} - 15.5$)
2.48	16.04	16040	47.12	7	10	2284.70	1599.29	2.48	47.12	47120	16.15	15.50	3038.96
2.49	15.78	15780	47.31	7	10	2247.53	1573.27	2.49	47.31	47310	16.34	15.50	3051.20
2.5	15.61	15610	47.5	7	10	2223.21	1556.25	2.5	47.5	47500	16.53	15.50	3063.45
2.51	19.19	19190	47.69	7	10	2734.62	1914.23	2.51	47.69	47690	16.72	15.50	3075.70
2.52	19.06	19060	47.88	7	10	2716.02	1901.21	2.52	47.88	47880	16.91	15.50	3087.94
2.53	18.87	18870	48.07	7	10	2688.85	1882.19	2.53	48.07	48070	17.1	15.50	3100.19
2.54	18.64	18640	48.26	7	10	2655.96	1859.17	2.54	48.26	48260	17.29	15.50	3112.43
2.55	18.37	18370	48.45	7	10	2617.36	1832.16	2.55	48.45	48450	17.48	15.50	3124.68
2.56	18.15	18150	48.64	7	10	2585.91	1810.14	2.56	48.64	48640	17.67	15.50	3136.92
2.57	18.09	18090	48.83	7	10	2577.31	1804.12	2.57	48.83	48830	17.86	15.50	3149.17
2.58	18.07	18070	49.02	7	10	2574.43	1802.10	2.58	49.02	49020	45.79	15.50	3159.63
2.59	18.09	18090	49.21	7	10	2577.26	1804.08	2.59	49.21	49210	45.98	15.50	3171.87
2.6	18.07	18070	49.4	7	10	2574.37	1802.06	2.6	49.4	49400	46.17	15.50	3184.12
2.61	18.01	18010	49.59	7	10	2565.77	1796.04	2.61	49.59	49590	46.36	15.50	3196.36
2.62	17.98	17980	49.78	7	10	2561.46	1793.02	2.62	49.78	49780	46.55	15.50	3208.61
3.2	22.27	22270	60.8	7	10	3172.74	2220.92	3.2	60.8	60800	46.74	15.50	3919.57
3.21	22.78	22780	60.99	7	10	3245.57	2271.90	3.21	60.99	60990	46.93	15.50	3931.81
3.22	23.36	23360	61.18	7	10	3328.40	2329.88	3.22	61.18	61180	47.12	15.50	3944.06
3.25	23.4	23400	61.75	7	10	3334.04	2333.83	3.25	61.75	61750	47.31	15.50	3980.82
3.26	23.09	23090	61.94	7	10	3289.72	2302.81	3.26	61.94	61940	47.5	15.50	3993.06
3.27	22.86	22860	62.13	7	10	3256.84	2279.79	3.27	62.13	62130	70.3	15.50	4003.85
3.28	22.75	22750	62.32	7	10	3241.10	2268.77	3.28	62.32	62320	70.49	15.50	4016.10
3.29	22.92	22920	62.51	7	10	3265.36	2285.75	3.29	62.51	62510	70.68	15.50	4028.34
3.3	23.23	23230	62.7	7	10	3309.61	2316.73	3.3	62.7	62700	70.87	15.50	4040.59

Table 39: Site 2 S_u obtained from Remai 2013 N_{kt} values

Depth, m	qt (MPa)	qt (kPa)	σ_v (kPa)	Min. Nkt	Max. Nkt	Su, kPa (Nkt - 12)	Su,kPa (Nkt - 32)	Depth, m	qt (MPa)	qt (kPa)	σ_v (kPa)	Min. Nkt	Max. Nkt	Su, kPa (Nkt -7)	Su , kPa (Nkt - 20)
2.48	16	16040	47.12	12	32	1332.74	499.78	2.48	16.04	16040	47.12	7	20	2284.70	799.64
2.49	15.8	15780	47.31	12	32	1311.06	491.65	2.49	15.78	15780	47.31	7	20	2247.53	786.63
2.5	15.6	15610	47.5	12	32	1296.88	486.33	2.5	15.61	15610	47.5	7	20	2223.21	778.13
2.51	19.2	19190	47.69	12	32	1595.19	598.20	2.51	19.19	19190	47.69	7	20	2734.62	957.12
2.52	19.1	19060	47.88	12	32	1584.34	594.13	2.52	19.06	19060	47.88	7	20	2716.02	950.61
2.53	18.9	18870	48.07	12	32	1568.49	588.19	2.53	18.87	18870	48.07	7	20	2688.85	941.10
2.54	18.6	18640	48.26	12	32	1549.31	580.99	2.54	18.64	18640	48.26	7	20	2655.96	929.59
2.55	18.4	18370	48.45	12	32	1526.80	572.55	2.55	18.37	18370	48.45	7	20	2617.36	916.08
2.56	18.2	18150	48.64	12	32	1508.45	565.67	2.56	18.15	18150	48.64	7	20	2585.91	905.07
2.57	18.1	18090	48.83	12	32	1503.43	563.79	2.57	18.09	18090	48.83	7	20	2577.31	902.06
2.58	18.1	18070	49.02	12	32	1501.75	563.16	2.58	18.07	18070	49.02	7	20	2574.43	901.05
2.59	18.1	18090	49.21	12	32	1503.40	563.77	2.59	18.09	18090	49.21	7	20	2577.26	902.04
2.6	18.1	18070	49.4	12	32	1501.72	563.14	2.6	18.07	18070	49.4	7	20	2574.37	901.03
2.61	18	18010	49.59	12	32	1496.70	561.26	2.61	18.01	18010	49.59	7	20	2565.77	898.02
2.62	18	17980	49.78	12	32	1494.19	560.32	2.62	17.98	17980	49.78	7	20	2561.46	896.51
3.2	22.3	22270	60.8	12	32	1850.77	694.04	3.2	22.27	22270	60.8	7	20	3172.74	1110.46
3.21	22.8	22780	60.99	12	32	1893.25	709.97	3.21	22.78	22780	60.99	7	20	3245.57	1135.95
3.22	23.4	23360	61.18	12	32	1941.57	728.09	3.22	23.36	23360	61.18	7	20	3328.40	1164.94
3.25	23.4	23400	61.75	12	32	1944.85	729.32	3.25	23.4	23400	61.75	7	20	3334.04	1166.91
3.26	23.1	23090	61.94	12	32	1919.01	719.63	3.26	23.09	23090	61.94	7	20	3289.72	1151.40
3.27	22.9	22860	62.13	12	32	1899.82	712.43	3.27	22.86	22860	62.13	7	20	3256.84	1139.89
3.28	22.8	22750	62.32	12	32	1890.64	708.99	3.28	22.75	22750	62.32	7	20	3241.10	1134.38
3.29	22.9	22920	62.51	12	32	1904.79	714.30	3.29	22.92	22920	62.51	7	20	3265.36	1142.87
3.3	23.2	23230	62.7	12	32	1930.61	723.98	3.3	23.23	23230	62.7	7	20	3309.61	1158.37
3.31	23.3	23340	62.89	12	32	1939.76	727.41	3.31	23.34	23340	62.89	7	20	3325.30	1163.86

Table 40: Site 2 S_u obtained from Almeida et al., 2010 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	σ_{vv} (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} - 4$)	S_u , kPa ($N_{kt} - 16$)	Depth, m	q_t (MPa)	q_t (kPa)	σ_{vv} (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} - 4$)	S_u , kPa ($N_{kt} - 16$)
2.48	16.04	16040	47.12	4	16	3998.22	999.56	2.48	16.04	16040	47.12	3	18	5330.96	888.49
2.49	15.78	15780	47.31	4	16	3933.17	983.29	2.49	15.78	15780	47.31	3	18	5244.23	874.04
2.5	15.61	15610	47.5	4	16	3890.63	972.66	2.5	15.61	15610	47.5	3	18	5187.50	864.58
2.51	19.19	19190	47.69	4	16	4785.58	1196.39	2.51	19.19	19190	47.69	3	18	6380.77	1063.46
2.52	19.06	19060	47.88	4	16	4753.03	1188.26	2.52	19.06	19060	47.88	3	18	6337.37	1056.23
2.53	18.87	18870	48.07	4	16	4705.48	1176.37	2.53	18.87	18870	48.07	3	18	6273.98	1045.66
2.54	18.64	18640	48.26	4	16	4647.94	1161.98	2.54	18.64	18640	48.26	3	18	6197.25	1032.87
2.55	18.37	18370	48.45	4	16	4580.39	1145.10	2.55	18.37	18370	48.45	3	18	6107.18	1017.86
2.56	18.15	18150	48.64	4	16	4525.34	1131.34	2.56	18.15	18150	48.64	3	18	6033.79	1005.63
2.57	18.09	18090	48.83	4	16	4510.29	1127.57	2.57	18.09	18090	48.83	3	18	6013.72	1002.29
2.58	18.07	18070	49.02	4	16	4505.25	1126.31	2.58	18.07	18070	49.02	3	18	6006.99	1001.17
2.59	18.09	18090	49.21	4	16	4510.20	1127.55	2.59	18.09	18090	49.21	3	18	6013.60	1002.27
2.6	18.07	18070	49.4	4	16	4505.15	1126.29	2.6	18.07	18070	49.4	3	18	6006.87	1001.14
2.61	18.01	18010	49.59	4	16	4490.10	1122.53	2.61	18.01	18010	49.59	3	18	5986.80	997.80
2.62	17.98	17980	49.78	4	16	4482.56	1120.64	2.62	17.98	17980	49.78	3	18	5976.74	996.12
3.2	22.27	22270	60.8	4	16	5552.30	1388.08	3.2	22.27	22270	60.8	3	18	7403.07	1233.84
3.21	22.78	22780	60.99	4	16	5679.75	1419.94	3.21	22.78	22780	60.99	3	18	7573.00	1262.17
3.22	23.36	23360	61.18	4	16	5824.71	1456.18	3.22	23.36	23360	61.18	3	18	7766.27	1294.38
3.25	23.4	23400	61.75	4	16	5834.56	1458.64	3.25	23.4	23400	61.75	3	18	7779.42	1296.57
3.26	23.09	23090	61.94	4	16	5757.02	1439.25	3.26	23.09	23090	61.94	3	18	7676.02	1279.34
3.27	22.86	22860	62.13	4	16	5699.47	1424.87	3.27	22.86	22860	62.13	3	18	7599.29	1266.55
3.28	22.75	22750	62.32	4	16	5671.92	1417.98	3.28	22.75	22750	62.32	3	18	7562.56	1260.43
3.29	22.92	22920	62.51	4	16	5714.37	1428.59	3.29	22.92	22920	62.51	3	18	7619.16	1269.86
3.3	23.23	23230	62.7	4	16	5791.83	1447.96	3.3	23.23	23230	62.7	3	18	7722.43	1287.07
3.31	23.34	23340	62.89	4	16	5819.28	1454.82	3.31	23.34	23340	62.89	3	18	7759.04	1293.17
3.32	23.23	23230	63.08	4	16	5791.73	1447.93	3.32	23.23	23230	63.08	3	18	7722.31	1287.05

Table 41: Site 2 S_u obtained from Hong et al.,2010 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	σ_{rv} (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa (N_{kt} -4)	S_u , kPa (N_{kt} -9)	Depth, m	q_t (MPa)	q_t (kPa)	σ_{rv} (kPa)	Min. N_{kt}	Max. N_{kt}	S_u ,kPa (N_{kt} -12)	S_u ,kPa (N_{kt} -19)
2.48	16.04	16040	47.12	4	9	3998.22	1776.99	2.48	16.04	16040	47.12	12	19	1332.74	841.73
2.49	15.78	15780	47.31	4	9	3933.17	1748.08	2.49	15.78	15780	47.31	12	19	1311.06	828.04
2.5	15.61	15610	47.5	4	9	3890.63	1729.17	2.5	15.61	15610	47.5	12	19	1296.88	819.08
2.51	19.19	19190	47.69	4	9	4785.58	2126.92	2.51	19.19	19190	47.69	12	19	1595.19	1007.49
2.52	19.06	19060	47.88	4	9	4753.03	2112.46	2.52	19.06	19060	47.88	12	19	1584.34	1000.64
2.53	18.87	18870	48.07	4	9	4705.48	2091.33	2.53	18.87	18870	48.07	12	19	1568.49	990.63
2.54	18.64	18640	48.26	4	9	4647.94	2065.75	2.54	18.64	18640	48.26	12	19	1549.31	978.51
2.55	18.37	18370	48.45	4	9	4580.39	2035.73	2.55	18.37	18370	48.45	12	19	1526.80	964.29
2.56	18.15	18150	48.64	4	9	4525.34	2011.26	2.56	18.15	18150	48.64	12	19	1508.45	952.70
2.57	18.09	18090	48.83	4	9	4510.29	2004.57	2.57	18.09	18090	48.83	12	19	1503.43	949.54
2.58	18.07	18070	49.02	4	9	4505.25	2002.33	2.58	18.07	18070	49.02	12	19	1501.75	948.47
2.59	18.09	18090	49.21	4	9	4510.20	2004.53	2.59	18.09	18090	49.21	12	19	1503.40	949.52
2.6	18.07	18070	49.4	4	9	4505.15	2002.29	2.6	18.07	18070	49.4	12	19	1501.72	948.45
2.61	18.01	18010	49.59	4	9	4490.10	1995.60	2.61	18.01	18010	49.59	12	19	1496.70	945.28
2.62	17.98	17980	49.78	4	9	4482.56	1992.25	2.62	17.98	17980	49.78	12	19	1494.19	943.70
3.2	22.27	22270	60.8	4	9	5552.30	2467.69	3.2	22.27	22270	60.8	12	19	1850.77	1168.91
3.21	22.78	22780	60.99	4	9	5679.75	2524.33	3.21	22.78	22780	60.99	12	19	1893.25	1195.74
3.22	23.36	23360	61.18	4	9	5824.71	2588.76	3.22	23.36	23360	61.18	12	19	1941.57	1226.25
3.25	23.4	23400	61.75	4	9	5834.56	2593.14	3.25	23.4	23400	61.75	12	19	1944.85	1228.33
3.26	23.09	23090	61.94	4	9	5757.02	2558.67	3.26	23.09	23090	61.94	12	19	1919.01	1212.00
3.27	22.86	22860	62.13	4	9	5699.47	2533.10	3.27	22.86	22860	62.13	12	19	1899.82	1199.89
3.28	22.75	22750	62.32	4	9	5671.92	2520.85	3.28	22.75	22750	62.32	12	19	1890.64	1194.09
3.29	22.92	22920	62.51	4	9	5714.37	2539.72	3.29	22.92	22920	62.51	12	19	1904.79	1203.03

Table 42: Site 2 S_u obtained from Hassan 2004 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	σ_{rv} (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} - 34$)	S_u , kPa ($N_{kt} - 62$)	Depth, m	q_t (MPa)	q_t (kPa)	σ_{rv} (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} - 8$)	S_u , kPa ($N_{kt} - 28$)
2.48	16.04	16040	47.12	34	62	470.38	257.95	2.48	16.04	16040	47.12	7.6	28.4	2104.33	563.13
2.49	15.78	15780	47.31	34	62	462.73	253.75	2.49	15.78	15780	47.31	7.6	28.4	2070.09	553.97
2.5	15.61	15610	47.5	34	62	457.72	251.01	2.5	15.61	15610	47.5	7.6	28.4	2047.70	547.98
2.51	19.19	19190	47.69	34	62	563.01	308.75	2.51	19.19	19190	47.69	7.6	28.4	2518.73	674.03
2.52	19.06	19060	47.88	34	62	559.18	306.65	2.52	19.06	19060	47.88	7.6	28.4	2501.59	669.44
2.53	18.87	18870	48.07	34	62	553.59	303.58	2.53	18.87	18870	48.07	7.6	28.4	2476.57	662.74
2.54	18.64	18640	48.26	34	62	546.82	299.87	2.54	18.64	18640	48.26	7.6	28.4	2446.28	654.64
2.55	18.37	18370	48.45	34	62	538.87	295.51	2.55	18.37	18370	48.45	7.6	28.4	2410.73	645.13
2.56	18.15	18150	48.64	34	62	532.39	291.96	2.56	18.15	18150	48.64	7.6	28.4	2381.76	637.37
2.57	18.09	18090	48.83	34	62	530.62	290.99	2.57	18.09	18090	48.83	7.6	28.4	2373.84	635.25
2.58	18.07	18070	49.02	34	62	530.03	290.66	2.58	18.07	18070	49.02	7.6	28.4	2371.18	634.54
2.59	18.09	18090	49.21	34	62	530.61	290.98	2.59	18.09	18090	49.21	7.6	28.4	2373.79	635.24
2.6	18.07	18070	49.4	34	62	530.02	290.65	2.6	18.07	18070	49.4	7.6	28.4	2371.13	634.53
2.61	18.01	18010	49.59	34	62	528.25	289.68	2.61	18.01	18010	49.59	7.6	28.4	2363.21	632.41
2.62	17.98	17980	49.78	34	62	527.36	289.20	2.62	17.98	17980	49.78	7.6	28.4	2359.24	631.35
3.2	22.27	22270	60.8	34	62	653.21	358.21	3.2	22.27	22270	60.8	7.6	28.4	2922.26	782.01
3.21	22.78	22780	60.99	34	62	668.21	366.44	3.21	22.78	22780	60.99	7.6	28.4	2989.34	799.97
3.22	23.36	23360	61.18	34	62	685.26	375.79	3.22	23.36	23360	61.18	7.6	28.4	3065.63	820.38
3.25	23.4	23400	61.75	34	62	686.42	376.42	3.25	23.4	23400	61.75	7.6	28.4	3070.82	821.77
3.26	23.09	23090	61.94	34	62	677.30	371.42	3.26	23.09	23090	61.94	7.6	28.4	3030.01	810.85
3.27	22.86	22860	62.13	34	62	670.53	367.71	3.27	22.86	22860	62.13	7.6	28.4	2999.72	802.74
3.28	22.75	22750	62.32	34	62	667.28	365.93	3.28	22.75	22750	62.32	7.6	28.4	2985.22	798.86
3.29	22.92	22920	62.51	34	62	672.28	368.67	3.29	22.92	22920	62.51	7.6	28.4	3007.56	804.84
3.3	23.23	23230	62.7	34	62	681.39	373.67	3.3	23.23	23230	62.7	7.6	28.4	3048.33	815.75

Table 43: Site 2 S_u obtained from Gebreselassie 2003 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,}$ (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} - 8$)	S_u , kPa ($N_{kt} - 28$)	Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,}$ (kPa)	Min. N_{kt}	S_u , kPa ($N_{kt} - 89.3$)
2.48	16.04	16040	47.12	8.0	29.0	1999.11	551.48	2.48	16.04	16040	47.12	89.3	179.09
2.49	15.78	15780	47.31	8.0	29.0	1966.59	542.51	2.49	15.78	15780	47.31	89.3	176.18
2.5	15.61	15610	47.5	8.0	29.0	1945.31	536.64	2.5	15.61	15610	47.5	89.3	174.27
2.51	19.19	19190	47.69	8.0	29.0	2392.79	660.08	2.51	19.19	19190	47.69	89.3	214.36
2.52	19.06	19060	47.88	8.0	29.0	2376.52	655.59	2.52	19.06	19060	47.88	89.3	212.90
2.53	18.87	18870	48.07	8.0	29.0	2352.74	649.03	2.53	18.87	18870	48.07	89.3	210.77
2.54	18.64	18640	48.26	8.0	29.0	2323.97	641.09	2.54	18.64	18640	48.26	89.3	208.19
2.55	18.37	18370	48.45	8.0	29.0	2290.19	631.78	2.55	18.37	18370	48.45	89.3	205.17
2.56	18.15	18150	48.64	8.0	29.0	2262.67	624.18	2.56	18.15	18150	48.64	89.3	202.70
2.57	18.09	18090	48.83	8.0	29.0	2255.15	622.11	2.57	18.09	18090	48.83	89.3	202.03
2.58	18.07	18070	49.02	8.0	29.0	2252.62	621.41	2.58	18.07	18070	49.02	89.3	201.80
2.59	18.09	18090	49.21	8.0	29.0	2255.10	622.10	2.59	18.09	18090	49.21	89.3	202.02
2.6	18.07	18070	49.4	8.0	29.0	2252.58	621.40	2.6	18.07	18070	49.4	89.3	201.80
2.61	18.01	18010	49.59	8.0	29.0	2245.05	619.32	2.61	18.01	18010	49.59	89.3	201.12
2.62	17.98	17980	49.78	8.0	29.0	2241.28	618.28	2.62	17.98	17980	49.78	89.3	200.79
3.2	22.27	22270	60.8	8.0	29.0	2776.15	765.83	3.2	22.27	22270	60.8	89.3	248.70
3.21	22.78	22780	60.99	8.0	29.0	2839.88	783.41	3.21	22.78	22780	60.99	89.3	254.41
3.22	23.36	23360	61.18	8.0	29.0	2912.35	803.41	3.22	23.36	23360	61.18	89.3	260.91
3.25	23.4	23400	61.75	8.0	29.0	2917.28	804.77	3.25	23.4	23400	61.75	89.3	261.35
3.26	23.09	23090	61.94	8.0	29.0	2878.51	794.07	3.26	23.09	23090	61.94	89.3	257.87
3.27	22.86	22860	62.13	8.0	29.0	2849.73	786.13	3.27	22.86	22860	62.13	89.3	255.30
3.28	22.75	22750	62.32	8.0	29.0	2835.96	782.33	3.28	22.75	22750	62.32	89.3	254.06
3.29	22.92	22920	62.51	8.0	29.0	2857.19	788.19	3.29	22.92	22920	62.51	89.3	255.96
3.3	23.23	23230	62.7	8.0	29.0	2895.91	798.87	3.3	23.23	23230	62.7	89.3	259.43

Table 44: Site 2 S_u obtained from Chen 2001 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,}$ (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} -5$)	S_u , kPa ($N_{kt} -12$)	Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,}$ (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} -6$)	S_u , kPa ($N_{kt} -15$)
2.48	16.04	16040	47.12	5	12	3198.58	1332.74	2.48	16.04	16040	47.12	6	15	2665.48	1066.19
2.49	15.78	15780	47.31	5	12	3146.54	1311.06	2.49	15.78	15780	47.31	6	15	2622.12	1048.85
2.5	15.61	15610	47.5	5	12	3112.50	1296.88	2.5	15.61	15610	47.5	6	15	2593.75	1037.50
2.51	19.19	19190	47.69	5	12	3828.46	1595.19	2.51	19.19	19190	47.69	6	15	3190.39	1276.15
2.52	19.06	19060	47.88	5	12	3802.42	1584.34	2.52	19.06	19060	47.88	6	15	3168.69	1267.47
2.53	18.87	18870	48.07	5	12	3764.39	1568.49	2.53	18.87	18870	48.07	6	15	3136.99	1254.80
2.54	18.64	18640	48.26	5	12	3718.35	1549.31	2.54	18.64	18640	48.26	6	15	3098.62	1239.45
2.55	18.37	18370	48.45	5	12	3664.31	1526.80	2.55	18.37	18370	48.45	6	15	3053.59	1221.44
2.56	18.15	18150	48.64	5	12	3620.27	1508.45	2.56	18.15	18150	48.64	6	15	3016.89	1206.76
2.57	18.09	18090	48.83	5	12	3608.23	1503.43	2.57	18.09	18090	48.83	6	15	3006.86	1202.74
2.58	18.07	18070	49.02	5	12	3604.20	1501.75	2.58	18.07	18070	49.02	6	15	3003.50	1201.40
2.59	18.09	18090	49.21	5	12	3608.16	1503.40	2.59	18.09	18090	49.21	6	15	3006.80	1202.72
2.6	18.07	18070	49.4	5	12	3604.12	1501.72	2.6	18.07	18070	49.4	6	15	3003.43	1201.37
2.61	18.01	18010	49.59	5	12	3592.08	1496.70	2.61	18.01	18010	49.59	6	15	2993.40	1197.36
2.62	17.98	17980	49.78	5	12	3586.04	1494.19	2.62	17.98	17980	49.78	6	15	2988.37	1195.35
3.2	22.27	22270	60.8	5	12	4441.84	1850.77	3.2	22.27	22270	60.8	6	15	3701.53	1480.61
3.21	22.78	22780	60.99	5	12	4543.80	1893.25	3.21	22.78	22780	60.99	6	15	3786.50	1514.60
3.22	23.36	23360	61.18	5	12	4659.76	1941.57	3.22	23.36	23360	61.18	6	15	3883.14	1553.25
3.25	23.4	23400	61.75	5	12	4667.65	1944.85	3.25	23.4	23400	61.75	6	15	3889.71	1555.88
3.26	23.09	23090	61.94	5	12	4605.61	1919.01	3.26	23.09	23090	61.94	6	15	3838.01	1535.20
3.27	22.86	22860	62.13	5	12	4559.57	1899.82	3.27	22.86	22860	62.13	6	15	3799.65	1519.86
3.28	22.75	22750	62.32	5	12	4537.54	1890.64	3.28	22.75	22750	62.32	6	15	3781.28	1512.51
3.29	22.92	22920	62.51	5	12	4571.50	1904.79	3.29	22.92	22920	62.51	6	15	3809.58	1523.83
3.3	23.23	23230	62.7	5	12	4633.46	1930.61	3.3	23.23	23230	62.7	6	15	3861.22	1544.49
3.31	23.34	23340	62.89	5	12	4655.42	1939.76	3.31	23.34	23340	62.89	6	15	3879.52	1551.81
3.32	23.23	23230	63.08	5	12	4633.38	1930.58	3.32	23.23	23230	63.08	6	15	3861.15	1544.46

Table 45: Site 2 S_u obtained from Karlsrud 1996 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	σ_v (kPa)	Min. N_{kt}	Max. N_{kt}	S_u kPa ($N_{kt}-6$)	S_u ,kPa ($N_{kt}-15$)	Depth, m	q_t (MPa)	q_t (kPa)	σ_v (kPa)	Min. N_{kt}	Max. N_{kt}	S_u ,kPa ($N_{kt}-2$)	S_u ,kPa ($N_{kt}-10$)
2.48	16.04	16040	47.12	11	30	1453.90	533.10	2.48	16.04	16040	47.12	2	10	7996.44	1599.29
2.49	15.78	15780	47.31	11	30	1430.24	524.42	2.49	15.78	15780	47.31	2	10	7866.35	1573.27
2.5	15.61	15610	47.5	11	30	1414.77	518.75	2.5	15.61	15610	47.5	2	10	7781.25	1556.25
2.51	19.19	19190	47.69	11	30	1740.21	638.08	2.51	19.19	19190	47.69	2	10	9571.16	1914.23
2.52	19.06	19060	47.88	11	30	1728.37	633.74	2.52	19.06	19060	47.88	2	10	9506.06	1901.21
2.53	18.87	18870	48.07	11	30	1711.08	627.40	2.53	18.87	18870	48.07	2	10	9410.97	1882.19
2.54	18.64	18640	48.26	11	30	1690.16	619.72	2.54	18.64	18640	48.26	2	10	9295.87	1859.17
2.55	18.37	18370	48.45	11	30	1665.60	610.72	2.55	18.37	18370	48.45	2	10	9160.78	1832.16
2.56	18.15	18150	48.64	11	30	1645.58	603.38	2.56	18.15	18150	48.64	2	10	9050.68	1810.14
2.57	18.09	18090	48.83	11	30	1640.11	601.37	2.57	18.09	18090	48.83	2	10	9020.59	1804.12
2.58	18.07	18070	49.02	11	30	1638.27	600.70	2.58	18.07	18070	49.02	2	10	9010.49	1802.10
2.59	18.09	18090	49.21	11	30	1640.07	601.36	2.59	18.09	18090	49.21	2	10	9020.40	1804.08
2.6	18.07	18070	49.4	11	30	1638.24	600.69	2.6	18.07	18070	49.4	2	10	9010.30	1802.06
2.61	18.01	18010	49.59	11	30	1632.76	598.68	2.61	18.01	18010	49.59	2	10	8980.21	1796.04
2.62	17.98	17980	49.78	11	30	1630.02	597.67	2.62	17.98	17980	49.78	2	10	8965.11	1793.02
3.2	22.27	22270	60.8	11	30	2019.02	740.31	3.2	22.27	22270	60.8	2	10	11104.60	2220.92
3.21	22.78	22780	60.99	11	30	2065.36	757.30	3.21	22.78	22780	60.99	2	10	11359.51	2271.90
3.22	23.36	23360	61.18	11	30	2118.07	776.63	3.22	23.36	23360	61.18	2	10	11649.41	2329.88
3.25	23.4	23400	61.75	11	30	2121.66	777.94	3.25	23.4	23400	61.75	2	10	11669.13	2333.83
3.26	23.09	23090	61.94	11	30	2093.46	767.60	3.26	23.09	23090	61.94	2	10	11514.03	2302.81
3.27	22.86	22860	62.13	11	30	2072.53	759.93	3.27	22.86	22860	62.13	2	10	11398.94	2279.79
3.28	22.75	22750	62.32	11	30	2062.52	756.26	3.28	22.75	22750	62.32	2	10	11343.84	2268.77
3.29	22.92	22920	62.51	11	30	2077.95	761.92	3.29	22.92	22920	62.51	2	10	11428.75	2285.75
3.3	23.23	23230	62.7	11	30	2106.12	772.24	3.3	23.23	23230	62.7	2	10	11583.65	2316.73

Table 46: Site 2 S_u obtained from Powell & Quaterman, 1988 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,}$ (kPa)	Min. N_{kt}	S_u , kPa ($N_{kt} - 70$)	Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,}$ (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} - 10$)	S_u , kPa ($N_{kt} - 20$)
2.48	16.04	16040	47.12	70	228.47	2.48	16.04	16040	47.12	10	20	1599.29	799.64
2.49	15.78	15780	47.31	70	224.75	2.49	15.78	15780	47.31	10	20	1573.27	786.63
2.5	15.61	15610	47.5	70	222.32	2.5	15.61	15610	47.5	10	20	1556.25	778.13
2.51	19.19	19190	47.69	70	273.46	2.51	19.19	19190	47.69	10	20	1914.23	957.12
2.52	19.06	19060	47.88	70	271.60	2.52	19.06	19060	47.88	10	20	1901.21	950.61
2.53	18.87	18870	48.07	70	268.88	2.53	18.87	18870	48.07	10	20	1882.19	941.10
2.54	18.64	18640	48.26	70	265.60	2.54	18.64	18640	48.26	10	20	1859.17	929.59
2.55	18.37	18370	48.45	70	261.74	2.55	18.37	18370	48.45	10	20	1832.16	916.08
2.56	18.15	18150	48.64	70	258.59	2.56	18.15	18150	48.64	10	20	1810.14	905.07
2.57	18.09	18090	48.83	70	257.73	2.57	18.09	18090	48.83	10	20	1804.12	902.06
2.58	18.07	18070	49.02	70	257.44	2.58	18.07	18070	49.02	10	20	1802.10	901.05
2.59	18.09	18090	49.21	70	257.73	2.59	18.09	18090	49.21	10	20	1804.08	902.04
2.6	18.07	18070	49.4	70	257.44	2.6	18.07	18070	49.4	10	20	1802.06	901.03
2.61	18.01	18010	49.59	70	256.58	2.61	18.01	18010	49.59	10	20	1796.04	898.02
2.62	17.98	17980	49.78	70	256.15	2.62	17.98	17980	49.78	10	20	1793.02	896.51
3.2	22.27	22270	60.8	70	317.27	3.2	22.27	22270	60.8	10	20	2220.92	1110.46
3.21	22.78	22780	60.99	70	324.56	3.21	22.78	22780	60.99	10	20	2271.90	1135.95
3.22	23.36	23360	61.18	70	332.84	3.22	23.36	23360	61.18	10	20	2329.88	1164.94
3.25	23.4	23400	61.75	70	333.40	3.25	23.4	23400	61.75	10	20	2333.83	1166.91
3.26	23.09	23090	61.94	70	328.97	3.26	23.09	23090	61.94	10	20	2302.81	1151.40
3.27	22.86	22860	62.13	70	325.68	3.27	22.86	22860	62.13	10	20	2279.79	1139.89
3.28	22.75	22750	62.32	70	324.11	3.28	22.75	22750	62.32	10	20	2268.77	1134.38
3.29	22.92	22920	62.51	70	326.54	3.29	22.92	22920	62.51	10	20	2285.75	1142.87
3.3	23.23	23230	62.7	70	330.96	3.3	23.23	23230	62.7	10	20	2316.73	1158.37

Table 47: Site 2 S_u obtained from La Rochelle et al., 1988 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	σ_v (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} - 11$)	S_u , kPa ($N_{kt} - 18$)	Depth, m	q_t (MPa)	q_t (kPa)	σ_v (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} - 8$)	S_u , kPa ($N_{kt} - 29$)
2.48	16.04	16040	47.12	11	18	1453.90	888.49	2.48	16.04	16040	47.12	8	29	1999.11	551.48
2.49	15.78	15780	47.31	11	18	1430.24	874.04	2.49	15.78	15780	47.31	8	29	1966.59	542.51
2.5	15.61	15610	47.5	11	18	1414.77	864.58	2.5	15.61	15610	47.5	8	29	1945.31	536.64
2.51	19.19	19190	47.69	11	18	1740.21	1063.46	2.51	19.19	19190	47.69	8	29	2392.79	660.08
2.52	19.06	19060	47.88	11	18	1728.37	1056.23	2.52	19.06	19060	47.88	8	29	2376.52	655.59
2.53	18.87	18870	48.07	11	18	1711.08	1045.66	2.53	18.87	18870	48.07	8	29	2352.74	649.03
2.54	18.64	18640	48.26	11	18	1690.16	1032.87	2.54	18.64	18640	48.26	8	29	2323.97	641.09
2.55	18.37	18370	48.45	11	18	1665.60	1017.86	2.55	18.37	18370	48.45	8	29	2290.19	631.78
2.56	18.15	18150	48.64	11	18	1645.58	1005.63	2.56	18.15	18150	48.64	8	29	2262.67	624.18
2.57	18.09	18090	48.83	11	18	1640.11	1002.29	2.57	18.09	18090	48.83	8	29	2255.15	622.11
2.58	18.07	18070	49.02	11	18	1638.27	1001.17	2.58	18.07	18070	49.02	8	29	2252.62	621.41
2.59	18.09	18090	49.21	11	18	1640.07	1002.27	2.59	18.09	18090	49.21	8	29	2255.10	622.10
2.6	18.07	18070	49.4	11	18	1638.24	1001.14	2.6	18.07	18070	49.4	8	29	2252.58	621.40
2.61	18.01	18010	49.59	11	18	1632.76	997.80	2.61	18.01	18010	49.59	8	29	2245.05	619.32
2.62	17.98	17980	49.78	11	18	1630.02	996.12	2.62	17.98	17980	49.78	8	29	2241.28	618.28
3.2	22.27	22270	60.8	11	18	2019.02	1233.84	3.2	22.27	22270	60.8	8	29	2776.15	765.83
3.21	22.78	22780	60.99	11	18	2065.36	1262.17	3.21	22.78	22780	60.99	8	29	2839.88	783.41
3.22	23.36	23360	61.18	11	18	2118.07	1294.38	3.22	23.36	23360	61.18	8	29	2912.35	803.41
3.25	23.4	23400	61.75	11	18	2121.66	1296.57	3.25	23.4	23400	61.75	8	29	2917.28	804.77
3.26	23.09	23090	61.94	11	18	2093.46	1279.34	3.26	23.09	23090	61.94	8	29	2878.51	794.07
3.27	22.86	22860	62.13	11	18	2072.53	1266.55	3.27	22.86	22860	62.13	8	29	2849.73	786.13
3.28	22.75	22750	62.32	11	18	2062.52	1260.43	3.28	22.75	22750	62.32	8	29	2835.96	782.33
3.29	22.92	22920	62.51	11	18	2077.95	1269.86	3.29	22.92	22920	62.51	8	29	2857.19	788.19
3.3	23.23	23230	62.7	11	18	2106.12	1287.07	3.3	23.23	23230	62.7	8	29	2895.91	798.87

Table 48: Site 2 S_u obtained from Ismail & Zein 1987 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	σ_v (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} - 32$)	S_u , kPa ($N_{kt} - 39$)	Depth, m	q_t (MPa)	q_t (kPa)	σ_v (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} - 8$)	S_u , kPa ($N_{kt} - 16$)
2.48	16.04	16040	47.12	32	39	499.78	410.07	2.48	16.04	16040	47.12	8	16	1999.11	999.56
2.49	15.78	15780	47.31	32	39	491.65	403.40	2.49	15.78	15780	47.31	8	16	1966.59	983.29
2.5	15.61	15610	47.5	32	39	486.33	399.04	2.5	15.61	15610	47.5	8	16	1945.31	972.66
2.51	19.19	19190	47.69	32	39	598.20	490.83	2.51	19.19	19190	47.69	8	16	2392.79	1196.39
2.52	19.06	19060	47.88	32	39	594.13	487.49	2.52	19.06	19060	47.88	8	16	2376.52	1188.26
2.53	18.87	18870	48.07	32	39	588.19	482.61	2.53	18.87	18870	48.07	8	16	2352.74	1176.37
2.54	18.64	18640	48.26	32	39	580.99	476.71	2.54	18.64	18640	48.26	8	16	2323.97	1161.98
2.55	18.37	18370	48.45	32	39	572.55	469.78	2.55	18.37	18370	48.45	8	16	2290.19	1145.10
2.56	18.15	18150	48.64	32	39	565.67	464.14	2.56	18.15	18150	48.64	8	16	2262.67	1131.34
2.57	18.09	18090	48.83	32	39	563.79	462.59	2.57	18.09	18090	48.83	8	16	2255.15	1127.57
2.58	18.07	18070	49.02	32	39	563.16	462.08	2.58	18.07	18070	49.02	8	16	2252.62	1126.31
2.59	18.09	18090	49.21	32	39	563.77	462.58	2.59	18.09	18090	49.21	8	16	2255.10	1127.55
2.6	18.07	18070	49.4	32	39	563.14	462.07	2.6	18.07	18070	49.4	8	16	2252.58	1126.29
2.61	18.01	18010	49.59	32	39	561.26	460.52	2.61	18.01	18010	49.59	8	16	2245.05	1122.53
2.62	17.98	17980	49.78	32	39	560.32	459.75	2.62	17.98	17980	49.78	8	16	2241.28	1120.64
3.2	22.27	22270	60.8	32	39	694.04	569.47	3.2	22.27	22270	60.8	8	16	2776.15	1388.08
3.21	22.78	22780	60.99	32	39	709.97	582.54	3.21	22.78	22780	60.99	8	16	2839.88	1419.94
3.22	23.36	23360	61.18	32	39	728.09	597.41	3.22	23.36	23360	61.18	8	16	2912.35	1456.18
3.25	23.4	23400	61.75	32	39	729.32	598.42	3.25	23.4	23400	61.75	8	16	2917.28	1458.64
3.26	23.09	23090	61.94	32	39	719.63	590.46	3.26	23.09	23090	61.94	8	16	2878.51	1439.25
3.27	22.86	22860	62.13	32	39	712.43	584.56	3.27	22.86	22860	62.13	8	16	2849.73	1424.87
3.28	22.75	22750	62.32	32	39	708.99	581.74	3.28	22.75	22750	62.32	8	16	2835.96	1417.98
3.29	22.92	22920	62.51	32	39	714.30	586.09	3.29	22.92	22920	62.51	8	16	2857.19	1428.59
3.3	23.23	23230	62.7	32	39	723.98	594.03	3.3	23.23	23230	62.7	8	16	2895.91	1447.96

Table 49: Site 2 S_u obtained from Lunne et al., 1985 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	σ_v (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} - 1$)	S_u , kPa ($N_{kt} - 13$)	Depth ,m	q_t (MPa)	q_t (kPa)	σ_v (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} - 6$)	S_u , kPa ($N_{kt} - 12$)
2.48	16.04	16040	47.12	1	13	15992.88	1230.22	2.48	16.04	16040	47.12	6	12	2665.48	1332.74
2.49	15.78	15780	47.31	1	13	15732.69	1210.21	2.49	15.78	15780	47.31	6	12	2622.12	1311.06
2.5	15.61	15610	47.5	1	13	15562.50	1197.12	2.5	15.61	15610	47.5	6	12	2593.75	1296.88
2.51	19.19	19190	47.69	1	13	19142.31	1472.49	2.51	19.19	19190	47.69	6	12	3190.39	1595.19
2.52	19.06	19060	47.88	1	13	19012.12	1462.47	2.52	19.06	19060	47.88	6	12	3168.69	1584.34
2.53	18.87	18870	48.07	1	13	18821.93	1447.84	2.53	18.87	18870	48.07	6	12	3136.99	1568.49
2.54	18.64	18640	48.26	1	13	18591.74	1430.13	2.54	18.64	18640	48.26	6	12	3098.62	1549.31
2.55	18.37	18370	48.45	1	13	18321.55	1409.35	2.55	18.37	18370	48.45	6	12	3053.59	1526.80
2.56	18.15	18150	48.64	1	13	18101.36	1392.41	2.56	18.15	18150	48.64	6	12	3016.89	1508.45
2.57	18.09	18090	48.83	1	13	18041.17	1387.78	2.57	18.09	18090	48.83	6	12	3006.86	1503.43
2.58	18.07	18070	49.02	1	13	18020.98	1386.23	2.58	18.07	18070	49.02	6	12	3003.50	1501.75
2.59	18.09	18090	49.21	1	13	18040.79	1387.75	2.59	18.09	18090	49.21	6	12	3006.80	1503.40
2.6	18.07	18070	49.4	1	13	18020.60	1386.20	2.6	18.07	18070	49.4	6	12	3003.43	1501.72
2.61	18.01	18010	49.59	1	13	17960.41	1381.57	2.61	18.01	18010	49.59	6	12	2993.40	1496.70
2.62	17.98	17980	49.78	1	13	17930.22	1379.25	2.62	17.98	17980	49.78	6	12	2988.37	1494.19
3.2	22.27	22270	60.8	1	13	22209.20	1708.40	3.2	22.27	22270	60.8	6	12	3701.53	1850.77
3.21	22.78	22780	60.99	1	13	22719.01	1747.62	3.21	22.78	22780	60.99	6	12	3786.50	1893.25
3.22	23.36	23360	61.18	1	13	23298.82	1792.22	3.22	23.36	23360	61.18	6	12	3883.14	1941.57
3.25	23.4	23400	61.75	1	13	23338.25	1795.25	3.25	23.4	23400	61.75	6	12	3889.71	1944.85
3.26	23.09	23090	61.94	1	13	23028.06	1771.39	3.26	23.09	23090	61.94	6	12	3838.01	1919.01
3.27	22.86	22860	62.13	1	13	22797.87	1753.68	3.27	22.86	22860	62.13	6	12	3799.65	1899.82
3.28	22.75	22750	62.32	1	13	22687.68	1745.21	3.28	22.75	22750	62.32	6	12	3781.28	1890.64
3.29	22.92	22920	62.51	1	13	22857.49	1758.27	3.29	22.92	22920	62.51	6	12	3809.58	1904.79
3.3	23.23	23230	62.7	1	13	23167.30	1782.10	3.3	23.23	23230	62.7	6	12	3861.22	1930.61

Table 50: Site 2 S_u obtained from Lunne & Kleven 1981 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	σ_{sv} (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} -15$)	S_u , kPa ($N_{kt} -20$)	Depth, m	q_t (MPa)	q_t (kPa)	σ_{sv} (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} -5$)	S_u , kPa ($N_{kt} -70$)
2.48	16.04	16040	47.12	15	20	1066.19	799.64	2.48	16.04	16040	47.12	5	70	3198.58	228.47
2.49	15.78	15780	47.31	15	20	1048.85	786.63	2.49	15.78	15780	47.31	5	70	3146.54	224.75
2.5	15.61	15610	47.5	15	20	1037.50	778.13	2.5	15.61	15610	47.5	5	70	3112.50	222.32
2.51	19.19	19190	47.69	15	20	1276.15	957.12	2.51	19.19	19190	47.69	5	70	3828.46	273.46
2.52	19.06	19060	47.88	15	20	1267.47	950.61	2.52	19.06	19060	47.88	5	70	3802.42	271.60
2.53	18.87	18870	48.07	15	20	1254.80	941.10	2.53	18.87	18870	48.07	5	70	3764.39	268.88
2.54	18.64	18640	48.26	15	20	1239.45	929.59	2.54	18.64	18640	48.26	5	70	3718.35	265.60
2.55	18.37	18370	48.45	15	20	1221.44	916.08	2.55	18.37	18370	48.45	5	70	3664.31	261.74
2.56	18.15	18150	48.64	15	20	1206.76	905.07	2.56	18.15	18150	48.64	5	70	3620.27	258.59
2.57	18.09	18090	48.83	15	20	1202.74	902.06	2.57	18.09	18090	48.83	5	70	3608.23	257.73
2.58	18.07	18070	49.02	15	20	1201.40	901.05	2.58	18.07	18070	49.02	5	70	3604.20	257.44
2.59	18.09	18090	49.21	15	20	1202.72	902.04	2.59	18.09	18090	49.21	5	70	3608.16	257.73
2.6	18.07	18070	49.4	15	20	1201.37	901.03	2.6	18.07	18070	49.4	5	70	3604.12	257.44
2.61	18.01	18010	49.59	15	20	1197.36	898.02	2.61	18.01	18010	49.59	5	70	3592.08	256.58
2.62	17.98	17980	49.78	15	20	1195.35	896.51	2.62	17.98	17980	49.78	5	70	3586.04	256.15
3.2	22.27	22270	60.8	15	20	1480.61	1110.46	3.2	22.27	22270	60.8	5	70	4441.84	317.27
3.21	22.78	22780	60.99	15	20	1514.60	1135.95	3.21	22.78	22780	60.99	5	70	4543.80	324.56
3.22	23.36	23360	61.18	15	20	1553.25	1164.94	3.22	23.36	23360	61.18	5	70	4659.76	332.84
3.25	23.4	23400	61.75	15	20	1555.88	1166.91	3.25	23.4	23400	61.75	5	70	4667.65	333.40
3.26	23.09	23090	61.94	15	20	1535.20	1151.40	3.26	23.09	23090	61.94	5	70	4605.61	328.97
3.27	22.86	22860	62.13	15	20	1519.86	1139.89	3.27	22.86	22860	62.13	5	70	4559.57	325.68
3.28	22.75	22750	62.32	15	20	1512.51	1134.38	3.28	22.75	22750	62.32	5	70	4537.54	324.11
3.29	22.92	22920	62.51	15	20	1523.83	1142.87	3.29	22.92	22920	62.51	5	70	4571.50	326.54
3.3	23.23	23230	62.7	15	20	1544.49	1158.37	3.3	23.23	23230	62.7	5	70	4633.46	330.96

Table 51: Site 2 S_u obtained from Bowles, 1995 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,}$ (kPa)	Min. Nkt	S_u , kPa ($N_{kt} -17$)	Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,}$ (kPa)	Min. Nkt	Max. Nkt	S_u , kPa ($N_{kt} -5$)	S_u , kPa ($N_{kt} -70$)
2.48	16.04	16040	47.12	17	940.76	2.48	16.04	16040	47.12	15	20	1066.19	799.64
2.49	15.78	15780	47.31	17	925.45	2.49	15.78	15780	47.31	15	20	1048.85	786.63
2.5	15.61	15610	47.5	17	915.44	2.5	15.61	15610	47.5	15	20	1037.50	778.13
2.51	19.19	19190	47.69	17	1126.02	2.51	19.19	19190	47.69	15	20	1276.15	957.12
2.52	19.06	19060	47.88	17	1118.36	2.52	19.06	19060	47.88	15	20	1267.47	950.61
2.53	18.87	18870	48.07	17	1107.17	2.53	18.87	18870	48.07	15	20	1254.80	941.10
2.54	18.64	18640	48.26	17	1093.63	2.54	18.64	18640	48.26	15	20	1239.45	929.59
2.55	18.37	18370	48.45	17	1077.74	2.55	18.37	18370	48.45	15	20	1221.44	916.08
2.56	18.15	18150	48.64	17	1064.79	2.56	18.15	18150	48.64	15	20	1206.76	905.07
2.57	18.09	18090	48.83	17	1061.25	2.57	18.09	18090	48.83	15	20	1202.74	902.06
2.58	18.07	18070	49.02	17	1060.06	2.58	18.07	18070	49.02	15	20	1201.40	901.05
2.59	18.09	18090	49.21	17	1061.22	2.59	18.09	18090	49.21	15	20	1202.72	902.04
2.6	18.07	18070	49.4	17	1060.04	2.6	18.07	18070	49.4	15	20	1201.37	901.03
2.61	18.01	18010	49.59	17	1056.49	2.61	18.01	18010	49.59	15	20	1197.36	898.02
2.62	17.98	17980	49.78	17	1054.72	2.62	17.98	17980	49.78	15	20	1195.35	896.51
3.2	22.27	22270	60.8	17	1306.42	3.2	22.27	22270	60.8	15	20	1480.61	1110.46
3.21	22.78	22780	60.99	17	1336.41	3.21	22.78	22780	60.99	15	20	1514.60	1135.95
3.22	23.36	23360	61.18	17	1370.52	3.22	23.36	23360	61.18	15	20	1553.25	1164.94
3.25	23.4	23400	61.75	17	1372.84	3.25	23.4	23400	61.75	15	20	1555.88	1166.91
3.26	23.09	23090	61.94	17	1354.59	3.26	23.09	23090	61.94	15	20	1535.20	1151.40
3.27	22.86	22860	62.13	17	1341.05	3.27	22.86	22860	62.13	15	20	1519.86	1139.89
3.28	22.75	22750	62.32	17	1334.57	3.28	22.75	22750	62.32	15	20	1512.51	1134.38
3.29	22.92	22920	62.51	17	1344.56	3.29	22.92	22920	62.51	15	20	1523.83	1142.87
3.3	23.23	23230	62.7	17	1362.78	3.3	23.23	23230	62.7	15	20	1544.49	1158.37

Table 52: Site 2 S_u obtained from Sanglerat, 1972 N_{kt} values

Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,}$ (kPa)	Min. N_{kt}	S_u , kPa ($N_{kt} - 5$)	Depth, m	q_t (MPa)	q_t (kPa)	$\sigma_{v,}$ (kPa)	Min. N_{kt}	Max. N_{kt}	S_u , kPa ($N_{kt} - 5$)	S_u , kPa ($N_{kt} - 70$)
2.48	16.04	16040	47.12	13.5	1184.66	2.48	16.04	16040	47.12	35.1	55.6	455.64	287.64
2.49	15.78	15780	47.31	13.5	1165.38	2.49	15.78	15780	47.31	35.1	55.6	448.22	282.96
2.5	15.61	15610	47.5	13.5	1152.78	2.5	15.61	15610	47.5	35.1	55.6	443.38	279.90
2.51	19.19	19190	47.69	13.5	1417.95	2.51	19.19	19190	47.69	35.1	55.6	545.36	344.29
2.52	19.06	19060	47.88	13.5	1408.31	2.52	19.06	19060	47.88	35.1	55.6	541.66	341.94
2.53	18.87	18870	48.07	13.5	1394.22	2.53	18.87	18870	48.07	35.1	55.6	536.24	338.52
2.54	18.64	18640	48.26	13.5	1377.17	2.54	18.64	18640	48.26	35.1	55.6	529.68	334.38
2.55	18.37	18370	48.45	13.5	1357.15	2.55	18.37	18370	48.45	35.1	55.6	521.98	329.52
2.56	18.15	18150	48.64	13.5	1340.84	2.56	18.15	18150	48.64	35.1	55.6	515.71	325.56
2.57	18.09	18090	48.83	13.5	1336.38	2.57	18.09	18090	48.83	35.1	55.6	513.99	324.48
2.58	18.07	18070	49.02	13.5	1334.89	2.58	18.07	18070	49.02	35.1	55.6	513.42	324.12
2.59	18.09	18090	49.21	13.5	1336.35	2.59	18.09	18090	49.21	35.1	55.6	513.98	324.47
2.6	18.07	18070	49.4	13.5	1334.86	2.6	18.07	18070	49.4	35.1	55.6	513.41	324.11
2.61	18.01	18010	49.59	13.5	1330.40	2.61	18.01	18010	49.59	35.1	55.6	511.69	323.03
2.62	17.98	17980	49.78	13.5	1328.16	2.62	17.98	17980	49.78	35.1	55.6	510.83	322.49
3.2	22.27	22270	60.8	13.5	1645.13	3.2	22.27	22270	60.8	35.1	55.6	632.74	399.45
3.21	22.78	22780	60.99	13.5	1682.89	3.21	22.78	22780	60.99	35.1	55.6	647.27	408.62
3.22	23.36	23360	61.18	13.5	1725.84	3.22	23.36	23360	61.18	35.1	55.6	663.78	419.04
3.25	23.4	23400	61.75	13.5	1728.76	3.25	23.4	23400	61.75	35.1	55.6	664.91	419.75
3.26	23.09	23090	61.94	13.5	1705.78	3.26	23.09	23090	61.94	35.1	55.6	656.07	414.17
3.27	22.86	22860	62.13	13.5	1688.73	3.27	22.86	22860	62.13	35.1	55.6	649.51	410.03
3.28	22.75	22750	62.32	13.5	1680.57	3.28	22.75	22750	62.32	35.1	55.6	646.37	408.05
3.29	22.92	22920	62.51	13.5	1693.15	3.29	22.92	22920	62.51	35.1	55.6	651.21	411.11