ESTABLISHMENT OF FUNDAMENTAL CHARACTERISTICS OF SOME UNSATURATED SRI LANKAN RESIDUAL SOILS

Nanthini Vasanthan

(138829P)

Supervised by Prof. S.A.S. Kulathilaka

M.Eng. in Foundation Engineering and Earth Retaining Systems

Department of Civil Engineering

University of Moratuwa

Sri Lanka

(2013/2014 BATCH)

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Thesis submitted in partial fulfillment of the requirements for the degree of Master of Engineering in Foundation Engineering and Earth Retaining Systems

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DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or Institute of higher learning to the best of our knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Nanthini Vasanthan

The above candidate has carried out research for the Master Dissertation under my supervision.

Signature of the supervisor:………………….. Date:…………………...

Professor S.A.S. Kulathilaka,
B.Sc. Eng. Hons (Moratuwa), Ph.D. (Monash), C.Eng., MIE(SL),
Department of Civil Engineering,
University of Moratuwa,
Sri Lanka.

ABSTRACT

Slope failure in tropical climates frequently occurs due to excessive rainfall. Heavy infiltration causes destruction of matric suctions, development of perched water table conditions and rise of ground water table. Severe erosion and surface destruction will also be caused by the heavy prolonged rainfall. In order to understand the threshold values of rainfall leading to instability it is necessary to model this process with a reasonable accuracy.

Sri Lankan residual soil formations are formed by weathering of the metamorphic parent rock and have inherited significant abrupt variations in engineering characteristics. Basic characteristics of these soil formations such as soil water characteristic curves (SWCCs), variation of permeability with water content and unsaturated shear strength parameters are essential parameters in these analyses. These characteristics have not been established for typical residual soils forming slopes in Sri Lanka.

This thesis highlights the need for detailed experimental studies and presents comprehensive studies that have been conducted at the University of Moratuwa and National Building Research Organization (NBRO) laboratories to establish the fundamental characteristics of unsaturated Sri Lankan residual soils. Undisturbed samples of soil obtained from the failed slope at Welipenna in the Southern Expressway were used in this study.

Direct shear tests were done by modifying the conventional apparatus by incorporating a miniature tensiometer which allows for the simple and direct measurement of soil matric suction during shearing. Soil water characteristic curves (SWCCs) were also established using these apparatus. Alternatively, pressure plate apparatus was also used for this purpose. In addition to that, soil water characteristic curves (SWCCs) were developed from gradation curve also.

Permeability of an unsaturated soil varies considerably with the level of saturation and will make a very significance influence on the infiltration process. Permeability function which defines the variation of permeability with matric suction was investigated on undisturbed samples. The method is based on continuously drying and wetting the soil sample while continuously monitoring the suction gradient and the change in soil mass. The thesis highlights the importance of these studies and presents the procedures that are being used.

DEDICATION

This thesis is dedicated to my parents Late Mr.N.Vethasalam and Mrs.V.Sakunthaladevi. They have encouraged me all the time "study, study, study……., then only you will achieve your target". As they said I have obtained my BSc. Eng. (Civil) in March 2004 and I started my master carrier in May 2013. I have lost my father in March 2015 during my masters. Appa! your dream came true and I know that you are somewhere around here watching our achievements.

ACKNOWLEDGMENTS

I would first and foremost like to thank my Lord, who has made this dream and all other realities possible.

First and foremost, I would like to express my deepest gratitude to Prof. Athula Kulathilaka, Professor at Civil Engineering Department of University of Moratuwa, for his dedication and keen interest to make success and as well as for setting me the platform to proceed my career in Geotechnical Engineering. I am highly indebted to Prof. Apiniti Jotisankasa, the head of the Geotechnical Engineering section of Kasetsart University, Thailand not only for supplying instruments and giving training on tensiometer at Universities of Kasetsart and Moratuwa but also clarifying the doubts, problems regarding the instruments and research throughout my research carrier. Without their guidance and persistent help this drive would not have been possible.

My sincere gratitude should go to Mr. Narin Hunsachainan, Assistant Lecturer of Civil Engineering Department of Kasetsart University and Mr. Ajintit, Masters Student, Kasetsart University for giving in hand training on installing and handling the tensiometer.

I should really pay my sincere gratitude to Eng. (Dr) Asiri Karunawardena, Director General of National Building Research Organization (NBRO), for his guidance and continuous support throughout the masters. It is my obligation to acknowledge the commitment and the courage given by Mr. K.N Bandara, Director of Geotechnical Engineering Division (GED) and all the other staff of Geotechnical Engineering Division of NBRO. In this regard I should especially acknowledge the assistance given by Mr. Lilanka Kankanamge, Engineer, Ms. Nirmanthi Idirimanne, Engineer and Ms. Chamila Jayasundara, Geologist, NBRO.

The assistance received from Mr.K.R.Pitipanaarachchi, Technical Officer, Mr. D.G.S Vithanage, Technical Officer, Mr. M.A.Ajith Piyasiri, Lab Assistant and Ms. Pradeepa Pieris, M.Eng. Course Assistant in the Soil Mechanics Laboratory, University of Moratuwa and similarly, Mr. Chandima Piumkith, Management Assistant-Technical, Mr.M.Abeysinghe, Management Assistant-Technical during the laboratory testing programme, and all other laboratory staff who have supported conducting all kind of laboratory tests in Geotechnical Engineering Laboratory, NBRO is acknowledged. Also I would like to acknowledge the assistance extended by Mr. U.K.Padmaperuma, Technical Officer, Civil Engineering Workshop and Mr.Yomal Dias, Lecturer (on contract), Civil Engineering Department for fabricating experimental setups successfully.

Last but not least, I would like to personally thank my superb husband Mr.S.Vasanthan, Consultant/Geotechnical Engineer, Resource Development Consultants (RDC) who has given tremendous support not only in the situation where it really matters but also research field as he is also in the same area and my lovely son Master.V.Kirthik, student, Royal College, Colombo-07 who has sacrificed lot of things/benefits for me as I am working woman and master student also.

Nanthini Vasanthan,
9th November 2016.

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List of symbols

A	- Cross sectional area of the sample
A*	- Point corresponds to the air-entry value
B*	- Point corresponds to residual Water Content
c_a	- Apparent cohesion
c^s	- Additional cohesion in unsaturated soil due to matric suction
c'	- Effective cohesion
C_v	- Coefficient of consolidation
dt	- Change of time
dV_w	- Change of volume of water
dz	- Change of elevation head
e	- Void ratio of the soil
e_0	- Initial void ratio
e_f	- Final void ratio
g	- Acceleration due to gravity
G_s	- Specific gravity of the soil
h_i	- Total pore length
h_t	- Total head
H_1	- Height of drainage path for section- 1
H_2	- Height of drainage path for section- 2
i	- Hydraulic gradient
I_r	- Rainfall intensity
k	- Permeability of the soil
m	- Soil mass
m_v	- Coefficient of volume compressibility

n_i	- Number of spherical particles
p	- Normal stress applied for consolidation test
q	- Boundary flux
Q	- Nodal flux
r_i	- Pore radius
R_i	- Mean particle radius
R_s	- Radius of curvature
s	- Matric suction
S_r	- Degree of saturation of the soil
t	- Elapsed time
t_{90}	- Time taken for 90% consolidation
$t_{90,1}$	- Time taken for 90% consolidation for Section-1
$t_{90,2}$	- Time taken for 90% consolidation for Section-2
T_{90}	- Time factor for 90% consolidation
T_s	- Surface tension
u_a	- Pore air pressure
u_w	- Pore water pressure
$(u_a - u_w)_b$	- Matric suction at air-entry value
$(u_a - u_w)_{calc}$	- Matric suction calculated
$(u_a - u_w)_{meas}$	- Matric suction measured
$(u_a - u_w)_r$	- Matric suction at residual water content
v	- Flux or discharge velocity
V	- Volume of soil
V_b	- Sample bulk volume per unit sample mass
V_{pi}	- Total solid volume

V_t	- Voltage at any suction/pressure at the time
V_{vi}	- Pore volume per unit sample mass in i^{th} particle size range
V_w	- Volume of water of soil
V_0	- Voltage at atmospheric pressure
w	- Gravimetric moisture content of the soil
W_i	- Solid mass per unit sample mass in i^{th} particle site range
z	- Elevation head of each tensiometer relative to the base of sample
W_s	- Solid weight of the soil
γ_w	- Unit weight of the water
θ_r	- Residual volumetric water content
θ_s	- Saturated volumetric water content
θ_w	- Volumetric water content
θ	- Contact angle
$(\sigma_n - u_a)$	- Net normal stress
τ	- Shear stress
ϕ'	- Effective internal angle of friction
σ_n	- Normal stress
σ', $(\sigma_n - u_w)$	- Effective stress
τ_{max}	- Shear strength at failure
ϕ^b	- Angle of shearing resistance due to suction
σ_x	- Total normal stress in the x-direction (or on the x-plane)
σ_y	- Total normal stress in the y-direction (or on the y-plane)
σ_z	- Total normal stress in the z-direction (or on the z-plane)
$(\sigma_x - u_a)$	- Net normal stress in the x-direction
$(\sigma_y - u_a)$	- Net normal stress in the y-direction

$(\sigma_z - u_a)$	- Net normal stress in the z-direction
τ_{xy}	- Shear stress on the x-plane in the y-direction
τ_{xz}	- Shear stress on the x-plane in the z-direction
τ_{yx}	- Shear stress on the y-plane in the x-direction
τ_{yz}	- Shear stress on the y-plane in the z-direction
τ_{zx}	- Shear stress on the z-plane in the x-direction
τ_{zy}	- Shear stress on the z-plane in the y-direction
ρ_p	- Particle density
θ_{vi}	- Volumetric water content i^{th} particle size range
θ^*_{vi}	- Average volumetric water content represent by mid-point of the i^{th} particle size range
θ_{vi+1}	- Volumetric water content $(i+1)^{th}$ particle size range
π	- Mathematical constant (Pi)
α	- Model parameter
ρ_w	- Density of water
ρ_d	- Dry density of soil
ρ_w	- Density of water
ψ	- Soil water pressure head

List of abbreviations

Al	- Aluminum
Al_2O_3	- Aluminum Oxide
ATM	- Atmospheric pressure
ATT	- At The Time
BSCS	- British Soil Classification System
Cr	- Chromium
E01	- Express way No.1
Fe	- Iron
Fe_2O_3	- Ferric Oxide
GED	- Geotechnical Engineering Division
GIL	- Geotechnical Innovation Laboratory
HC	- Highland Complex
KC	- Kadugannawa Complex
KU	- Kasetsart University
KU T1	- Kasetsart University Tensionmeter type 1
KU T2	- Kasetsart University Tensionmeter type 2
KU T3	- Kasetsart University Tensionmeter type 3
KU T4	- Kasetsart University Tensionmeter type 4
LCD	- Liquid Crystal Display
MEMs	- Micro Electro Mechanical System
Mn	- Manganese
MH	- SANDY elastic SILT
MS	- SANDY SILT
NBRO	- National Building Research Organization

Ni	- Nickel
PVC	- Poly Vinyl Chloride
SD	- Secure Digital
SM	- SILTY SAND
SWCC	- Soil Water Characteristic Curve
VC	- Vijayan Complex
WC	- Wanni Complex
1-D	- One Dimensional

Annexures