



# **STUDY OF PULLOUT RESISTANCE OF SOIL NAILS IN TROPICAL RESIDUAL SOIL**



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**Supervised By prof: S.A.S Kulathilaka**

**M.Eng IN FOUNDATION ENGINEERING AND EARTH RETAINING SYSTEMS**

**DEPARTMENT OF CIVIL ENGINEERING**

**UNIVERSITY OF MORATUWA**

**(2011/2012 BATCH)**

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**Degree of Master of Engineering**



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**June 2016**

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**Eng. Ranjan Kumara W.E.P.**

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**Thesis Submitted To University Of Moratuwa In Partial Fulfillment Of The  
Requirements For The Degree of Master of Engineering in Foundation  
Engineering And Earth Retaining Systems.**



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**June 2016**

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Signature of the supervisor:.....

Date:.....

Professor S A S Kulathilaka

BSc Eng Hons (Moratuwa), PhD (Monash), CEng, MIE (SL)

Professor  
Department of Civil Engineering,  
University of Moratuwa,  
Moratuwa,  
Sri Lanka.

## ABSTRACT

As a norm, most design engineers typically resort to theoretical and empirical approaches in order to determine the pullout resistance of soils while designing soil nailed retaining walls. The tendency to design based on actual field tests are minimal due to the time and cost involved while implementing such tests. Though results obtained through pull out tests done within the laboratory have been used to perform design calculations, the outcome of such test results are questionable, as such tests do not replicate precise site conditions.

This research primarily juxtaposes and establishes a relationship between the theoretical and on field practical pullout resistance of soil nails in unsaturated conditions with the use of information extracted from an extensive literature review and data obtained through an actual pull out test conducted on a set of soil nails installed in predetermined locations of a 25ft high embankment spanning 70ft.

This research also attempts to explore the effects of over burden pressure on the pull out resistance of the soil nails and the behavior of the actual failure surface of the soil nail, which has also been mentioned as the effective diameter in this report.



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## List of Symbols

$(u_a - u_w)$	Matric suction
$(\sigma_n - u_a)$	Net normal stress
$A_s$	Surface area of the nail
$D_{eq}$	Equivalent width of flat reinforcement
$K_s$	Coefficient of lateral earth pressure
$Q(u_a - u_w)$	Capacity of soil nails due to the contribution of matric suction
$Q_f$	Capacity of soil nails installed in saturated soils
$c'$	Soil cohesion
$c_a$	Soil adhesion at the grout/soil interface
$d_i^d$	Minimum grain diameter of the corresponding fraction
$d_i^g$	Maximum grain diameter of the corresponding fraction
$k_e$	Coefficient of lateral earth pressure with respect to soil nail inclination
$q_s$	Shaft capacity of piles
$\delta$	Interface friction angle
$e_s$	Saturated volumetric water content
$\mu^*$	Coefficient of apparent friction of soil ( $\mu^* = \tan \phi'$ and $c' = 0$ for granular soil)
$\sigma'_n$	Effective normal stress
$\sigma'_v$	Vertical stress calculated at the mid-depth of the nail in the resistance zone
$\sigma'_z$	Effective overburden stress
$T_{us}$	Shear strength of unsaturated soils
$\phi'$	Angle of internal friction of soil
$\phi^b$	The angle of shearing resistance with respect to matric suction
$\Delta_{wg}$	Fraction weight in parts of the total weight
$cu$	Coefficient of uniformity
$D$	Nail diameter (m)
$d_e$	Dominant particle size diameter, <i>mm</i>
$e$	Void ratio
$f_b$	Coefficient of roughness
$f_c$	Coefficient defined by $c_a/c'$
$f_s$	Coefficient defined by $\delta/\phi$
$L_s$	Embedment depth of soil nail (m)

## List of Symbols Abbreviations

<b>m</b>	Soil parameter related to residual water content
<b>n</b>	Soil parameter related to the slope at the inflection point of the SWCC
<b>P</b>	Nail perimeter
<b>S<sub>r</sub></b>	Residual degree of saturation
<b>T<sub>pull-out</sub></b>	Failure load at which pull-out failure occurs (kN)
<b>W<sub>r</sub></b>	Residual gravimetric water content
<b>W<sub>s</sub></b>	Saturated gravimetric water content
<b>w<sub>w</sub></b>	Gravimetric water content
<b>ψ</b>	Dilation angle.
<b>C (ψ)</b>	Correction factor that forces the SWCC through a suction of 1,000,000 kPa and zero water content.
<b>S</b>	Degree of saturation
<b>β</b>	Bjerrum –Burland coefficient
<b>ϑ</b>	Volumetric water content
<b>K</b>	Fitting parameter used for obtaining a best-fit between the measured and predicted values.
<b>λ</b>	Pull-out factor
<b>κ</b>	Parameter dependent on the degree of saturation (varies from 0 to 1)



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## List of Abbreviations

<b>SW</b>	Well-graded sand
<b>SP</b>	Poorly graded sand
<b>CDG</b>	Completely decomposed granite
<b>CFEM</b>	Canadian Foundation Engineering Manual
<b>CU</b>	Consolidated undrained
<b>DAS</b>	Data Acquisition System
<b>FHWA</b>	Federal Highway Administration
<b>GSD</b>	Grain size distribution
<b>GWT</b>	Ground-water table
<b>HSS</b>	Hollow Steel Section
<b>NATM</b>	New Austrian Tunneling Method
<b>M</b>	Silty sand
<b>SPT</b>	Standard penetration test
<b>SWCC</b>	Soil-water characteristic curve

## List of Symbols Abbreviations

TYP	Typical
USCS	Unified soil classification system
WWM	Welded wire mesh



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