

**EVALUATION OF THE STIFFNESS AND  
STRENGTH PARAMETERS OF HARDENING  
SOIL MODEL FOR THE SIMULATION OF THE  
TWIN TUNNELS INTERACTION IN KENNY  
HILL FORMATION RESIDUAL SOIL**

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**UNIVERSITI SAINS MALAYSIA**

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by

**LIM SIAO PHIN**

**Thesis submitted in fulfilment of the  
requirements for the degree of  
Master of Science**

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## LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
C/D	Cover to Tunnel Diameter Ratio
CIU test	Consolidated Isotropic Undrained triaxial test
CPT	Cone Penetration Test
DEM	Discrete Element Method
FE	Finite Element
FEM	Finite Element Method
HS	Hardening Soil
IDW	Inverse Distance Weighting
OK	Ordinary Kriging
KVMRT	Klang Valley Mass Rapid Transit
MC	Mohr Coulomb
MZ	Morphological Zone
NB	North Bound tunnel
PMT	Pressuremeter Test
SB	South Bound tunnel
SBK	Sungai Buloh Kajang
SPT	Standard Penetration Test
SPT-N	Standard Penetration Test Blow Count Value
TBM	Tunnel Boring Machines
Z4h	Region in Zone 4 with twin tunnels in horizontal alignment
Z4i	Region in Zone 4 with twin tunnels in inclined alignment
Z4v	Region in Zone 4 with twin tunnels in vertical alignment

## LIST OF SYMBOLS

$Z(X_o)$	Interpolation value of Inverse Distance Weighting (IDW) function
$Z(X_i)$	Value at measured data points
$n$	Number of data points (borehole)
$W_i$	Weighted value assigned to data point
$h_i$	Distance between data points
$\mu$	Stationary mean
$\lambda_i$	Kriging weight
$\mu(x_o)$	Mean of sample within search boundary
$\gamma$	Semivariance of true value $Z$
$S(x)$	Surface settlement at point $x$
$S_{max}$	Maximum point of tunnelling induced surface settlement trough
$i$	Horizontal distance between tunnel centreline and point of inflection
$V_s$	Volume of settlement trough
$z_o$	Tunnel overburden
$R$	Tunnel radius
$V_L$	Volume loss
$V_t$	Over excavation volume
$\beta$	Stress release factor
$P_o$	Original soil pressure at tunnel boundary
$P_\beta$	Soil pressure at tunnel boundary
$\tau'$	Effective stress shear strength
$c'$	Effective stress cohesion
$\sigma'$	Effective overburden pressure

$\phi'$	Effective stress friction angle
$E_i$	Initial stiffness modulus
$R_f$	Failure ratio
$q_f$	Ultimate deviatoric stress
$E_{50}$	Secant stiffness in standard drained triaxial test
$E_{oed}$	One-dimensional compression stiffness
$E_{ur}$	Unload-reloading stiffness
$\sigma_h'$	In-situ horizontal pressure
$\sigma_v'$	In-situ vertical pressure
$P_l$	Limit pressure of soil
$G$	Shear modulus of soil
$E_m$	Elastic modulus of soil
$S_u$	Undrained shear strength
$\psi$	Dilation angle
$\phi_{peak}$	Peak angle of friction
$L_u$	Lugeon value
$K$	Coefficient of permeability
$e$	Void ratio
$P_c$	Pre-compression pressure
$C_c$	Compression index
$V_{ur}$	Poisson's ratio for unload-reloading

**PENILAIAN PARAMETER KEKAKUAN DAN KEKUATAN DALAM  
MODEL Pengerasan Tanah UNTUK SIMULASI INTERAKSI ANTARA  
TEROWONG BERKEMBAR DI DALAM TANAH SISA FORMASI  
GEOLOGI KENNY HILL**

**ABSTRAK**

Simulasi berangka untuk masalah geoteknikal sering melibatkan proses pemudahan dan andaian kerana ia merupakan tugas hampir mustahil untuk mensimulasikan semua ciri-ciri yang terlibat dalam persekitaran tanah. Untuk pembinaan berskala besar, terutamanya seperti pembinaan terowong berkembar Klang Valley Mass Rapid Transit (KVMRT) dibawah persekitaran bandar, simulasi geoteknik yang realistik adalah penting kerana pembinaan terowong akan mempengaruhi kestabilan struktur-struktur di atas permukaan dan bawah tanah. Dalam kajian ini pendekatan parameter penentuan dicadangkan untuk menentukan kekerasan dan kekuatan parameter untuk model Pengerasan Tanah (HS) berdasarkan tafsiran ujian tanah in-situ dan makmal. Penyiasatan ciri-ciri subpermukaan tanah dilakukan dengan membentuk model tanah, model terowong tiga dimensi dan keratan rentas subpermukaan tanah untuk empat zon yang dibahagikan daripada kawasan kajian berdasarkan keserupaan dari segi litologi dan taburan nilai SPT-N. Tiga keratan rentas tanah yang kritikal telah dikenalpastikan berdasarkan input daripada model terowong, keratan rentas tanah, konfigurasi terowong berkembar yang terlibat dan data pergerakan tanah yang disebabkan oleh pembinaan terowong yang sedia ada. Profil dan parameter lapisan tanah dalam keratan rentas subpermukaan tanah telah dikenalpastikan untuk membangunkan model konseptual bagi simulasi pergerakan tanah teraruh daripada pengorekan terowong secara unsur tidak terhingga (FEM).

Parameter untuk sisa tanah geologi formasi Kenny Hill telah dinilai dengan membandingkan lengkungan tegasan-terikan yang dipantau daripada simulasi berangka dan ujian in-situ pressuremeter (PMT). Model HS diselaraskan dengan meoptimumkan parameter kekakuan dan kekuatan untuk memadankan lengkungan tegasan-terikan yang dipantau dalam ujian PMT. Analisis kepekaan parameter HS terhadap reaksi tanah menunjukkan bahawa parameter kekakuan oedometer lebih berkesan dalam mengawal canggan plastik manakala parameter kekakuan unload-reload menunjukkan kesan yang ketara dalam canggan anjal reaksi tanah. Keberkesanan penyelarasan model tanah ditentukan daripada pengesahan analisis pengorekan terowong berkembar. Analisis terowong dengan parameter yang diselaraskan meramalkan keputusan yang selari dengan pergerakan tanah yang dipantau dari pembinaan terowong berkembar dengan penjajaran mendatar, condong dan menegak. Walau bagaimanapun, simulasi dengan model Mohr Coulomb (MC) menramalkan pergerakan tanah yang bercanggar dengan arah pergerakan tanah yang dipantau. Analisis parametrik dijalankan untuk menentukan pengaruh konfigurasi terowong dan turutan pembinaan terowong berkembar terhadap interaksi terowong berkembar dalam formasi Kenny Hill. Kajian ini menunjukkan pendekatan bersepadu untuk penentuan parameter model juzuk dengan pengabungan pemodelan subpermukaan dan penyelarasan model juzuk bersama penentusahan. Parameter HS sisa tanah formasi Kenny Hill yang diselaraskan menyumbangkan untuk projek pembinaan masa depan yang mempunyai ciri-ciri geologi yang sama sebagai rujukan. Pendekatan penentuan parameter dengan penyelarasan model juzuk membantu jurutera dan penyelidik dalam pendekatan alternatif untuk penentuan parameter selain daripada data empirikal atau persamaan korelasi.

**EVALUATION OF THE STIFFNESS AND STRENGTH PARAMETERS OF  
HARDENING SOIL MODEL FOR THE SIMULATION OF THE TWIN  
TUNNELS INTERACTION IN KENNY HILL FORMATION RESIDUAL  
SOIL**

**ABSTRACT**

Numerical simulation for geotechnical problem often involved simplifications and assumptions as it is nearly impossible to simulate all features involved in the ground environment. For large scale construction like Klang Valley Mass Rapid Transit (KVMRT) twin tunnels construction under urban environment, realistic geotechnical simulation is essential. In this study, a parameters determination approach is developed to determine stiffness and strength parameters for Hardening Soil (HS) models based on evaluation of in-situ and laboratory soil testing data for the simulation of twin tunnels interaction in Kenny Hill Formation residual soil. Subsurface characterization conducted to develop three-dimensional (3D) ground models, tunnel filtered models and ground sections for four zones divided from study area based on similarity in lithology and Standard Penetration Test Blow Count (SPT-N) Value distribution. Three critical ground sections were selected based on input of tunnel filtered models and ground sections, twin tunnels configuration associated in respective sections and availability of tunnelling induced ground movement data. The soil profiles and corresponding soil parameters were determined for selected ground sections to develop conceptual model for finite element method (FEM) simulation of tunnelling induced deformation. The soil parameters for Kenny Hill residual soil were evaluated by comparing numerical simulated and in-situ monitored Pressuremeter test (PMT) stress strain curves. The HS model is calibrated by optimization of stiffness