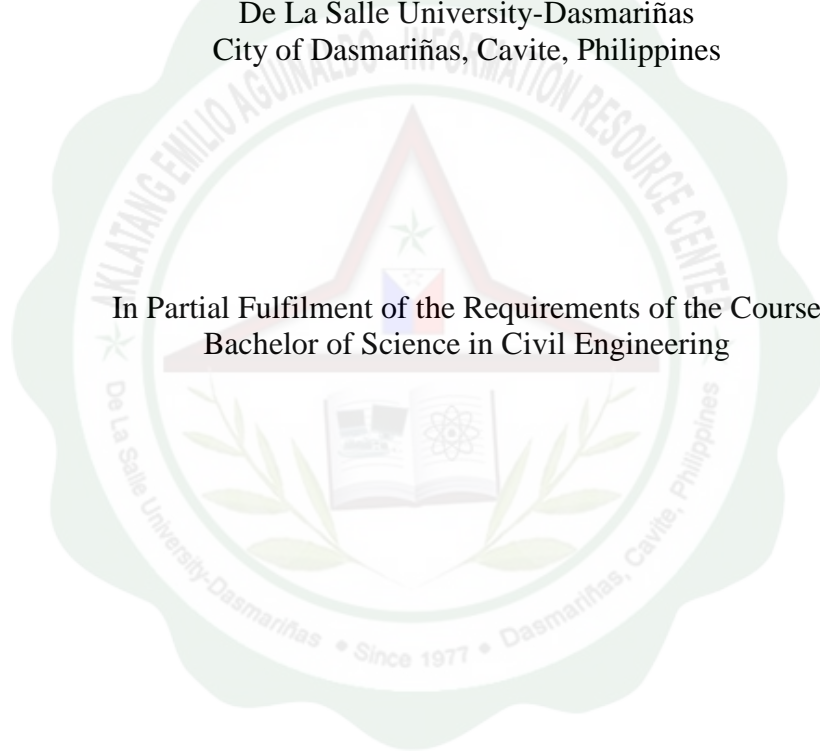


**Mathematical Modeling of the Hydraulic Gradients of  
Stratified Soils in a Steady State Upward Seepage Condition**

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## ABSTRACT

As of this writing, studies about upward seepage normally analyze soils as a homogenous block. This kind of assumption, however, leaves much to be desired since soils in its natural state are stratified. For this reason, the research explores the possibility of analyzing soils as a stratified block, particularly through the observation of the behavior of hydraulic gradient through each stratum of significantly different soil physical properties, as the entire soil block becomes subjected to steady-state upward seepage pressure.

Twelve disturbed soils samples representative of the soil textures in the United States Department of Agriculture soil texture triangle was subjected to steady-state upward seepage test to determine the relationship between their hydraulic gradients, and the combined effect of effective stresses and permeabilities. Using Microsoft Excel 2013 Analysis Toolpak, multiple linear regression was performed on homogeneous, two-strata, and three-strata setups of the disturbed samples to model their corresponding equations, which were then compared to the yielded values of hydraulic gradients of real-world undisturbed stratified soil samples collected from identified locations.

In all setups, the effective stresses and permeabilities all greatly influenced the behavior of the hydraulic gradient. The two-stratum model turned to be at least 92% accurate whereas the three-stratum model turned to be at least 78% accurate, thus implying inverse proportional relationship between degree of stratification and model accuracy. The use of the two-stratum mathematical model is deemed to be advisable for use in analysis of real-world scenarios involving stratified soils.

## TABLE OF CONTENTS

Approval Sheet.....	ii
Abstract.....	ii
Acknowledgement.....	iii
Table of Contents.....	iv
List of Tables.....	vii
List of Figures.....	ix
List of Equations.....	x
List of Symbols.....	xi
Chapter 1.....	1
1.1 Introduction.....	1
1.2 Statement of the Problem.....	2
1.3 Objectives of the Study.....	3
1.4 Significance of the Study.....	3
1.5 Scope and Limitation.....	4
1.6 Conceptual Framework.....	5
1.7 Definition of Terms.....	5
Chapter 2.....	7
2.1 Soil Textures.....	7
2.2 Stratification of Soils in Artesian Setting.....	7
2.3 Block Sampling.....	9
2.4 Specific Gravity.....	9

2.5 Void Ratio.....	10
2.6 Permeability .....	10
2.7 Upward Seepage .....	11
2.8 Hydraulic Gradient.....	12
2.9 Critical Hydraulic Gradient.....	13
2.10 Factor of Safety.....	14
2.11 Darcy's Law .....	15
2.12 Computer-aided Regression Analysis.....	15
Chapter 3.....	17
3.1 Methodological Framework.....	17
3.2 Gathering of Samples.....	18
3.3 Selection of Samples.....	19
3.4 Experimental Setup.....	21
3.4.1 Apparatus .....	21
3.4.2 Pump .....	22
3.5 Statistical Treatment .....	22
3.6 Experimental Procedure on Disturbed Soil Samples .....	23
3.7 Mathematical Modeling.....	24
3.8 Experimental Procedure on Disturbed Soil Samples .....	25
Chapter 4.....	27
4.1 Disturbed Samples .....	27
4.1.1 Hydraulic Gradient.....	27
4.1.2 Specific Gravity .....	41

4.1.3 Void Ratio.....	41
4.1.4 Permeability.....	42
4.1.5 Seepage Test.....	42
4.1.6 Critical Hydraulic Gradient.....	51
4.2 Undisturbed Samples.....	53
Chapter 5.....	55
5.1 Summary of Findings.....	55
5.2 Conclusion.....	55
5.3 Recommendation.....	58
Bibliography.....	59
Appendix.....	61
A.1 Design of Upward Seepage Apparatus.....	61
A.2 Soil Extruder Model.....	62
A.3 Photos.....	63
A.4 Activity Chart.....	66
A.5 Pertinent Documents.....	68

## LIST OF TABLES

Table 2.1 Coefficient of permeability of primary soil textures .....	8
Table 2.2 Phenomenological factors of safety of soils .....	14
Table 3.1 Organizational standards on soil texture particle diameters .....	18
Table 3.2 Percentage distribution of strata of disturbed soil samples.....	20
Table 4.1 Hydraulic gradients of Sand .....	27
Table 4.2 Hydraulic gradients of Silt.....	28
Table 4.3 Hydraulic gradients of Clay .....	28
Table 4.4 Hydraulic gradients of Loamy Sand .....	31
Table 4.5 Hydraulic gradients of Silty Clay .....	31
Table 4.6 Hydraulic gradient of Sandy Clay .....	32
Table 4.7 Hydraulic gradients of Clay Loam.....	34
Table 4.8 Hydraulic gradients of Silty Clay Loam.....	35
Table 4.9 Hydraulic gradients of Sandy Clay Loam.....	35
Table 4.10 Hydraulic gradients of Silty Loam.....	36
Table 4.11 Hydraulic gradients of Loam .....	36
Table 4.12 Hydraulic gradients of Sandy Loam .....	37
Table 4.13 Specific gravities of primary soil texture samples.....	41
Table 4.14 Void ratios of primary soil texture samples.....	41
Table 4.15 Permeabilities of primary soil texture samples.....	42
Table 4.16 Upward seepage test of Sand .....	42
Table 4.17 Upward seepage test of Silt .....	43

Table 4.18 Upward seepage test of Clay .....	43
Table 4.19 Regression coefficients of one stratum samples .....	44
Table 4.20 Regression statistics on one stratum .....	44
Table 4.21 Upward seepage test of Loamy Sand.....	45
Table 4.22 Upward seepage test of Silty Clay .....	45
Table 4.23 Upward seepage test of Sandy Clay .....	45
Table 4.24 Regression coefficients of two strata samples .....	46
Table 4.25 Regression statistics on two strata .....	46
Table 4.26 Upward seepage test of Clay Loam .....	47
Table 4.27 Upward seepage test of Silty Clay Loam.....	47
Table 4.28 Upward seepage test of Sandy Clay Loam .....	47
Table 4.29 Upward seepage test of Silty Loam .....	48
Table 4.30 Upward seepage test of Loam.....	48
Table 4.31 Upward seepage test of Sandy Loam.....	48
Table 4.32 Regression coefficients of three strata samples .....	49
Table 4.33 Regression Statistics on three strata.....	49
Table 3.34 Logarithmic regression coefficients of three strata samples.....	50
Table 4.35 Logarithmic regression statistics on three strata.....	51
Table 4.36 Critical hydraulic gradients of one stratum soil samples .....	51
Table 4.37 Critical hydraulic gradient of two strata soil samples.....	52
Table 4.38 Critical hydraulic gradients of three strata soil samples .....	52
Table 4.39 Theoretical hydraulic gradients of three strata undisturbed samples.....	54
Table 4.40 Upward seepage test of three strata undisturbed samples.....	54

## LIST OF FIGURES

Figure 2.1 Profile view of an artesian setting .....	8
Figure 2.2 Parameters of a steady state upward seepage setup.....	13
Figure 3.1 Methodological framework of the study .....	17
Figure 3.2 USDA soil texture triangle .....	20
Figure 4.1 Hydraulic gradient of Sand.....	29
Figure 4.2 Hydraulic gradient of Silt .....	30
Figure 4.3 Hydraulic gradient of Clay .....	30
Figure 4.4 Hydraulic gradient of Loamy Sand .....	33
Figure 4.5 Hydraulic gradient of Silty Clay.....	33
Figure 4.6 Hydraulic gradient of Sandy Clay .....	34
Figure 4.7 Hydraulic gradients of Clay Loam .....	38
Figure 4.8 Hydraulic Gradient of Silty Clay Loam .....	38
Figure 4.9 Hydraulic Gradient Sandy Clay Loam .....	39
Figure 4.10 Hydraulic Gradient Silty Loam .....	39
Figure 4.11 Hydraulic Gradient of Loam .....	40
Figure 4.12 Hydraulic Gradient of Sandy Loam .....	40
Figure 4.13 Comparative graph of hydraulic gradient parameters .....	53



## LIST OF EQUATIONS

Equation 2.1 Specific gravity of soil solids .....	9
Equation 2.2 Calibrated specific gravity of soil solids .....	10
Equation 2.3 Void ratio.....	10
Equation 2.4 Coefficient of permeability.....	11
Equation 2.5 Effective stress in a steady state upward seepage .....	12
Equation 2.6 Hydraulic gradient of given soil height.....	12
Equation 2.7 Critical hydraulic gradient of soil.....	14
Equation 2.8 Factor of safety in a steady state upward seepage condition.....	15
Equation 2.9 Velocity of flow through a soil layer.....	15
Equation 2.10 Flow rate through a soil layer.....	15
Equation 2.11 Square of standard error in multiple linear regression .....	16
Equation 3.1 Sample correlation coefficient.....	23
Equation 3.2 Percent error .....	23
Equation 3.3 Multiple regression model.....	23
Equation 4.1 Proportionality of hydraulic gradient, permeability and effective stress ....	43
Equation 4.2 Multiple linear regression equation of one stratum soil samples .....	44
Equation 4.3 Multiple linear regression equation of two strata soil samples .....	46
Equation 4.4 Multiple linear regression equation of three strata soil samples .....	49
Equation 4.5 Log multiple linear regression equation of three strata soil samples .....	50

## LIST OF SYMBOLS

$A$	Area of soil cylinder	$k$	Permeability
$e$	Void ratio	$k_{ave}$	Average permeability
$e_{ave}$	Average void ratio	$k_c$	Bottle calibration constant
$EV$	Experimental value	$k_t$	Permeability of top stratum
$f$	Seepage pressure	$k_m$	Permeability of middle stratum
$FS$	Factor of safety	$k_b$	Permeability of bottom stratum
$\gamma$	Moist unit weight of soil	$L$	Total length of soil
$\gamma_d$	Dry unit weight of soil	$\sigma'$	Effective stress
$\gamma_{sat}$	Saturated unit weight of soil	$\sigma'_t$	Effective stress at top stratum
$\gamma_w$	Unit weight of water	$\sigma'_m$	Effective stress at middle stratum
$\gamma'$	Buoyant unit weight of soil	$\sigma'_b$	Effective stress at bottom stratum
$G_s$	Soil specific gravity	$P_{error}$	Percent error
$G_{s\ ave}$	Average soil specific gravity	$Q$	Rate of discharge
$h$	Height of stratum	$r^2$	Coefficient of correlation
$i$	Hydraulic gradient	$s$	Degree of saturation
$i_{ave}$	Average hydraulic gradient	$t$	Time
$i_c$	Critical hydraulic gradient	$V_w$	Volume of discharged water
$i_{EV}$	Experimental hydraulic gradient	$y$	Piezometric head
$i_{TV}$	Theoretical hydraulic gradient	$\Delta y$	Difference in piezometric heads