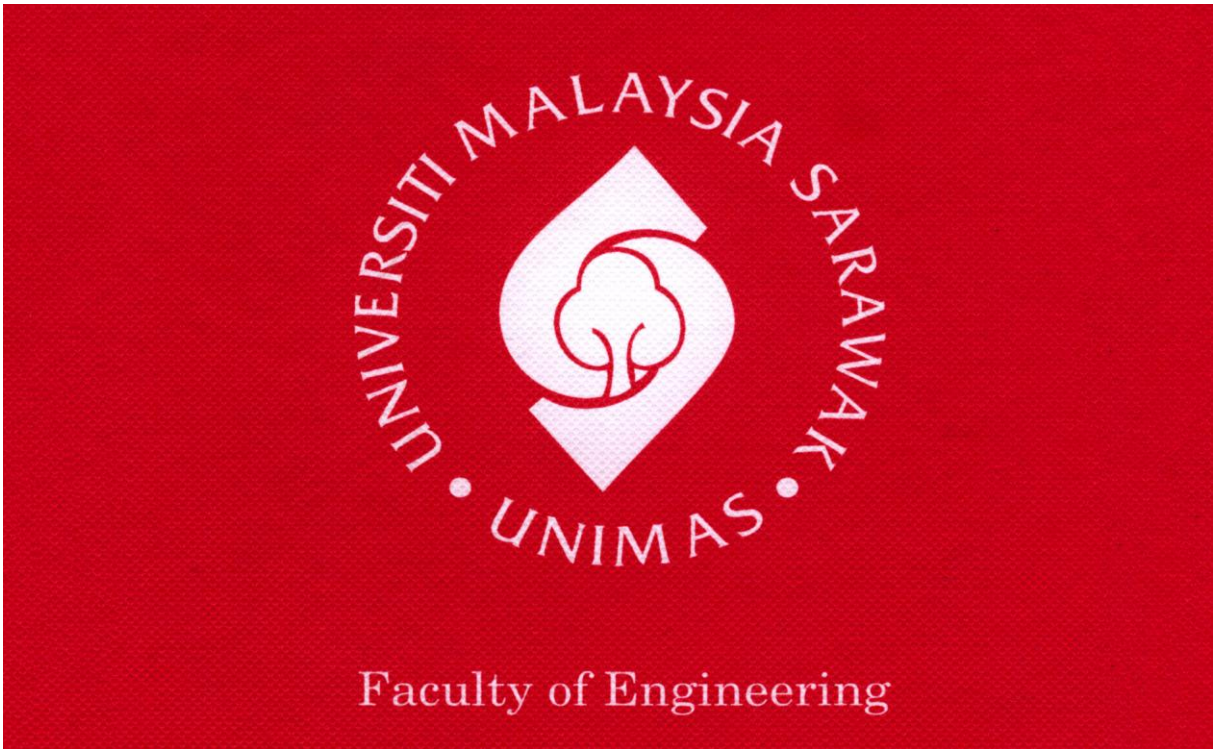

ARTIFICIAL NEURAL NETWORK (ANN) MODELING & VALIDATION TO PREDICT COMPRESSION INDEX OF TROPICAL SOFT SOIL

Shirley Yong Xiao Wei

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(Civil Engineering)
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Author : Shirley Yong Xiao Wei

Matrix Number : 17832

Was read and certified by:

_____ _____

Dr. Prabir K. Kolay Date

Project Supervisor

ARTIFICIAL NEURAL NETWORK (ANN) MODELING & VALIDATION TO PREDICT COMPRESSION INDEX OF TROPICAL SOFT SOIL

SHIRLEY YONG XIAO WEI

This project is submitted to
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I would like to dedicate this thesis to God, my family, and all who like to know more about soil settlement prediction by using Artificial Neural Network (ANN).

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ABSTRAK

Tanah lembut memendap apabila mengalami tekanan yang disebabkan kandungan air meningkat di mana kadungan tanah berkurang. Dengan ini, pelbagai jenis ramalan pemendapan telah difokuskan pada ujian-ujian in-situ, seperti Ujian Penembusan Kon (CPT), Ujian Penembusan Piawai (SPT), Ujian Modulus Dilatometer (DMT), Ujian Beban Plat, dan Ujian Meter Tekanan. Pada kajian ini, data *bore hole* telah dikumpul dari JKR, Kuching untuk digunakan meramalkan indeks pemendapan (C_c) daripada petempatan beberapa tanah lembik tropikal. ANN amat berpotensi dalam situasi di mana hubungan proses fizikal tersirat tidak difahami sepenuhnya dan disesuaikan dalam model sistem dinamik secara serta-merta. Ciri-ciri kemampatan tanah lembik boleh diramalkan dengan ANN, jika sifat-sifat fizikal tanah seperti kandungan kelembapan, graviti tentu, had cecair dan sebagainya telah diketahui. Kajian ini menunjukan perbandingan C_c secara konvensyen antara persamaan pemendapan Terzaghi dan ramalan C_c daripada ANN. Untuk tujuan ini, satu pengaturcaraan telah ditulis dengan menggunakan MATLAB 6.5 dan dilatih oleh lapan jenis latihan algoritma yang berbeza, iaitu Propagasi Balik Bingkas (rp), Kecerunan Konjugat Polak-Ribiére (cgp), Kecerunan Konjugat Skala (scg), Levenberg-Marquardt (lm), BFGS Quasi-Newton (bfg), Kecerunan Konjugat dengan permulaan semula Powell/Beale (cgb), Kecerunan Konjugat Fletcher-Powell (cgf), dan One-step Secant (oss) telah dibandingkan untuk ramalan C_c terbaik. Simulasi rangkaian yang menggunakan algoritma Propagasi Balik Bingkas (rp) menunjukkan keputusan yang lebih persis secara konsisten.

ABSTRACT

Soft soil due to high settlement when it subjected to certain stress, caused pore water pressure increase and finally reduced the volume of the soil mass. Therefore, many settlement prediction methods have focused on correlations with in-situ tests, such as the Cone Penetration Test (CPT), Standard Penetration Test (SPT), Dilatometer Modulus Test (DMT), plate load test, and pressure-meter test. In current study, bore hole data was collected from JKR, Kuching to train and validate the neural network for the prediction of settlement rather than compression index (Cc). Artificial Neural Network is the potential software that suitable to perform a kind of function fitting by using multiple parameters on existing information and predict the possible relationship of compressibility characteristics for the soft soil, if the physical properties of soil e.g., moisture content, specific gravity, liquid limit etc. are known. This study demonstrates the comparison between the conventional estimation of C_c by using Terzaghi's settlement equation and the predicted C_c from ANN. Therefore, a programming was written by using MATLAB 6.5 and train with eight different training algorithm, namely Resilient Backpropagation (rp), Conjugate Gradient Polak-Ribiére algorithm (cgp), Scale Conjugate Gradient (scg), Levenberg-Marquardt algorithm (lm), BFGS Quasi-Newton (bfg), Conjugate Gradient with Powell/Beale Restarts (cgb), Fletcher-Powell Conjugate Gradient (cgf), and One-step Secant (oss) have been compared for the best prediction of C_c. The result shows that the network trained with Resilient Backpropagation (rp) simulates the most accurate results of correlation coefficient, R and efficiency coefficient, E^2.

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LIST OF NOTATIONS

C_c	-	Compression index
σ'_{vm}	-	Maximum past pressure
w	-	Moisture content
G_s	-	Specific gravity
LL	-	Liquid Limit
S_c	-	Settlement due to primary consolidation
H_0	-	Initial thickness
e_0	-	Initial void ratio
σ'_{v0}	-	Initial vertical effective stress
$\Delta\ \sigma_v$	-	Increase in load
E	-	Global error
P	-	Total number of training patterns
E_p	-	Error for training pattern
N	-	Total number of output nodes
o_k	-	Network output at the *k*th output node
t_k	-	Target output at the *k*th output node
R	-	Coefficient of correlation
E^2	-	Coefficient of efficiency (Nash-Sutcliffe equation)

$\overline{Q_m}$ - Observed compression index

$\overline{Q_s}$ - Simulated compression index

PI - Plasticity index

CHAPTER 1

INTRODUCTION

1.1 Introduction

In general, soft soil's characteristics are very low shear strength, high compression, and excessive water content. Soft soil is due to high settlement when it subjected to certain stress, caused pore water pressure increase and finally reduced the volume of the soil mass. Structure due to impressed load on soft soil are subject to settlement. Some settlement is often inevitable, and depending on circumstances, some settlement is tolerable Therefore, it is important to acknowledge the knowledge of causes for settlement and means computing or predicting settlement quantitatively to geotechnical engineer in every kind of construction.

Basically, soft soil consists of clayey silt, consolidated clay and also peat soil, which has the big reserve in Sarawak and relatively under developed. However, there were quite a number of construction build on soft soil layer over the past many years. Dealing with this, if foundation is poorly designed, it could easily lead to the retaining structure's excessive lateral displacement, surface subsidence and the

surroundings, bottom uplift and others problem that may caused foundation failure. It probably will affect the stability and security of the foundation pit (Das, 2002).

The problem of settlement is significant when dealing with structures such as building, dam, roads, bridges, houses and other embankment construction on clay or peat soil. As mentioned above characteristics of soft soil, the structures may settle excessively both due to high compressibility and low shear strength. The settlement may take long time depending on the ability of the soil to dissipate the excess pore pressure induced by the construction (Das, 2002).

Clay is a naturally occurring material composed primarily of fine-grained minerals, which shows plasticity through a variable range of water content, and which can hardened when dried and or fired. Clay deposits are mostly composed of clay minerals which also named as phyllosilicate minerals, minerals which impart plasticity and harden when fired and or dried, and variable amounts of water trapped in the mineral structure by polar attraction. Organic materials which do not impart plasticity may also be a part of clay deposits.

Clay minerals are typically formed over long periods of time by the gradual chemical weathering of rocks by low concentrations of carbonic acid and other diluted solvents. These solvents are usually acidic and migrate through the weathering process, some clay minerals are form by hydrothermal activity. Clay

deposits may be formed in place as residual deposits, but thick deposits usually are formed as the result of a secondary sedimentary deposition process after it have been eroded and transported from their original location of formation. Clay deposits are typically associated with very low energy depositional environments such as large lake and marine deposits.

Meanwhile, peat is formed in a water-saturated environment from the accumulation of incompletely decomposed plant material. It is characterized by a high water retention capacity and a very high cation exchange capacity. Peat coagulant had a wide pH working range, however its optimum pH range was from 3 to 5 (alkaline) which contrast with clay pH value (Das, 2002).

1.2 Settlement Prediction Methods

There are numerous prediction method for the magnitude of consolidation settlement, these includes the conventional Terzaghi one dimensional theory, two dimensional Rendulic theory, Skempton-Bjerrum 3 dimensional, stress path, elastic theory, finite element and so on. Those theory are most used for compare with in-situ test, e.g., Cone Penetration Test (CPT), Standard Penetration Test (SPT), Piezocone penetration test (PCPT), Dilatometer Modulus Test (DMT), plate load test, pressure-meter test, as well as laboratory test such as Vacuum-Surcharge Consolidation Method which introduced by Kjellman and One –Dimensional

Laboratory Consolidation Test suggested by Terzaghi (Ling, 2007).

Abu Baker (1994) mentioned Asaoka method is use to predict the primary and secondary consolidation settlement using the procedure outlined by Magnan. Back calculated field *Cv* is also computed using Terzaghi curve fitting, square root time and Asaoka method. Skempton also proposed a settlement prediction method which based on statistical relationship between *Cc* and *LL* of soil. By using the observed settlement data many uncertainties regarding the variability of soil, magnitude and distribution of load can be minimize. Therefore, using the settlement data manage to give a good estimation of final settlement for practicing engineer.

Laboratory test on undisturbed saturated clay specimens can be conducted (ASTM D-2435) to predict the value of consolidation settlement caused by different additional loadings. For saturated cohesive soil, oedometer test (ASTM D 2435-96, 1998) which also known as one-dimensional consolidation in current laboratory company, can be conducted and get the compression index *Cc* value to calculate the value of settlement.

1.3 Basics of Artificial Neural Network (ANN)

Artificial Neural Network (ANN) is a potential software that are able to learn from example and generalize knowledge, where the underlying physical process relationships are not fully understood and well-suited in modeling dynamic systems on a real-time basis, for predicting the compressibility characteristics of the soft soil. The compressibility characteristics of the soft soil can be predicted by using ANN, if the physical properties of soil e.g., moisture content (w) specific gravity (G_s), Plasticity index ($P.I$) etc. are known. It will be much more convenient and economical as compared to laboratory consolidation tests for calculating the compression characteristics and predicting the settlement of tropical soil. Hence, in this paper an attempt has been made to predict the settlement of tropical soil by using ANN.

1.4 Objective of The Study

The objective of this study is to model and validate the prediction on compression index of Tropical soft soil by using Artificial Neural Network (ANN). Borehole data were collected from JKR, Kuching to train and validate the neural network for the prediction of compression index (Cc). To satisfy this study, a program will be written using MATLAB 6.5. The scope of the present study is as

follows:

(a) To train and validate the parameters that distributed towards C_c of soil.

(b) To simulate C_c by using the relevant parameters.

(c) To compare the exact or real with predicted C_c values.

(d) To compare different training algorithm e.g., Resilient Backpropagation (*trainrp*), Conjugate Gradient Polak-Ribiére algorithm (*traincgp*), Scale Conjugate Gradient (*trainscg*), Levenberg-Marquardt algorithm (*trainlm*), BFGS Quasi-Newton (*trainbfg*), Conjugate Gradient with Powell/Beale Restarts (*traincgb*), Fletcher-Powell Conjugate Gradient (*traincgf*), and One-step Secant (*trainoss*) and check the suitable training algorithm for the present study.

(e) To compare the effects of number of neurons towards the network.

(f) To compare the effects of different learning algorithm towards the network.

CHAPTER 2

LITERATURE REVIEW

2.1 General

Artificial neural networks (ANNs) are a form of artificial intelligence which attempt to mimic the function of the human brain and nervous system. It has been found to have ability to learn and generalize knowledge from sufficient data pairs which makes it possible to solve large-scale complex problem as it is well suited to modeling complex behavior of most of the geotechnical engineering material which, by their very nature, exhibit extreme variability. ANN have demonstrated superior predictive ability when compare with most traditional empirical and statistical methods, which need prior knowledge about the nature of the relationships among the data. By using ANNs, there is no need for making assumptions about what the underlying rules that govern the problem in hand could be.

McCulloch and Pitts (1943) were the persons who developed the first Artificial Neuron. However, it was not until psychologists David Rumelhart, of University of California at San Diego, and James McClelland, of Carnegie-Mellon

University, developed the backpropagation algorithm for training multi-layer perceptrons, that interest in ANNs flourished (Rumelhart et al., 1986 a, b; McClelland and Rumelhart 1988).

Since early 1990s, Artificial Neural Network (ANN) has been applied successfully to almost all the problems in geotechnical engineering and it is able to determine the relationship between a set of input data and the corresponding output data without the need for predefined mathematical equations between these data.

Lately, it is found that ANN is a strong tool for modeling many of the non-linear regression models. ANN is suitable to perform a kind of function fitting by using multiple parameters on the existing information and predict the possible relationships in the coming future, if some of the physical variables are known, without knowing the exact relationships. This sort of problem included predict the friction capacity of piles in clays, prediction of settlement of a vertically loaded pile foundation, prediction of soil properties and behavior, prediction of liquefaction potential, predict the site characterization, estimates of maximum wall deflections for braced excavations in soft clay, evaluating the stability of slopes and prediction of settlements of tunnels.

Various studies from different countries have been done on application of ANN software. This chapter reviews study of definition and different types of ANN