GEOTECHNICAL ENGINEERING

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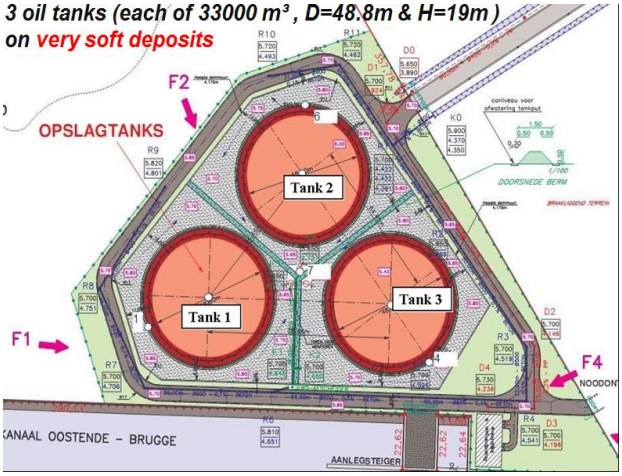
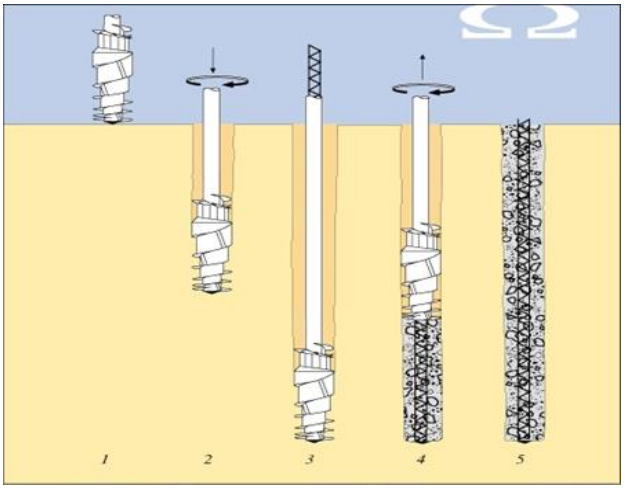
EDITORS: MADHAVI LATHA & MURALI KRISHNA

Prof Madhira Madhav Honoured with Special Issue March 2018 of SEAGS-AGSSEA Journal





Pile design and group behaviour: a case study of large tank foundations in soft soil conditions (After W.F. Van Impe, P.O. Van Impe and A. Manzotti, 2018)

GEOTECHNICAL ENGINEERING

March 2018 Issue to Honour Prof Madhira Madhav

For his Contributions in Geotechnics through Indian Geotechnical Society, ISSMGE and Universities in IIT Kanpur, IIT Bangalore, Saga etc

Prof. M.R.Madhav, Visiting Professor, IIT, Hyderabad, Professor Emeritus, J.N.T.U, Hyderabad, Resource Person, Rajiv Gandhi University of Knowledge Technology, Chairman, Research Council, CSIR-CRRI, and Advisor/Consultant to Energy Infratech, Halcrow, KSK Infra, etc., retired as Professor of Civil Engineering, IIT, Kanpur. He graduated in Civil Engineering from Andhra University in 1960, obtained the Master of Engineering and the Doctorate of Philosophy degrees from the Indian Institute of Science, Bangalore in the years 1961 and 1967 respectively. Prof. Madhav worked at several universities - Sydney, Australia; Concordia, Canada, Saga, Saga, Japan; Ghent, Belgium, Queen's, Belfast, etc.. He was an Associate at the International Center for Theoretical Physics, Trieste, Italy, Vice President for Asia, International Society of Soil Mechanics & Geotechnical Engineering, advisor to Navi Mumbai SEZ, CRRI, New Delhi.

Prof. Madhav's research interests span the whole gamut of Geotechnical Engineering. He guided more than 45 doctoral and several master's theses and final year projects. He co-edited books entitled 'Lowlands - Development and Management' and on 'Foundations and Soft Ground Engineering Challenges in Mekong Delta, and authored more than 500 publications in refereed international and national journals and conferences.

Prof Madhav is well known internationally as a researcher, teacher and consultant. He established schools of research at IIT, Kanpur, and JNTU, Hyderabad in Geotechnical Engineering, was associated closely in developing the schools of research at the Institute of Lowland Technology, Saga and IIT, Hyderabad. His work on Modelling and Numerical Analyses of Geotechnical and Ground Engineering Problems is monumental. He has contributed to the Practice of Geotechnical Engineering as a Consultant and to the Indian Geotechnical Society as a Member of the Executive Committee, as a Reviewer for and Editor of the Indian Geotechnical Journal and as President.

Prof. Madhav delivered Keynote/Plenary Lectures, Chaired Technical Sessions in several International and National Conferences, was a Panelist in the XIII, XV and XVI International Conferences on Soil Mechanics and Geotechnical Engineering at New Delhi (1994), Istanbul (2001) and Osaka (2005). He delivered the prestigious Annual Lecture of the IGS, Keynote Lecture at the 12th Asian Regional Conference at Singapore, the Inaugural Miura Lecture at Busan, etc. He is Life Fellow of the Indian National Academy of Engineering, the Indian Geotechnical Society, The Institution of Engineers (India), etc. He is recipient of the Keucklemann Award of the IGS, the Prof. Mehra Research Award of the University of Roorkee, Pundit Jawaharlal Nehru Birth Centenary Research Award of CBIP, the Doctor of Science degree of the Indian Institute of Science, Distinction in Engineering Technology from the Central Board of Irrigation and Power, IGS – Prof. Dinesh Mohan Prize, etc. He was the President of IGS, and the Vice President for Asia of ISSMGE, the Vice President (1998-2010) and currently (2010 onwards) the President of the International Association of Lowland Technology. He has been awarded the Honorary Fellowship and Diamond Jubilee Honour by the Indian Geotechnical Society. He received the prestigious Bharat Ratna M Visweswaraya Award by Government of AP & Institution of Engineers

(I) AP State Centre, Gopal Ranjan Research award of IIT, Roorkee for Innovative and Outstanding Research, Outstanding Researcher Award from IANAMG, IGS-MS Jain Prize for Innovations in Piling, Vishwakarma Award for Academic Excellence from Construction Industry Development Council, IGS – H C Verma Diamond Jubilee Award for Innovative Instrument Design, the Distinguished Alumnus Award from the Indian Institute of Science, Bangalore in August 2014 (the second graduate from Civil Engineering) and the Prof. Dinesh Mohan Award for Excellence in Geotechnical Practice, etc. and delivered the most prestigious IGS-Ferroco Terzaghi Oration. Most recently, Prof. Madhav delivered the first Victor de Mello Goa lecture. Prof. Madhav pursues Origami as his hobby.

GEOTECHNICAL ENGINEERING

March 2018: Guest Editors

Edited by: Madhavi Latha & Murali Krishna

Madhavi Latha

Madhavi Latha is a Professor at IISc, Bangalore. She obtained her Ph.D. degree from IIT Madras. Prior to joining IISc in 2003, she was an Assistant Professor at IIT Guwahati for a year. Her research areas include geosynthetics, earthquake geotechnical engineering and rock engineering. She has so far supervised 10 Ph.D. students and published more than 150 technical papers. She is one of the geotechnical consultants for the world's highest railway bridge being constructed in Jammu, India. She is a member of ISSMGE Technical Committee on soil structure interaction and retaining walls and IGS Technical Committee on soil reinforcement. She is currently the Editor-in-chief of the Indian Geotechnical Journal.

Murali Krishna

Dr. A. Murali Krishna is a faculty member in Department of Civil Engineering at Indian Institute of Technology (IIT) Guwahati, since 2008. He obtained Doctoral degree from Indian Institute of Science Bangalore for his Ph. D work on "Shaking table tests on Geosynthetic reinforced soil retaining walls". He received his M.Tech degree from IIT Kanpur and B.Tech degree from Sri Venkateswara University, Tirupati. His research interests include: Earthquake Geotechnics, Geosynthetics and Ground Improvement, Site characterization and Numerical and Physical modelling of geotechnical structures. Dr. Murali Krishna supervised 4 Doctoral students and 20 Masters Students. He co-authored nearly 150 publications of technical papers in International/National Journals and Conference/Seminar Proceedings including book chapters. He is a recipient of BRNS Young Scientist Research award, BOYSCAST fellowship and HERTAGE fellowship. Dr. Murali Krishna is currently serving as an 'Executive Member' of the IGS and Member of TC 203 of ISSMGE, since 2011. He is the executive member of ISRM (India) and ISET. Dr. Murali Krishna organised national and international workshops and short courses. He is a reviewer for several national and international journals.

Preface

This Issue contains sixteen papers, the first ten was acquired by Profs Madhavi Latha and Murali Krishna to honour Prof Madhira Madhav and the other six are directly contributed papers to our Journal Office.

The first paper is by Harry G. Poulos on Rational Assessment of Modulus of Subgrade Reaction: The concept of modulus of subgrade reaction has been employed within the engineering world for almost 150 years. It has been especially embraced by structural engineers who have found it convenient to represent the behaviour of the ground supporting their structures by elastic springs. Despite the best efforts of the geotechnical profession to dissuade our structural colleagues from using this flawed concept in foundation design, requests to provide a modulus of subgrade reaction continue almost unabated. Given this situation, a suitable response is to provide such values via a rational process of evaluation, rather than by empirical correlations which have little theoretical basis and which may not be applicable to the foundation being considered.

This paper sets out an approach to the estimation of values of modulus of subgrade reaction for various types of foundation. The key points made are that the modulus of subgrade reaction (k) is not a fundamental soil property, but varies with the foundation type, foundation dimension, and type of loading. k can be related to the Young's modulus of the supporting soil and to the foundation dimensions, but for pile groups, account must be taken of the reduction in k because of group effects arising from pile-soil-pile interaction. It is also emphasized that careful distinction must be made between the modulus of subgrade reaction, k, and the spring stiffness K.

The second paper is by S**.** Basack, B. Indraratna and C. Rujikiatkamjorn on Effectiveness of Stone Column Reinforcement for Stabilizing Soft Ground with Reference to Transport Infrastructure: The use of stone columns for soft soil stabilization has numerous advantages compared to other methods. There are many factors controlling performance of stone columns including column geometry and particle morphology. The reinforced soft ground supporting transport infrastructure like the railways and highways is subjected to cyclic loading, usually initiating a partially drained condition. The study reveals that the stone columns are more effective in mitigating the built up of cyclic excess pore water pressure compared to conventional vertical drains. This paper presents a brief overview on the rigorous theoretical and experimental studies carried out by the Authors to investigate the effectiveness of stone column reinforcement for stabilizing soft ground with particular reference to transport infrastructure.

The third paper on Pile design and group behavior; a case study of large tank foundations in soft soil conditions is by W.F. Van Impe, P.O. Van Impe and A. Manzotti: The paper presents the case study on the construction of three 48m diameter oil tanks in Ostend (Belgium), each founded on a group of 422 displacement cast in-situ screw piles. The three tanks are close enough to each other to induce interaction. Monitoring of the tanks' movements has been performed during the hydro-testing of the steel tanks and during the subsequent working stage of the tanks. The bearing layer of the pile group is a 5m thick stiff sand layer at a depth of about 20m, overlain by a very heterogeneous soft clayey/silty fill containing sand pockets, and underlain by very thick slightly over-consolidated clay. Some short and long term settlement prediction of the tanks have been done, assuming soil parameters derived from the CPT data on site, and compared to the measured settlements. The initially derived soil parameters are then re-evaluated in order to predict the long term settlement for the full life span of the construction.

The fourth paper is by V Sivakumar on Granular Columns for Geotechnical Applications: Soft clay deposits are globally widespread and often coincide with strategic transport links and growing urban developments. These soft deposits are often waterlogged and are composed of clay with varying degrees of silt, sand and organic matter. These soils have low undrained shear strength and high compressibility, contributing to construction

problems in relation to stability and settlement. Granular columns, also referred to as flexible piles, are one of the techniques widely considered in the industry for improving soft deposits for low-moderate structural loading. The purpose of this article is to highlight some of the key investigations carried out in the topic of granular columns at Queen's University Belfast, the UK.

The investigations focused on several aspects: (a) the interaction between columns and surrounding clay (b) containment of columns in geo-grid for enhanced strength performance (c) settlement performance under single or multiple column configuration (d) stress distribution under the footing and along the column (e) assessment of consolidation and creep settlement under constant loading and (f) granular columns for anchoring purposes and therefore stabilization of slopes. Overall observations are: settlement improvement factors were moderate under isolated loading, but granular columns are very effective in providing pull-out capacity in the form of anchors.

The paper entitled Ground Engineering Using Prefabricated Vertical Drains: A Review is the fifth paper by V.A. Sakleshpur, M. Prezzi, and R. Salgado: Improvement of soft ground by preloading with prefabricated vertical drains (PVDs) is a common practice in the field of ground engineering. PVDs accelerate the consolidation process of soft soils by providing a shorter drainage path for the pore water and thereby increase the strength and stiffness of soft soils over time. This paper presents a review of recent analytical, laboratory, numerical and field studies performed using preloading with PVDs for improvement of soft ground. The focus of the paper is on conventional PVDs without the use of vacuum, thermal and electro-osmosis techniques. Summary tables, which provide quick and easy access to the latest information from various research efforts, have been prepared and discussed. The review is complemented by two case histories that highlight the performance of PVDs in the field.

The sixth paper is on Soil Reinforcement under Oblique Pull- An updated Discretization by S Patra & J.T. Shahu: Reinforced soil structures are gaining popularity for a variety of reasons mainly because it is safe, economical, aesthetic and rapid in constructions. However, the actual behaviour of these structures at failure is still not properly understood. The present study attempts to evaluate the internal stability of these structures against pullout failure. Kinematics of failure suggests that the failure surface intersects the reinforcement obliquely causing an oblique pullout of the reinforcement. In this paper, an updated discretization technique is used to determine the pullout capacity of an inextensible reinforcement resting on a linear elastic Pasternak subgrade and subjected to an oblique end force. A parametric study is conducted and a new factor, length correction factor is introduced in the present analysis. The correction factors have a significant influence on the pullout response especially for high values of obliquity and end displacement. Present analysis thus gives a more realistic value of pull out capacity which is required for the internal stability analysis and design of reinforced soil structures. A case study is also presented to validate the proposed analysis. The maximum reinforcement tension is predicted for top few reinforcements using the proposed method and the AASHTO Simplified Method. The present analysis gives a better prediction of the mobilized reinforcement tension compared to the AASHTO method.

The paper by Madhavi Latha G and Manju G. S. is the seventh paper on Effect of Facing Slope on the seismic response of Geocell Walls: This paper presents the effect of slope angle of facing on the seismic response of retaining walls with geocell facing. Keeping the dimensions and configuration of geocell layer same, shaking table model tests were carried out with vertical and battered walls retaining sand backfill. In case of battered walls, geocell layers were laid with an offset, resulting in an overall slope of the wall. Vertical walls were constructed with geocell layers stacked vertically above each other. Gravel was used as infill material in geocells. Models were subjected to different levels of ground motion conditions by controlling the acceleration and frequency of shaking. Acceleration amplitudes of 0.2g and 0.3g with frequencies ranging between 1 Hz and 7 Hz were used in the model tests. Response of models was monitored with cyclic shaking at intended acceleration and frequency by measuring the face deformations and acceleration amplifications along the height

of the retaining wall, Results from model tests showed that battered walls perform better than the vertical walls since the measured deformations and acceleration amplifications were comparatively low in battered walls. The improved performance of battered walls is due to the increased stiffness and increase in dynamic impedance caused due to shifting of moment of inertia of pressure distribution at the back of the wall in case of walls battered towards the backfill.

The eighth paper is on Evaluation of Resilient Modulus of Geosynthetic Reinforced Layers Using Repeated Load Triaxial Tests by Sudheer S Prabhu, Lekshmi Suku and G L Sivakumar Babu: The stiffness and strength of the pavement layers are the major parameters that influence the design of highway pavements which in turn decides the thickness of various pavement layers. Studies have shown that the thickness of the base layer plays a crucial role in limiting the rutting of the in situ subgrade soil. Due to the lack of availability of aggregates, there is a dire need to minimize the thickness of the base. Geosynthetics in the form of geogrid and geocell have long been used for reinforcing unbound base/subbase layers in paved and unpaved roads and have been found to be effective in reducing the base thickness. A few laboratory studies have been conducted to evaluate the different aspects of geosynthetic reinforced base layers, and further studies are required to examine the behavior of these reinforced sections under elastic and plastic shake down range. The purpose of the current study is to evaluate and compare the resilient modulus of geogrid reinforced, geocell reinforced and the unreinforced granular base under repeated loading using the Repeated Load Triaxial tests. The response of aggregate under repeated loading expressed in terms of resilient modulus is a key parameter in the new Mechanistic Empirical Pavement Design Guide (MEPDG). The permanent strains of aggregates are also compared in the study to get an overall idea about the reinforcement effect in the granular base.

The paper by Ritwik Nandi and Deepankar Choudhury is the ninth paper on Seismic Analysis of Reinforced Soil Wall Considering Oblique Pullout of Reinforcements: A Review: Several methods are available for stability analysis of reinforced soil structures. However, most of these methods mainly concentrated on the horizontal pullout of the reinforcement in spite of the evidences available that show the failure surface of reinforced soil structure will always intersect reinforcement layers diagonally due to the failure kinematics. It will cause oblique/transverse deformation to reinforcements across the failure surface. In the present paper, state-of-the-art review of earthquake stability analysis of reinforced soil-wall by employing the oblique/transverse pull of reinforcements is discussed. Formulations that are developed in various studies to determine the mobilization of diagonal pullout resistance of reinforcements, the amount of drag force triggered in the reinforcement sheets due to instability in the structure and the factor of safety against pullout are presented. A comparative study is also carried out between existing models and methods that are used in determining the seismic stability of reinforced soil structure subjected to diagonal pullout of soil reinforcements. The comparative study shows the effect of various models and methods on the factor of safety against reinforced soil-wall stability and the influence of different parameters i.e., horizontal seismic acceleration, internal friction angle of soil, interface friction angle of soil and reinforcement, relative subgrade stiffness factor etc. Depending on the model used in analyses, the computed factor of safety may vary significantly.

The tenth paper is by Nevin Koshy, S. U. Sushalekshmi, Susmita Sharma, Jeevan Joseph, Vikas, D. N. Singh, Bhagwanjee Jha and M. Singh on Characterization of the Soil Samples from the Lonar Crater, India: The Lonar crater and its enclosed lake have been a universally recognized young and well preserved meteoritic formation in the state of Maharashtra, India. Previous studies on the uniqueness (salty and alkaline nature) of sediments (the crater soil) and the lake water, hint at its creation by meteor impact and post-impact induced hydrothermal interaction between the meteor and the then earth surface in the region. Also, the earlier reports confirm the sediments as basaltic rock, in nature. However, not many efforts have been made by the present generation of researchers for detailed chemical and mineralogical characterization of the sediments, which may reveal an analogue relationship between the crater sediments and a meteor (the lunar or the Martian soil) from the space. In this context, the present study attempts to understand the characteristics of the soil samples extracted from the crater region, with respect to their physical, chemical, mineralogical, electrical and magnetic properties. The

findings also shed light into the response of the crater samples when subjected to different energy fields (viz., mechanical, chemical, electrical and X-rays). Based on a critical synthesis of the results, the characteristics (viz., alkalinity, saltiness, geological-structural properties, water-sediment interaction) of the sediments have been showcased and evaluated for their partial conformity with extraterrestrial objects (i.e., the meteors).

The eleventh paper by J. Jayapal & K. Rajakopal is on Encased Columnar Inclusions in Soft Grounds - A Review: Even before the evolution of soil mechanics, the research on mitigating the problems induced by soft soils has started. The granular column is one of the promising ground improvement technique widely accepted as a solution to soft soil problems all over the world. Recently the performance of it is improved by encasing with geosynthetic products like geogrid and geotextiles. This paper gives an insight into the technical aspects of encased granular columns by reviewing the advancements that have happened in the published literature. The focus of this paper is more on the problems associated with soft clay deposits, although granular columns can also be employed to mitigate liquefaction in saturated loose sand deposits. Discussions on the key technical aspects associated with encased granular columns and its applicability in the field are provided.

The twelfth paper by P. A. Faby Mole, S. Sireeshand M. R. Madhav on Influence of Shear Stiffness of Geocell Mattress on the Performance of Strip Footings- A Numerical Study**:** A modified Pasternak model was proposed to predict the behaviour of a strip footing resting on a geocell reinforced granular layer overlying weak soil, especially considering the variation of shear stiffness of the geocell mattress. Both linear and nonlinear responses of the geocell reinforced beds were considered in the analysis. Results from the present model were validated with independent experimental load-deformation responses. The model parameters viz. inverse of normalized shear stiffness of the geocell and inverse of normalized ultimate bearing capacity of foundation soil were varied for the parametric study. It was found that the shear stiffness of the reinforced granular bed i.e. the product of shear modulus and the height of the geocell reinforced granular bed plays an important role in improving the performance of the foundation system. Design charts are presented in the form of improvement factors for the practical range of shear layer width, shear stiffness of the geocell reinforcement and ultimate bearing capacity of the soft soil**.**

The thirteenth paper is on Interference of Two Closely-Spaced Footings on Finite Sand Layer by Macharam Rohith, Sasanka Mouli, and Umashankar Balunaini: Bearing capacity of footing is influenced by the presence of adjacent footing. In this study, two closely-spaced strips, square, and circular footings are modelled in finite elements using commercially available software - PLAXIS 2D and 3D. Analysis is done considering both smooth and rough footing bases. The effect of spacing between the footings is examined for footings resting on both semi-infinite and finite sand layers. In addition, angle of shearing resistance of foundation soil is varied from 30° to 40° to investigate its effect on the bearing capacity. Bearing capacity of footings with rough base are found to attain a peak value at a particular spacing indicating the “blocking effect”. For square and circular footings, interference due to spacing is found to be insignificant compared to strip footing. Interference factors for rough footings are found to be higher than that for smooth footings.

The fourteenth paper on Stone Columns/Granular Piles for Improving Liquefiable Sites: Case studies are by A. Murali Krishna, A. Madan Kumar, Utpal Kr. Baruah: Liquefaction is considered as a major hazard among different seismic risks. Ground improvement methods are commonly adopted to improve the liquefiable sites. The paper presents various aspects of liquefaction mitigation strategies to be implemented for liquefaction susceptible sites with focus on granular inclusions. A short discussion on liquefaction susceptible soils and its evaluation followed by outlines of the ground engineering applications is presented herein. Mechanisms that function at sites treated with stone columns/granular piles for liquefaction mitigation are discussed. Design aspects of granular piles for liquefaction mitigation are outlined. Few case studies, wherein stone columns have been adopted for improving the liquefiable sites, are presented. The paper concludes and highlights the effectiveness of granular inclusions in improving the liquefiable sites through various mechanisms.

The paper on Biogeotechnological Methods for Mitigation of Liquefaction is the fifteenth by S. Wu, B. Li, J. He and J. Chu: Liquefaction of granular soils during earthquake has long been identified as one of the major geohazards. Conventional soil improvement methods for mitigating liquefaction such as dynamic compaction or deep mixing are costly for large-scale applications. Recently some biological processes have shown significant influence on both the physical and chemical performance of geotechnical systems. Two types of biogeotechnological methods, biocementation and biogas desaturation, have been experimentally examined in this study. For the former, a microbial induced carbonate precipitation (MICP) process has turned one cubic meter of loose sand into sandstone-like material. The shear strength of the sand is greatly improved whereas the permeability is reduced at the same time. For the later, tiny inert gas bubbles are generated microbiologically within liquefaction prone ground to increase the resistance of sand to liquefaction. A series of shaking table model tests on biogas treated sand have demonstrated that this biogas desaturation method is effective for reducing pore pressure generation and shaking induced settlement during cyclic loading. When the degree of saturation of the soil is controlled to be around 90%, the generation of pore pressure in sand and the potential for liquefaction could be largely contained.

The last paper in this issue is the sixteenth paper on A Critical and Comparative Study on 2D and 3D Analyses of Raft and Piled Raft Foundations by V. Balakumar, Min Huang, Erwin Oh and A. S. Balasubramaniam: The piled raft foundation has gained a very high level of acceptance as a foundation system whenever settlement alone governs the design. In the design of piled raft many of the traditional methods could not be applied due to the complex nature of interactions involved. Hence there is a need to use detailed three dimensional finite element analyses for the final design. But in the initial stages of design a simpler but effective analytical process need to be used to save the computational efforts. Since the primary requirement in the piled raft design is the design of optimum pile group to achieve the desired settlement reduction, through number of trials, the applicability of simpler two dimensional analyses are examined to save the computational efforts during the initial trials. It was found that simple two dimensional analyses provide results of acceptable accuracy for the design office requirements.

Madhavi Latha
Murali Krishna

ACKNOWLEDGEMENTS

Sixteen papers are contained in this issue. The first ten was acquired by Profs Madhavi Latha and Murali Krishna to honour Prof Madhira Madhav and the other six are directly contributed papers to our Journal Office. No doubt the material contained herein would be most valuable to our profession. The editors have adequately described the contributions in the preface. They are to be congratulated for these contributions.

Dr. Teik Aun Ooi
Prof. San Shyan Lin
Prof. Kwet Yew Yong
Dr. Noppadol Phienwej
Prof. A. S. Balasubramaniam

GEOTECHNICAL ENGINEERING

March 2018: Issue to Honour Prof M. R. Madhav for his Contributions in Geotechnics Through Indian Geotechnical Society, ISSMGE and Universities in IIT Kanpur, IIT Bangalore, Saga etc.

Edited by:
Madhavi Latha & Murali Krishna

TABLE OF CONTENTS

List of Papers **Page**

Cover Photographs

1. Pile design and group behaviour: a case study of large tank foundations in soft soil conditions
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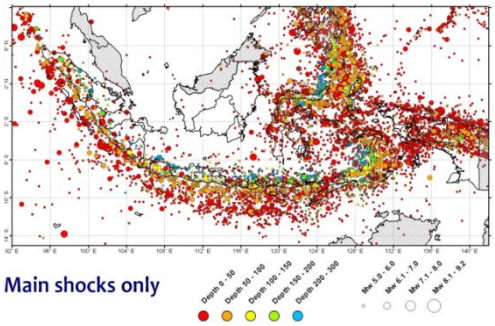

Figure 1: Proposed Design Guideline of Dynamic Compaction for Practicing Engineers (After Tjie-Liong GOUW, 2018)

Figure 2: Recent Development on Soft Ground Tunnelling (After Mitsutaka Sugimoto, Hideyuki Tanaka, Ngoc Thi Huynh, Salisa Chaiyaput, Le Gia Lam, and Jian Chen, 2018)

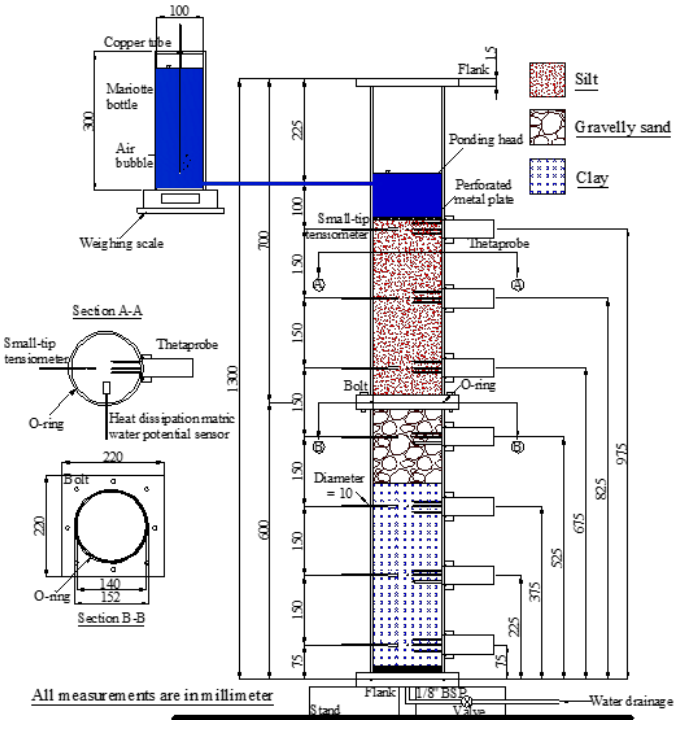

Figure 9: Schematic diagram of the soil column: State-of-the-Art Research in Geo-energy and Geo-environmental Engineering: Energy Pile and Earthen Capillary Landfill Cover System (After Charles W.W. Ng, Jason L. Coo & Anthony Gunawan,2018)

GEOTECHNICAL ENGINEERING

June 2018: Part 1 papers of SEAGS 50th Anniversary

Edited by: NOPPADOL PHIENWEJ, SUTTISAK SORALUMP, APINITI JOTISANKASA, SUCHED LIKITLERSUANG AND TIRAWAT BOONYATEE

Dr. Noppadol Phienwej

Dr. Noppadol was an Associate Professor in Geotechnical and Earth Resources Engineering in AIT's School of Engineering and Technology (SET).He became SEAGS President in May 2016. Prior to taking over as President, Dr. Noppadol was serving as Honorary Secretary General of SEAGS. Other AIT faculty members who have served as Secretary General of the Society include Dr. John Nelson (1970-1973), Prof. A.S. Balasubramaniam 1972-2000), and Prof. D.T. Bergado (2000-2013). Prof. Balasubramaniam has also served as President from 1985 – 1987. AIT's association with SEAGS stems back from 1967, when the Society was founded at AIT Bangkok by Dr Za-Chieh Moh, a former AIT faculty member, to cover Thailand, Malaysia, Singapore, Hong Kong and Taiwan and other societies in Asia. With a membership of over 200, the Society members are active in soil mechanics and foundation engineering, engineering geology, rock mechanics and geosynthetic engineering.

Dr Suttisak Soralump

Dr Suttisak Soralump is currently an Associate Professor at Kasetsart University in Bangkok, Thailand. He is also the President of the Thai Geotechnical Society. An Alumnus of Chulalongkorn University in 1994, he is also a Distinguished AIT Alumnus who received his Doctoral Degree from Utah State University in 2001. Dr Suttisak has wide range of Geotechnical Engineering interest and these include: ground improvement techniques, risk assessment and analysis of dams, dam engineering, probabilistic analyses, as well as field and laboratory testings. Dr Suttisak is an active geotechnical consultant in Thailand and under his leadership; the Thai Geotechnical Society has arranged conferences, symposia and courses. The Annual Thai Geotechnical Conferences are worthy of praise.

Prof. Suched Likitlersuang

Prof Suched Likitlersuang is currently a full professor at the Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University. He joined the Department of Civil Engineering at Chulalongkorn University as a lecturer (2004-2006), as an assistant professor (2006-2009) and as an associate professor (2009-2011). He was promoted to full professorship in 2011. He is also the founder of the Geotechnical Research Unit, which came into being in early 2016. His research interests include constitutive modeling for geomaterial, stress-strain characteristic of soils, numerical analysis in geomechanics, pavement engineering, geoenvironments, geotechnical earthquake engineering and soil bioengineering. He has supervised 24 Master and 10 Ph.D. students. He has published over 80 articles in international conference proceedings and international journals. Suched Likitlersuang was born in Bangkok. He graduated with a bachelor degree in civil engineering from Chulalongkorn University in 1998 and received a master degree in geotechnical engineering from Asian Institute of Technology in 2000. He obtained a doctorate in civil engineering from the University of Oxford in 2004.

His contributions through research to innovative design and construction practices in geotechnical engineering and problematic ground improvement have been widely recognized. He received many research grants from national and international agencies. Recently, his works have moved closer to industrial needs by collaborating with the private and non-governmental sector in the implementation of innovative research-based solution. He is a member of the Thai Geotechnical Society and the Engineering Institute of Thailand. He is also an Editorial Board member of Geotechnical Research and serves as Editor of the Southeast Asian Geotechnical Society Journal. He has also served as a reviewer in many reputable journals.

Dr. Apiniti Jotisankasa

Dr. Apiniti Jotisankasa is currently an Associate Professor at Department of Civil Engineering, Kasestsart University Bangkok. After obtaining his BEng degree in Civil Engineering from Kasetsart University in 1999, he pursued his MSc and PhD in Soil Mechanics at Imperial College London with the generous support of the Anandamahidol Scholarship from Thailand. His research topics were the Collapse behaviour of compacted silty clay.

Since 2005, he focused his research activities on application of unsaturated soil mechanics on practical geotechnical engineering problems, such as rainfall-induced landslide, excavation, embankment stability, bio-slope engineering, geohazard mitigation, as well as other issues such as energy piles, tree stability, and geophysics investigation for tree root architecture. He and his team has been developing a system for monitoring slope behaviour such as suction, pore water pressure, slope movement and earth pressure. Dr. Apiniti is the recipient of the best paper award (Geotechnical Engineering) in the National Convention in Civil Engineering twice in 2009 and 2012 from the Thai Geotechnical Society and Chai Mukthabhan foundation for his comprehensive works on the behaviour of slopes subject to rainfall.

In 2011, he was awarded the Young Technologist Award from the Foundation for the Promotion of Science and Technology under the Patronage of His Majesty the King of Thailand. Dr. Apiniti has been international Secretary General of the Thai Geotechnical Society since 2009 and currently a member of the TC106 (Unsaturated soils) of the International Society of Soil Mechanics and Geotechnical Engineering. Currently; he is a committee member of the Chaipattana Foundation working on the project on landslide hazard mitigation by the use of vegetation and engineering methods.

Dr. Apiniti was a conference secretary of the 5th Asia-Pacific conference on unsaturated soil in 2012 and the 50th anniversary symposium of SEAGS in 2017. Currently, he serves as an editorial board member of Soils and Foundations Journal of the Japanese Geotechnical Society and International Journal of Geosynthetics and Ground Engineering, Springer.

Dr Tirawat Boonyatee

Dr. Tirawat Boonyatee is currently an Associate Professor in Geotechnical Engineering at the Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University. He obtained his B.Eng. (Civil Engineering) at Chulalongkorn University, Thailand, in 1995 and furthers his studies at Kyoto University, Japan where he obtained his M.Eng. (Civil Engineering) in 1998 and D.Eng. (Civil Engineering) in 2001respectively. Dr Tirawat Boonyatee is a committee member of Subcommittee on Geotechnical in Civil Engineering Committee of The Engineering Institute of Thailand Under H.M. The King's Patronage.

PREFACE

This volume contains 20 papers from invited authors from SEAGS-AGSSEA member countries, Japan, Korea, India and elsewhere.

1. The first paper by Charles W.W. Ng, Jason L. Coo & Anthony Gunawan deals with "State-of-the-Art Research in Geo-energy and Geo-environmental Engineering: Energy Pile and Earthen Capillary Landfill Cover System". Geo-energy and geo-environment are two branches of geotechnical engineering representing current and future grant challenges because of the pressing need to conserve energy and protect the environment. The Hong Kong University of Science and Technology has been actively seeking solutions to these two challenges. The first part (geo-energy) of this paper describes a series of novel cyclic heating and cooling centrifuge tests performed on replacement and displacement floating energy piles installed in both saturated sand and clay. The test results reveal that replacement floating energy piles exhibit ratcheting settlement under a constant working load but at a reducing rate when subjected to temperature cycles, irrespective of the type of soil in which they are embedded. On the contrary, displacement floating energy piles exhibit heave behaviour. No existing theoretical model can capture observed ratcheting pile settlement well. This suggests that care must be taken when designing replacement floating energy piles. In the second part (geo-environment) of the paper, a novel three-layer environmentally friendly earthen cover system for climate regions like Thailand, Indonesia, the Philippines, Malaysia and Singapore is investigated through theoretical examination, physical modelling (e.g., one-dimensional soil column and two dimensional large flume tests), and advanced numerical simulations. This novel cover system consists of a fine-grained soil underneath a conventional two-layer cover with capillary barrier effects. Two-dimensional water infiltration experiments and numerical simulations show that the newly introduced fine-grained soil layer can greatly minimize rainfall infiltration even after a 4-h rainfall event having a return period of 100 years in climate regions. One-dimensional gas emission tests and numerical simulations reveal that a minimum of 0.6 m thick fine grained soil layer compacted at 10% saturation (e.g. those in arid regions) can adequately satisfy the Australian guidelines. No geomembrane is needed. This new environmentally friendly and robust earthen landfill cover system is thus a promising alternative to other landfill covers for minimizing rainfall infiltration and landfill gas emission under all kinds of weather conditions.

2. Yin & Feng in the second paper deal with the "validation of a new simplified Hypothesis B method for calculating consolidation settlement of clayey soils exhibiting creep". This paper introduces a new simplified Hypothesis B method for calculating consolidation settlement of clayey soils exhibiting creep. The general equations of the new simplified Hypothesis B method are presented and explained first. After this, four different cases are used to examine the validation of this new method. The first case is a single layer of clay with test data. Two fully coupled finite element (FE) programs, the new method, and Hypothesis A method are used to calculate the consolidation settlements of the clay which are compared with test data. The second case is one layer of Hong Kong Marine Deposits (HKMD) with four different over-consolidation ratios. Again, the two FE programs, the new method, and Hypothesis A method are used to calculate the consolidation settlements of the HKMD with results compared and relative errors obtained. The third case is two layers of soils: one is HKMD and the other is Alluvium. One commercial FE program, the new method, and Hypothesis A method are used to calculate the consolidation settlements of this two-layer system. Two methods for determining the average degree of consolidation of the two layers are used in the new simplified method. All results in this case are compared with relative errors obtained. The fourth case is one layer of Hong Kong Marine Deposits (HKMD) with vertical drain. The commercial FE program, the new method, and Hypothesis A method are used to calculate the consolidation settlements of this HKMD with vertical drain. Two methods for determining the average degree of consolidation of the HKMD with vertical drain are used in the new simplified method. Results from the FE analysis and the new method are compared with relative errors obtained. From the above validation cases, it is found that the settlements from the new simplified Hypothesis B method are closer to test data or the values from the fully coupled finite element modelling with least relative errors. Hypothesis A normally underestimates the settlement a lot and with largest errors when compared with Hypothesis B. The main conclusion is that the new simplified Hypothesis B method is very suitable for calculating consolidation settlement of clayey soils exhibiting creep and is easy to use by simple spreadsheet calculation.

3. The third paper is by Chao-Kuang Hsueh et al on "Finite Element Analysis to Characterize the Lateral Behaviour of a Capped Pile Group". Finite element simulation for analysis of a capped pile group was conducted to investigate the interaction among piles, soil and pile cap, especially the effects resulted from concrete damaging. The simulation was to develop a calibrated model using the test data and to apply that model for conditions not present during the test. In addition to consider pile/soil and cap/pile interaction in the numerical simulation, interaction between steel

reinforcement and concrete was also modelled in the analysis. In the numerical analysis each steel reinforcement installed in the tested piles and the pile cap was modelled as an individual element at its installed position. The simulation results showed that the leading and the middle row piles in the group carried the highest and the lowest fraction of pile head loads when concrete around the pile cap/soil contact area remained its integrity. Increasing loading level, the pile head load carried by the middle row of piles increased due to constraint of the pile cap affected by the concrete damage at the pile cap/soil contact zone.

4. The fourth paper is by Tjie Leong Gouw on "Proposed Design Guideline of Dynamic Compaction for Practicing Engineers". During an earthquake, saturated fine sands tend to lose its bearing capacity due to the earthquake induced and accumulated excess pore water pressure. The phenomenon, known as liquefaction, is one of the earthquake hazards that need to be mitigated in an earthquake prone area such as the archipelagos of Indonesia. The occurrence of an earthquake cannot be prevented and, with the present knowledge, is difficult - if not impossible - to predict. However, liquefaction potential can be mitigated by carrying out proper ground improvement methods. The most common ground improvement schemes that have been widely implemented in mitigating liquefaction potential of saturated fine sands in Indonesia are dynamic compaction and vibro-compaction. However, many practicing engineers are still not familiar with the methods. This paper presents the design, execution, and evaluation methods of dynamic compaction. Two case histories on real projects are also presented as examples.

5. Yasuhara et al are authors of the fifth paper on "Settlement of river dykes and their adjacent residences on soft clay deposits after the Tohoku-Pacific Ocean Earthquake of 2011." Among the cases of extensive infrastructural collapse that resulted from the cataclysmic earthquake that struck off the eastern coast of Japan on March 11, 2011, long-term settlement and deformation of clay deposits during earthquakes have sometimes been overlooked. This paper presents a case history of clay deposit settlement and deformation beneath river dykes and their adjacent residences after the Great East Japan Earthquake in 2011. As a countermeasure against damage of this kind, parts of existing river dykes were removed and then sheet piles were installed immediately after the earthquake at the toes of river dykes. Thereafter, the river dykes were returned to the original height by surcharging the fills for dykes. In addition to measurement of river dyke and residence behavior after those countermeasures, numerical analysis was conducted using ALID software for dynamic analysis of behavior during earthquakes and DACSAR software for static analysis of post-earthquake behavior to predict settlement and deformation of deposits consisting of the thick clay layer underlying the sand layer and to verify effectiveness of the countermeasures.

6. Sixth paper is by Dong Huyn Kim et al on Application of photogrammetry and image processing for rock slope investigation: High-resolution 3D photogrammetric models facilitate the generation of rock surface attributes which can be used to highlight the products of weathering on rock slopes. Recent studies of image analysis have also demonstrated that if the features of interest are clearly visible in digital photographs, various surface features which are associated with its weathering characteristics can be investigated using image analysis techniques. However, combining their potential of both 3D and 2D images for providing more reliable data, these approaches are computationally complicated and difficult to implement. This article presents an image analysis workflow via a MATLAB image filtering code for the estimation of a recession area focusing on the variation of rock surface roughness. By comparing annual photogrammetric 3D images, the roughness variations were processed with relative brightness integers (I) obtained from their greyscale images. The results show that the loss of roughness on the exposed surface appeared to be strongly related to the changes of brightness integers (I) derived from filtered greyscale images. The combined image analysis with 3D photogrammetric models could compensate the limitations of the uses of both digital photographs and 3D surface models for quantifying weathering patterns.

7. The seventh paper is by Boon & Ooi on advances in tunnelling Geotechnics – stacked twin tunnels: The construction of underground metro projects involves both tunnelling and deep excavations for station construction. The construction programme of the contractor needs to take into account the time required for excavating the launching shaft or station to launch the tunnel boring machines (TBMs), and also the interfacing of the tunnelling activities with the intermediate stations located in between the launching and retrieval shafts or stations. Risks in construction programme may arise in a project for instance due to land issues such as merger and acquisition or relocation of the original land occupants. The risks in construction programme can nonetheless be addressed through design provided there is strong understanding of its mechanics. This also allows more optimal construction programmes to be developed at the outset of a project. An example is demonstrated for the unusual case of stacked twin tunnels in residual soils where the upper tunnel is constructed first and undermined subsequently by the lower tunnel. The mathematics and the mechanics governing their interactions are detailed.

8. Shaw-Shong Liew is the author of the eighth paper on Common Blind Spots in Ground Investigation, Design, Construction, Performance Monitoring and Feedbacks in Geotechnical Engineering: In geotechnical engineering dealing with risks and uncertainties, the processes involved start from the investigation with the fundamental intention to attain better understanding of the subsurface conditions and acquisition of the engineering parameters for the subsequent engineering analyses, designs, detailing, tender documentation and calling, followed by design validation tests at field and construction problem solving. With the forensic investigation experiences by the author in the past, some interesting findings and surprises are compiled in this paper to illustrate these common blind spots at the aforementioned engineering processes. The importance of desk study and sound geological knowledge in planning of investigation programme have not received sufficient emphasis in the higher education system, thus resulting in significant wastage by the trained graduate in using the investigating tools and generating excessive amount of redundant information. Some of the mistakes are fundamental errors in perceiving the engineering behaviours when using the software with intuitive and illusive perception rather than based on sound engineering understanding. There is also strain compatibility issue in mobilising material strength of composite materials with drastic stiffness contrast when approaching failure state of a soil structure interaction problems. Design validation tests are crucial to ensure design methods adopted able to reasonably behave as intended. However, the tests usually do not reveal the overall behaviours of the design in actual scale and time factors, but rather a behaviours of a special case or prototype. Geotechnical instrumentation on a larger scale with time might be a more representative of practical performance with totality. This will be more useful for review and back-analysed of a big picture performance of the geotechnical structures.

9. The ninth paper is by Dr Dominic Ong on “detrimental effects of lateral soil movements on pile behaviour”. Deep excavation, tunnelling and river tidal fluctuations are some activities that can induce lateral soil movements, which can detrimentally impact nearby existing infrastructure. One major design concern is that the behaviour and mechanisms of complex soil-structure interaction that occur in these situations are often still not well understood. Limited design methods are currently available to evaluate these problems in practice. Therefore, the latest development and understanding of soil-structure interaction involving pile foundations subject to lateral soil movements are presented with reference to successfully implemented projects and research outcomes based on finite element modelling, centrifuge experiments as well as field observations and interpretations. The novel concept of passive pile behaviour and limiting soil pressure due to stress relief will be evaluated and explained in detail.

10. Tenth paper is by Siau Chen Chian on Optimising Cement Dosage in Ground Improvement and Early Quality Control Schemes: Judicious dosage of cement in soft clayey soils is key in reducing waste, time and cost in this growingly environmental conscious modern society. Despite being a well-established technique in ground improvement, studies on the prediction of strength development of cement stabilised soils are often limited to a couple of clay types or site specific. This paper presents an extensive suite of unconfined compressive strength tests of cement-mixed clayey soils over a wide range of mix ratios, curing ages and sand impurities. A strength predictive model encompassing the above variables was developed and validated with several types of clay and cement from different sources. This enables the optimisation of cement dosage to achieve a desirable unconfined compressive strength to satisfy the ground improvement criteria with ease. Quality control schemes using early age strength and portable bender element were also discussed in this paper.

11. Effects of Preloading of Struts on Retaining Structures in Deep Excavations” is the eleventh paper by Richard N. Hwang and Lup-Wong Wong. The performance of an excavation of 19.4 m in depth in soft ground has been reviewed by interpreting the readings of inclinometers in wall of 35 m in length and strain gauges in six levels of struts. Assuming the wall deflections at the first strut level would not move after preloading, the corrected inclinometer readings show that the deflections at the wall toes and at the tips of inclinometers were as much as 43 % and 25 % of the maximum wall deflections respectively. The large toe and tip movements are verified by numerical analyses, which have been conducted to study the effects of preloading of struts as well. The strain gauge readings show that the preloads applied to the struts do not sustain and drop significantly after subsequent preloading of struts. Four cases, namely, struts with full preloads, 50% preload to the first strut level, zero preload and actually observed preloads, have been adopted in the analyses to evaluate the effects of preloads. The results of the numerical analyses using the Mohr-Coulomb model are then compared with the observed wall deflection profiles in the final excavation stages. The Young’s moduli for clay and sand layers have been correlated with the soil strengths. It is found that computed peak strut loads are in agreement with the observed peak loads for the upper 3 levels of struts. For the lower 3 levels, the computed strut loads are however as much as 50% larger than those observed.

12. The twelfth paper in this volume is by Hung Jiun Liao et al on Anchors of Anchored Slopes in Taiwan: A catastrophic failure of an anchored cut slope at the national expressway in 2010 uncovered the status quo of tie-back anchors in Taiwan. Serious corrosion of anchor components due to poor corrosion protection was found to be the most obvious factor contributing to this landslide among other factors. After an extensive island-wide investigation on the existing anchored slopes, similar corrosion problem was found in many other anchored slopes. After the investigation, the construction and maintenance practice of anchored slopes had been fundamentally changed in Taiwan. This paper covers the inspection results on anchored slopes and also the measures taken to improve the corrosion protection of existing anchors and new anchors. Based on the problems found from the existing anchored slopes, some modifications on anchor tendon assembly and cement grouting practice had been developed to upgrade the corrosion protection of the new anchors and to monitor the long-term anchor load change as well.

13. The thirteenth paper is by Chiwan Hsieh et al. on Hexagonal Wire Mesh Panel Tensile Behaviour due to Weaving Patterns. The tensile engineering properties of a commonly used wire mesh (120mm x150mm, ψ=4.0mm) with triple-twist (Type A) and fourth-twist (Type B) weaving methods according to the ASTM A975 test standard are studied. Wire mesh panel tensile tests loaded in the longitudinal and transverse directions with and without centre cut wire conditions and panel connection to selvedge tests were evaluated. Generally, the longitudinal tensile strengths were higher than that for the transverse tensile strengths. The Type B panel longitudinal and transverse direction tensile strengths and connection to selvedge strengths were all greater than those for Type A panel. In addition, the Type B panel showed better strength retention rates than the Type A panel with and without centre cut wire condition. The Type B panel showed better tensile behaviour than the Type A panel.

14. Keh-Jian Shou et al. are the authors of the fourteenth paper on Trenchless Excavations for Underground Pipelines in Difficult Geology. No-Dig constructions in the city might encounter various difficulties. And the difficulties or obstacles, which might cause schedule delays and damage to the pipes. Among the others, the conditions of overcut and stuck could be the most common and critical to a pipejacking project. This study considered various difficult conditions, including different overcut range and sticking position, together with different resistance, jacking force, etc. The ABAQUS finite element software was applied for three-dimensional numerical simulations for pipe-jacking with different difficult situations. The analyses focused on the pipejacking in gravel formations, and the suggestions were concluded based on the results. The results suggest that the location of sticking and its severity (different frictional coefficient was set) affect the stress field in the pipe. And the worst condition, i.e., the totally stuck, the adjacent soil and pipe will experience excessive deformation, which must be avoided. Therefore, lubrication to avoid this extreme scenario is essential in the pipejacking operation. For the case with large diameter, unavoidable overcut and highly variable geology, the above suggestions are more crucial.

15. The fifteenth paper is by C.W. Lu et al. on Liquefaction-Induced Settlement of Structures on Shallow Foundation. Unlike the liquefaction potential assessment, the liquefaction-induced ground settlement has not been studied extensively. The uncertainty of the ground profile and associated soil engineering properties is the major challenging to advance the current knowledge on this subject. Within Ishihara and his colleagues' framework, the liquefaction-induced settlement is computed by the associated post-liquefaction volumetric strain, once the factor of safety for liquefaction is evaluated. For estimating settlement of a building with shallow foundation in liquefiable soils, on the other hand, dynamic behavior of the soils, its relative density, and the thickness of liquefiable soil, building's weight and dimensions, seismic intensity, and structure-soil interaction should be considered accordingly. This paper aims to develop a practical and simple procedure to estimate the liquefaction-induced settlement on structures on shallow foundation, based on the framework proposed by Sawicki and Mierczynski in 2009. A series of comprehensive numerical analyses were carried out to incorporate the above-mentioned factors in the developed procedure. Data of liquefaction-induced settlement of structures on shallow foundation reported in the literature were used to compared with the estimated ones.

16. Geoff Chao et al are the authors of the sixteenth paper on the Evaluation of Factors Influencing Expansive Soil Embankment Slope Failure: Slope failures in embankments constructed in expansive soils are often induced by rainfall infiltration during wet seasons or after a heavy rainfall event. Field investigations regarding the effect of rainfall infiltration on slope instability for expansive soil embankments indicate that shrinkage cracks developed during the drying and wetting cycles play an important role on the slope instability. The excessive amount of infiltration through the shrinkage cracks decreases the matric suction of the expansive soil, and hence, results in a reduction of the shear strength of the soil accompanied with soil expansion, or heave. Furthermore, the modulus of elasticity of the soil decreases as water content increases and the soil heaves. The influence of these factors on the

slope stability of expansive soil embankments is reviewed and discussed in the paper. Numerical modeling using the finite element computer programs SEEP/W and SIGMA/W was conducted to evaluate the volume change of an expansive soil embankment slope due to changes in suction arising from infiltration. Long-term stability of the expansive soil embankment slope was conducted using the computer program SLOPE/W. The expansive soil slope was also analyzed with a proposed remediation scheme to evaluate the effect of the remediation on long-term stability. The results of the numerical modeling for the slope with remediation were compared to those obtained for the slope without remediation. Furthermore, heaving of the expansive soil is accompanied by a reduction in the shear strength of the soil. Therefore, analysis of heave using the oedometer method was discussed in the paper. The results of the heave prediction using the oedometer method were compared to those obtained from the numerical modeling method. Reasons for the differences in amounts of predicted heave using both methods are discussed in the paper.

17. Strength and stiffness parameters of Bangkok clays for finite element analysis is the title of the seventeenth paper by Suched Likitlersuang, Chhunla Chheng, Chanaton Surarak and Arumugam Balasubramaniam: Constitutive soil model and its parameters are the important issue in finite element analysis. Hardening soil model and Mohr-Coulomb model parameters of Bangkok clays for finite element analysis were evaluated in this study. To achieve this purpose, a case study of Sukhumvit MRT Station was selected to model in three dimension with hardening soil and Mohr-Coulomb models. The instrumented data during construction was used to compare with the results from finite element analysis. PLAXIS 3D software was adopted as solving tool in this study. Lateral wall movement and ground surface settlement predictions were used to compare with the data. The outcomes were concluded that the hardening soil model characterized the Bangkok clay better than Mohr-Coulomb model in 3D finite element analysis for excavation.

18. The eighteenth paper is on Failure of riverbank protection structure and remedial approach by S. Horpibulsuk et al. This paper presents the case study of the collapsed riverbank protection structure along the Pasak river in Saraburi province, Thailand. The site investigation and finite element analysis using PLAXIS 2D results show that the failure occurred in sliding mode due to the natural forces. During the rainy season, water flow from the farmlands to the river by crossing the backfill of the retaining wall. Hence, seepage force was developed in the direction of the flow and induced the stability of the riverbank protection. Furthermore, the rivers and streams continuously scour the banks and undermined the natural slope, which caused the soil erosion in passive zone and resulted in instability. Based on these causes of failure, a new reinforced retaining wall structure using bored pile, geocomposite, and riprap at the front of retaining wall to protect the circular failure mechanism, seepage forces, as well as soil erosion and sedimentation, respectively was designed. The finite element verification on the new retaining wall structure showed that this structure had a sufficient factor of safety against the external and internal slope failure.

19. The last paper of this issue is the nineteenth paper is by Bergado et al on the “Development of Soft Ground Improvements Using Prefabricated Vertical Drains (PVD) and Deep Cement Mixing (DCM) Techniques”: Thailand, located on soft clay, has highly settlement. Ground improvement has become one alternative to increase soil strength, soil stiffness and reduce soil compressibility. This paper focuses on comparative performances of prefabricated vertical drain (PVD) in the improvement of soft Bangkok clay using surcharge, vacuum and heat preloading. The Vacuum-PVD can increase the horizontal coefficient of consolidation, Ch, resulting in faster rate of settlement at the same magnitudes of settlement compared to PVD. Moreover, the Thermal PVD and Thermal Vacuum PVD can increase further the coefficient of horizontal consolidation, Ch, with the associated reduction of kh/ks values by reducing the drainage retardation effects in the smear zone around the PVD which resulted in faster rates of consolidation and higher magnitudes of settlements. In addition, a new kind of reinforced method, namely: Stiffened Deep Cement Mixing (SDCM) pile is introduced to mitigate the problems of the Deep Cement Mixing (DCM) pile due to the low flexural resistance, lack of quality control in the field and unexpected failure. The SDCM pile consists of DCM pile reinforced with precast concrete core pile. The full scale embankment test on soft clay improved by SDCM and DCM piles was studied. The 3D finite element and parametric study have been investigated to understand the behavior of SDCM and DCM piles. The simulation results indicated that the surface settlements decreased with increasing lengths of the concrete core piles, and increasing sectional areas of the SDCM piles. In addition, the lateral movements of the embankment decreased by increasing the lengths (longer than 4 m) and, the sectional areas of the concrete core piles in the SDCM piles. The results of the numerical simulations closely agreed with the observed data and successfully verified the parameters affecting the performances and behavior of both SDCM and DCM piles.

20. The last paper of this issue is the twentieth paper and is by Mitsutaka Sugimoto et al on the “Study on Shield Operation Method in Soft Ground by Shield Simulation”: Shield tunneling technologies have been developed for constructing tunnels in soft ground especially under groundwater. Recently, challenging projects from the viewpoint of tunnelling technology have been planned. To realize these constructions, it is necessary to examine the shield

operation method preliminarily. The authors have developed a method to carry out the above examination and have confirmed its validity for a tunnel in stiff ground. In this research, to examine the performance of the proposed method for soft ground tunnel, the simulation on shield behaviour was carried out using the estimated shield operational data for a tunnel in soft ground. As a result, the following were found: the shield steering conditions by the proposed method are not enough to rotate the shield along a sharp curve in case of soft soil; and the simulation results have a good agreement with the planned alignment using proper shield operational data.

ACKNOWLEDGEMENT

Twenty papers are contained in this issue. Twelve of them are assembled by the Guest Editors and another eight contributed papers by the in-house editors. No doubt the material contained herein would be most valuable to our profession. The editors have adequately described the contributions in the preface. They are to be congratulated for these contributions.

Dr. Teik Aun Ooi
Prof. San Shyan Lin
Prof. Kwet Yew Yong
Dr. Noppadol Phienwej
Prof. A. S. Balasubramaniam

GEOTECHNICAL ENGINEERING

June 2018:

Special Issue on 50th Anniversary of the Southeast Asian Geotechnical Society

Edited by
Noppadol Phienwej, Suttisak Soralump, Apiniti Jotisankasa, Suched Likitleruang and Tirawat Boonyatee

TABLE OF CONTENTS

Cover Photographs

Figure 1: Proposed Design Guideline of Dynamic Compaction for Practicing Engineers
(After Tjie-Liong GOUW,2018)

Figure 2: Recent Development on Soft Ground Tunnelling
(After Mitsutaka Sugimoto, Hideyuki Tanaka, Ngoc Thi Huynh, Salisa Chaiyaput, Le Gia Lam, and Jian Chen, 2018)

Figure 9: Schematic diagram of the soil column: State-of-the-Art Research in Geo-energy and Geo-environmental Engineering: Energy Pile and Earthen Capillary Landfill Cover System
(After Charles W.W. Ng, Jason L. Coo & Anthony Gunawan, 2018)

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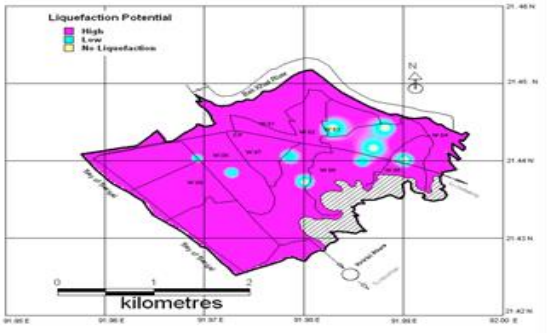
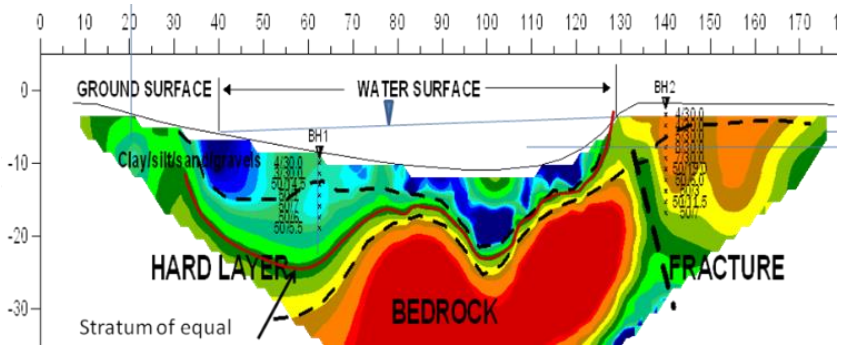
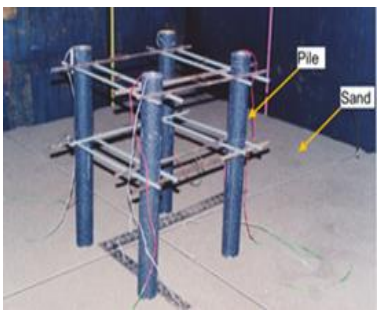
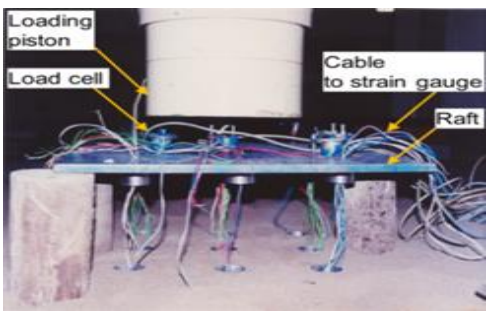


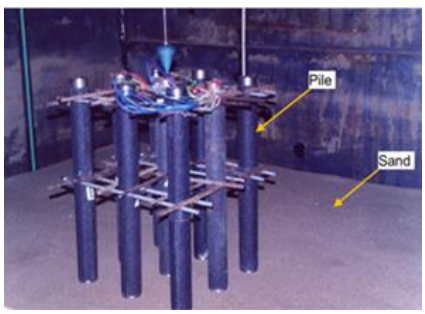
Seismic Microzonation of Cox's Bazar Municipal Area Bangladesh :
Figure 8 Microzonation map based on regional distribution of liquefied areas
(After A. Imtiaz, A. Barua, M. Sakib and M.A. Ansary, 2018)



Geophysical Investigation in Bukit Merah Reservoir :
Figure 4 Resistivity image for section under check pier alignment
(After M. R. Selamat, A. Shafie, R. Saad, and M. M. Nordiana, 2018)







Bearing Capacity and Settlement Study on Small-Scale Piled-Raft Groups in Sand:
Figure 3 Laboratory tests setup:
(b) Installation of 2×2 group piled-raft; (c) Installation of 3×3 group piled-raft; (d) Raft installation of 3×3 group piled-raft with load cells
(After Sengara, IW., Roesyanto, Krisnanto, S., Jayaputra, A. A., and Irsyam, M., 2018)

GEOTECHNICAL ENGINEERING

September 2018: Contributed Papers

Edited by: Dominic Ong, San Shyan Lin & Ooi Teik Aun

Dominic Ong

Ir. Dr. Dominic Ong obtained his Bachelor's Degree in Civil Engineering from the University of Western Australia (UWA) and his PhD in Geotechnical Engineering from the National University of Singapore (NUS). Currently, he is an Associate Professor and Director of the Research Centre for Sustainable Technologies, Faculty of Engineering, Computing & Science, Swinburne University of Technology Sarawak Campus. He is also actively involved in geotechnical consultancy works within the local industry and previously in Singapore. Ir. Dr. Ong has particular interests in the fields of deep excavation, tunnelling, soil-structure interaction, ground improvement, field instrumentation works, biocementation and finite element modelling. He currently supervises 10 PhD candidates in these fields. He also holds the position of Executive Committee Member of the Association of Consulting Engineers Malaysia (ACEM) Sarawak Branch, Vice-Chairman Institution of Engineers Malaysia (IEM) Sarawak Branch and is also a Founding Member of both the Malaysian Geotechnical Society (MGS) and the Malaysian Society for Trenchless and Tunnelling Technology (MSTTT). He is also an Editorial Board Member of the UK's Institution of Civil Engineer (ICE) journal, *Geotechnical Research* as well as an Editorial Panel Member of the Southeast Asia Geotechnical Society (SEAGC)-Association of Geotechnical Societies in Southeast Asia (AGSSEA) *Geotechnical Engineering* journal. Recently, he serves in the International Society for Soil Mechanics & Geotechnical Engineering (ISSMGE) Technical Committees, namely, TC104 Physical Modelling and TC207 Soil-Structure Interaction & Retaining Walls.

San Shyan Lin

Prof. San-Shyan Lin graduated from Chung Yuan University with a BSCE degree in 1981. He then obtained his master degree from Utah State University, Logan, Utah in 1985 and his PhD from Washington University in St. Louis, Missouri in 1992. Before his teaching career at university, Dr. Lin served as an engineer at Taiwan Area National Expressway Engineering Bureau between1992 to1994. Dr. Lin has been serving at Department of Harbor and River Engineering (DHRE) of National Taiwan Ocean University (NTOU) since 1994. He was promoted as a full professor in 2000. Thereafter, he took some university duties by serving as the secretary-general at office of the secretariat between 2001 and 2003; the chairman of DHRE between 2005 and 2006; the acting dean of college of engineering in 2007 and the vice president of NTOU between 2006 and 2012.

Prof. Lin served as a committee member of committee A2K03-Foundations of Bridges and Other Structures of TRB, USA between 1995 and 2004. Currently, he is still serving as a committee member of TC-212 and ATC-1 of ISSMGE and as an editorial board member of four international journals. In addition, Dr. Lin also served as the president of Taiwan Geotechnical Society (2011-2013); Chairman of International Geosynthetics Society- West Pacific Regional Chapter (2002-2004); CEO of Sino-Geotechnics Foundation (2011-2014) etc. Dr. Lin received the distinguished alumnus award from Chung Yuan University in 2009 and the distinguish Engineering Professor Award from Taiwan Pavement Engineering Society in 2011. Prof. Lin's research and practical experiences have been dealt with deep foundations and geosynthetics.

Ir. Dr. Teik Aun Ooi

Ir. Dr. Teik Aun Ooi obtained his Bachelor of Civil Engineering and Master of Engineering from Auckland Universiity in 1966 and 1968 respectively. He obtained his PhD from University of Sheffield in 1980. He was the Co - Organizing Chairman of the recently concluded SEAGC2016. He is the immediate Past President of the Southeast Asian Geotechnical Society (SEAGS), Founder Chairman of the Association of Geotechnical Societies in Southeast Asia (AGSSEA). He is a Past President of the Malaysian Institute of Arbitrators (MIArb). He is the Immediate Past ICE Country Representative for Malaysia (2000 - 2015), Founder Chairman of IEM Tunnelling and Underground Space Technical Division (TUSTD), Founder Chairman of IEM Consulting Engineering Special Interest Group (CESIG), He is an Honorary Fellow of The Institution of Engineers, Malaysia (Hon. FIEM), Fellow of the Institution of Civil Engineers (CEng FICE), Fellow of the MIArb (FMIArb), Fellow of Malaysian Society of Adjudicators (FMSA) and Fellow of Asean Academy of Engineering and Technology (FAAET). Dr. Ooi has fifty years of experience in the Construction Industry. He spent his initial fourteen years with the Public Works Department Malaysia before leaving to work in the private sector where he spent seventeen years working in the construction sector. He play major role in the Johore Baru Causeway widening and the design and construction of Senai Airport in 1970s. He was the Project manager for the Wisma Saberkas Building Project in Kuching in 1980s. He was Project Director for the Design and Construction supervision of the New Kuching Deep Water Port at Kampung Senari in 1990s. He started his consultancy practice in 2000 specialising in Civil and Geotechnical Engineering works. Dr. Ooi is a practicing Consulting Engineer, An Expert Witness in Court and in Arbitration, An Accredited Checker, An Arbitrator and An Adjudicator. He is a member of the Accredited Checker Committee of the Board of Engineers, Malaysia. Dr. Ooi devoted much of his time in honorable public service in continuing education of engineers and development of Malaysia Annexes for Eurocode 7 and 8. He is an independent executive director of IEM Training Centre Sdn Bhd since 1992. In 2013 he was appointed executive director of the IEM Academy Sdn Bhd. He has been Organizing Secretary and Chairman of numerous IEM Workshops, Seminars, and Conferences since 1970s. He was responsible for forming five active ICE Student Chapters in Universities in Kuala Lumpur. Dr Ooi conducted touring lectures in geotechnical engineering to Malaysia, Vietnam, Thailand, Cambodia, Laos, Myanmar and Philippines. In Malaysia he was invited to deliver the prestigous 19th Professor Chin Fung Kee Memorable Lecture in 2009. He frequently delivered lectures to the final year University engineering students

GEOTECHNICAL ENGINEERING

PREFACE

There are thirteen papers in this Issue: The first paper is by Hai-lei Kou and Wen-gang Zhang on Strength Characteristics of Soda Waste Treated with Fly Ash and Lime: Soda waste is a kind of industrial waste when traditional technology of soda production is adopted. The soda waste cannot be directly used as engineering soil as its low strength. However, it can be used after be mixed with other materials. In this paper, chemical materials such as fly ash and lime are used to be mixed with soda waste. The strength characteristics of soda mixtures with different ratio are studied in detail. Compaction test and unconfined compressive test are conducted respectively to assess the feasibility of these two materials. Based on test results, the mechanical properties of soda mixtures with different ratios of fly ash and lime are discussed. It is indicated that the microstructure of soda waste is similar with soil and the particle size distribution is well to mix with other materials to be used as engineering soil. The optimal ratio of soda waste and fly ash is 7:3 while the ratio is 7 % for soda waste and lime. Using the optimal ratio, the unconfined compression strength of fly ash treated soda and lime treated soda after 14 curing days is 6.5 and 6.1 times of pure soda respectively.

The second paper is by A. Puttiwongrak, K. Sam Ol1 and V. Sakanann on Groundwater Recharge Estimation in Kathu, Phuket using Groundwater Modelling: Kathu is a district of Phuket Island in Thailand, and is the district with the largest number of communities in Phuket. Groundwater is the main water supply on Phuket. Urbanization is occurring very rapidly on Phuket and this has stimulated water demand at an accelerating rate. A lack of fresh water and the results of over-use of groundwater could be serious problems in Phuket in the near future. The study described in this paper simulated groundwater recharge flux in Kathu, using groundwater modelling to estimate groundwater recharge. The simulation was carried out across the locations in Kathu for the period, 2006-2016. Historical Groundwater well data were collected and used to create a groundwater model. The trial and error method was applied to the recharge flux to obtain matches between simulated and observed groundwater heads or levels within acceptable ranges of error. Finally, it was concluded that the groundwater recharge in Kathu is currently able to maintain the groundwater level, although groundwater has been withdrawn at a highly accelerating rate, especially between 2012 and 2016. The positive trend in the recharge rate can be attributed to increasing efficiency in the use of water catchment areas, high rainfall, and rising sea levels.

In the third paper, A. Imtiaz, A. Barua, M. Sakib and M.A. Ansary; describe Seismic Microzonation of Cox's Bazar Municipal Area Bangladesh: Cox's Bazar municipal area runs a high risk of earthquake exposure due to geologic and tectonic structures. As a part of adopting earthquake mitigation approaches for the region, a seismic microzonation map was developed on the basis of potential of earthquake occurrences and ground susceptibility to earthquake. For microzonation purposes, a total of 26 borelogs were used to study site amplification as well as soil liquefaction potential of the municipality area. Site responses were estimated through one dimensional wave propagation software SHAKE. The liquefaction potential was evaluated using two simplified procedures, proposed by Seed et al. (1983) and Iwasaki et al. (1986) to measure whether the site is liquefiable or non-liquefiable. For slope stability analysis, XSTABL programme was used which performs two dimensional limit equilibrium analyses to evaluate the factor of safety for a layered slope using the simplified Bishop Method. These results were transformed into a map which will serve as a general guide to ground-failure susceptibility, effective land use, and efficient town-planning.

In their paper (fourth one), M. R. Selamat, A. Shafie, R. Saad, and M. M. Nordiana on Geophysical Investigation in Bukit Merah Reservoir : The suspected cavity presence in the bedrock of the outlet canal of Bukit Merah Reservoir in Malaysia raised concern that it could undermine the integrity of a check pier structure planned just ahead of the spillway. Boring into a cavity could also compromise reservoir containment capacity. A seismic refraction and electrical resistivity tomography carried out for the

subsurface section spanning the two banks revealed not only the presence of a relatively porous zone towards one end but also the undulating material boundaries towards the other. The results called for review of the original foundation of the check pier structure involving bore piles of equal length. The suspected porous zone was avoided in the renewed bore pile design while the bedrock depressions were appointed with deeper bores for adequate pile embedment. The design review resulted in piles resting on a stratum of equal geotechnical quality with each new pile now having a different length.

The fifth paper is on Effect of Ground Disruption on the Strength of Gatch Soil in Kuwait by Ziad Abdelsalam and Nabil Ismael: Kuwait soil is commonly known as 'Gatch' and classified as very dense cemented sand Kuwait sand has sulphates and calcium carbonated in form of gypsum components that caused cementation bonds with environment aids such as highly evaporation of rainfall in winter season. This soil is used as a backfill material and it is important to know the effect of excavation and recompaction on the strength characteristics. The present study provides experimental results on the effect of ground disruption on strength parameters of cemented sand in Kuwait, such as they are the cohesion c, and the angle of friction ϕ' and stress strain characteristics. The triaxial test was used to determine these parameters on undisturbed and remolded specimens at different depths. The results show a disturbance of cemented sands cause loss of the cohesion component of strength and a minor reduction in the angle of shearing resistance.

In the sixth paper is on Greenheart Timber Strip Reinforcement for Reinforced Soil Retaining Walls by Sean A. Surujdas and C.N.V. Satyanarayana Reddy: This article presents the result of investigating the feasibility of using greenheart timber strips as reinforcement for reinforced soil retaining walls in Guyana. The work is intended to assess the cost economics between greenheart timber strips and geogrids as reinforcements. Medium grained river sand is used as fill material in reinforced soil retaining wall designs. The interfacial friction between greenheart timber and fill material is determined by the laboratory pullout test. The designs of reinforced soil retaining wall revealed that Greenheart timber strips of 350mm width and 25mm thickness are sufficient to reinforce retaining wallswith backfill of heights 4m and 6m, while greenheart timber strips of 350mm width and 50mm thickness are sufficient to reinforce retaining walls with backfill of heights 8m and 10m. It is observed that as height of retaining wall increases from 2m to 10m, the percentage cost saving of using greenheart timber strips as compared with geogrids, increases from 10% to 24%.

In the subsequent seventh paper in the series Yudhi Lastiasih and Herman Wahyudi present the HWYL Method for Predicting Settlement of Soft Soil: The HWYL method is one of the analytical methods for predicting the amplitude and time of settlement that occurs, based on the field observations using a settlement plate or extensometer. The data used for the analysis was the result of observations from a settlement monitoring instrument of some road embankment and reclamation projects on soft soil in Indonesia. The data was analyzed using a statistical approach to determine the behavior and correlation of settlement amplitude versus time curve shape. This method obtains an equation formula to predict the consolidation amplitude and when the final settlement of last embankment occurred.

Sengara, IW., Roesyanto, Krisnanto, S., Jayaputra, A. A., and Irsyam, M. in the eighth paper deal with Bearing Capacity and Settlement Study on Small-Scale Piled-Raft Groups in Sand: Pile group foundation with a pile cap can be considered as a piled-raft foundation. Previous studies indicate that in a piled-raft foundation, the piles contributes to reduce settlement of the raft whereas the raft provides an additional bearing capacity of the pile group. Laboratory testings were performed to investigate the performance of piled-raft group from bearing capacity and settlement point of views. Instrumented laboratory models of 2x2 and 3x3 piled-raft group were loaded vertically to obtain load vs. settlement curves and load-transfer to raft, to pile shaft, and to pile tip. From the load-settlement curves of piled-raft group, the performance of bearing capacity and settlement was then observed and quantified. The laboratory test results indicated that the presence of piles reduced the settlement of raft significantly, whereas the presence of raft provided additional bearing capacity to the pile.

In the ninth paper the Influence of Two Rough Parallel Joint Surface Profiles on Stress Wave Energy Dissipation is described by Yexue Li,; Hongke Pan, Li Qinand Jianhui Fan: A new method called YUV dimension is proposed to describe joint surface configuration on the basis of the interdisciplinary theory of iconography, graphics, and fractal geometry. This method can be used as substitute for traditional fractal dimensions. On this basis, the influence of two joint surface profiles (described by using the YUV dimension method) on stress wave energy dissipation is investigated by split Hopkinson pressure bar on embedded rough parallel two-joint rocks. The following conclusions are drawn: (1) the YUV dimension method, a new approach for characterizing surface configuration, exhibits more advantages than the traditional dimension; (2) the energy dissipation of the joints increases with increasing two-joint dimensions or their sums. This increase is attributed to the fact that the increase in YUV dimensions leads to the decrease in rock joint stiffness; thus, a decrease in rock joint stiffness leads to the increase in stress wave energy dissipation. A nonlinear relationship also exists among two YUV dimensions and energy dissipation. The nonlinear relationship is attributed to the nonlinear deformation of the joints. For engineering applications, a two-variable function between the energy dissipation and YUV dimensions of two joints is also formulated

Wang Ning, Zhou Xiaolong and Zhu Dengyuan are the authors of the tenth paper on Failure mode for creep area of high open-pit slope under the influence of underground mining: With mining intensity increasing, more and more deep open-pit mines are gradually transformed to underground mining in China nowadays. Focusing on high open-pit slope under the influence of underground mining, the spatial distribution and development trend of slope displacement monitoring data were analyzed, combined with calculation of slope stability under different engineering conditions. The results show that the slope deformation has a periodic change with the seasons, and the rainy season is the most intense period of deformation development, when the tensile cracks on the top platform of the slope become seepage channel for rainwater. The slope stability coefficient of the creep area under the drainage condition is 1.010 and the most dangerous sliding surface is located in the upper part, whereas sliding zone is obviously reduced compared to saturated condition and dangerous sliding surface also decreases, and reasonably slope cutting can largely improve the slope stability. By studying the deformation process of high open-pit slope, the deformation development characteristics and possible failure modes are got, and it could provide guidance to the reinforcement measures of landslides and ground subsidence.

The eleventh paper b Nabil Ismael and Hasan Al-Sanad is on the Properties of Desert Sands Reinforced with Ground Tire Rubber in Kuwait: The abundance of waste tires in Kuwait created a major problem requiring disposal sites and causing environmental and safety problems especially in the summer months as the temperature often exceeds 50□C. Numerous fires have occurred causing air contamination and health hazards. To find useful uses of ground tire rubber an extensive laboratory testing program was carried out using rubber aggregates produced locally as additive in small quantities up to 20% by weight to the local surface sands of Kuwait. Testings included grain size, unit weight, Modified Proctor compaction, permeability, direct shear, consolidation, and CBR tests. The effect of increased rubber content on the different properties was measured. The results indicate a reduction of the density and CBR, an increase in the permeability and compressibility and no change in the angle of friction □ with increasing rubber content. Therefore, the use of rubber additive is beneficial for many practical applications such as light weight fill, as a drainage layer, and on the grounds of sporting facilities, and in embankment construction.

The twelfth on a study on behavior of vertical pile in sand under uplift load by R. Saravanan and P.D. Arumairaj: The significant design parameter for supporting the piles and the ground anchors for tension loads and compressive loads is shaft resistance. Steel pipe piles often mentioned as cylindrical piles are used often in offshore projects and in harbor structures. Since the end condition of the cylindrical piles (open and closed end) plays a significant change in the shaft capacity of the pile, an experimental study is proposed to predict the load displacement characteristics of single vertical pile subjected to uplift load. The pile is embedded in sand with varying relative densities. The analytical study was developed based on the failure mechanism from limit equilibrium technique. The present study takes into account of

significant parameters such as length, diameter and as surface characteristics of pile. The axial load-displacement behavior of vertical pile is studied under the different length to diameter (L/d) ratio which is adopted for the experimental analysis. The uplift co-efficient (Ku) is evaluated by using ultimate uplift capacity load. The obtained experimental results were compared with the reported data to elucidate the significance of the work done.

The last paper of this issue is the thirteenth paper on Numerical Simulations of K0 Triaxial Tests on Collapsible Porous Clay by J.C. Ruge, A. López, F.A. Molina-Gómez, R.P da Cunha and J.E. Colmenares: This paper addresses numerical simulations of K0 triaxial tests performed using a single element program. The methodology was based on construction of numerical models with three different constitutive models in order to represent the soil behaviour during stress path states. The constitutive models used were (i) the Mohr-Coulomb, (ii) the Cam-Clay, and (iii) a hypoplastic model. The material used was a collapsible porous Brazilian clay. The values obtained were compared and calibrated with experimental data. Results show that it is possible to assess soil behaviour via a single element program and that triaxial K0 stress path tests can be simulated with numerical methods. Results show that it is possible to replicate and calibrate soil behaviour under zero lateral displacement using computational tools.

Editors:
Dominic Ong
San Shyan Lin &
Ooi Teik Aun

ACKNOWLEDGEMENT

Thirteen papers are contained in this issue. No doubt the material contained herein would be most valuable to our profession. The editors have adequately described the contributions in the preface. They are to be congratulated for these contributions.

Dr. Teik Aun Ooi
Prof. San Shyan Lin
Prof. Kwet Yew Yong
Dr. Noppadol Phienwej
Prof. A. S. Balasubramaniam

GEOTECHNICAL ENGINEERING

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Dominic Ong, San Shyan Lin & Ooi Teik Aun

TABLE OF CONTENTS

Cover Photograph

1. Seismic Microzonation of Cox's Bazar Municipal Area Bangladesh: Figure 8 Microzonation map based on regional distribution of liquefied areas
(After A. Imtiaz, A. Barua, M. Sakib and M.A. Ansary, 2018)

2. Geophysical Investigation in Bukit Merah Reservoir: Figure 4 Resistivity image for section under check pier alignment
(After M. R. Selamat, A. Shafie, R. Saad, and M. M. Nordiana, 2018)

3. Bearing Capacity and Settlement Study on Small-Scale Piled-Raft Groups in Sand: Figure 3 Laboratory tests setup: (b) Installation of 2×2 group piled-raft; (c) Installation of 3×3 group piled-raft; (d) Raft installation of 3×3 group piled-raft with load cells
(After Sengara, IW., Roesyanto, Krisnanto, S., Jayaputra, A. A., and Irsyam, M., 2018)

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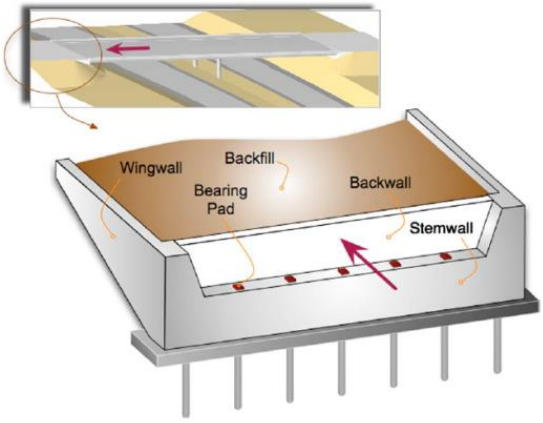


Figure 1 Typical seat type bridge abutment
(After M. Ramalakshmi and G. R. Dodagoudar, 2018)

Figure 2(b) View of the equipment during one of the tests
(After Maria P.S. Susunaga, Ennio M. Palmeira and Gregório L.S. Araújo, 2018)

Figure 1 (a) Ballast breakage in a rail track
(b) Buckling of track due to insufficient lateral confinement
(After Indraratna et al. 2011);
(Qouted by Syed Khaja Karimullah Hussaini, Buddhima Indraratna, and J. S. Vinod, 2018)

GEOTECHNICAL ENGINEERING

PREFACE

There are sixteen papers in this Issue; the first paper is by Akshay Kumar Jha, M.R. Madhav and GVN Reddy on Analysis of Effect of Reinforcement on Stability of Slopes and Reinforcement Length optimization: Steepening of slopes for construction of rail/road embankments or for widening for other civil engineering structures is a necessity for development. Use of geosynthetics for steep slope construction or repair of failed slopes considering all aspects of design and environment could be a viable alternative to these problems. Literature survey indicates that efforts are being made for optimization of length of reinforcement for overall economy. The present paper details an analysis to optimize the length of geosynthetic reinforcement from the face or near end of the slope with respect to its location to obtain the desired minimum factor of safety. Unreinforced and reinforced slopes are analyzed using Morgenstern-Price method to obtain critical factors of safety. The effect of providing geosynthetic reinforcement layer in shifting the critical slip circle has been identified and quantified. Consequently relatively smaller magnitude of force gets mobilized in the reinforcement.

The second paper is by V. Vinay Kumar and S. Sireesh on Fatigue Performance of Geosynthetic Reinforced Two-Layered Asphalt Concrete Beams: One of the most common rehabilitation techniques adopted for distressed pavements is hot mix asphalt (HMA) overlay. It is often practiced to include geosynthetic interlayers before placing an HMA overlay. The interlayers in HMA overlay not only improves the performance life of the pavement structure by increasing the stiffness, but also, reduces the maintenance cost and the cost of construction by reducing the thickness of HMA overlay. In the current study, the performance of geosynthetic reinforced two layered asphalt beams is evaluated in two stages. During the first stage, the fatigue performance of the two layered asphalt beams is evaluated using a flexural fatigue test (four point bending). During the second stage, the fracture energy required for crack propagation in the beams during fatigue loading and the corresponding tensile stiffness of two layered asphalt beams with and without geosynthetic interlayers are determined using Fenix test. Three types of geosynthetics, namely biaxial polyester grids, woven geo-jute mat and biaxial polypropylene grids are used in the study. The results from fatigue and Fenix tests indicated that the fatigue life and the tensile stiffness of the geosynthetic reinforced asphalt beams have drastically increased against the control specimens. A 30 times increase in fatigue life is noticed in polyester grid reinforced asphalt beams against unreinforced beams at 10 mm vertical deformation, which is attributed to the increase in tensile stiffness of the specimens from 7.3 kN/mm to 17.6 kN/mm. A linear regression equation is proposed to correlate the normalized complex modulus and tensile stiffness index to estimate the complex modulus of the geosynthetic reinforced asphalt beams.

The third paper by Priti Maheshwari and G. L. Sivakumar Babu is on Deformation Response of Geocells in Pavements under Moving Loads**:** Geocells are extensively used in pavements as one of the ground improvement techniques. Pavements are subjected to various types of loading pattern and its deformation under these loads plays an important role in its analysis and design. In the present work, a deformation model of geocell has been proposed in which geocell has been idealized as an infinite beam subjected to a concentrated load moving with constant speed. The foundation soil has been modeled as Winkler springs. Influence of magnitude and speed of applied load, flexural rigidity of geocell, modulus of subgrade reaction of foundation soil, mass of beam, viscous damping and interfacial resistance between geocell reinforcement and the neighboring soil on response of geocell has been studied. Non-dimensional charts have been developed for normalized deflection and the bending moment in geocell reinforcement. These charts will be useful while analyzing and designing the pavements under moving loads. A numerical example has also been presented for the better understanding of results from the proposed model.

In the paper (fourth one) by K. Deb on Effect of Multilayered Geosynthetic Reinforcements on the Response of Foundations resting on Stone Column-Improved Soft Soil**:** The present paper pertains to the

development of a mechanical model based on soil-structure interaction to study the effect of multilayered geosynthetic reinforcements on the behaviour of footings resting on stone column-improved soft soil. The footing is idealized as a beam. The soft soil and granular layer are idealized as nonlinear spring-dashpot and Pasternak shear layer, respectively. The geosynthetic reinforcements are modelled by elastic membranes. The stone columns are idealized by nonlinear springs. The governing differential equations are solved by finite difference method and results are presented in non-dimensional term. It is observed that multilayered-reinforced system is not effective for settlement reduction, but it is effective for bending moment and shear force reduction. However, for higher modular ratio (>40), the multilayered-reinforced system is not useful for maximum bending moment reduction. As the modular ratio increases positive bending moment at the centre of the beam decreases and the positive bending moment of the beam above middle of the stone column becomes negative. The negative bending moment of the beam above middle of the stone column increases as the modular ratio increases. The maximum shear force is observed for s/b_w ratio 3 and 5 corresponding to the modular ratio 10 and 100, respectively.

The fifth paper is on A Critical Review of the Performance of Geosynthetic-Reinforced Railroad Ballast by Syed Khaja Karimullah Hussaini, Buddhima Indraratna, and J. S. Vinod: In the recent times, railway organizations across the world have resorted to the use of geosynthetics as a low-cost solution to stabilize ballast. In this view, extensive studies have been conducted worldwide to assess the performance of geosynthetic-reinforced ballast under various loading conditions. This paper evaluates the various benefits the rail industry could attain because of the geosynthetic reinforcement. A review of literature reveals that geogrid arrests the lateral spreading of ballast, reduces the extent of permanent vertical settlement and minimizes the particle breakage. The geogrid was also found to reduce the extent of volumetric compressions in ballast. The overall performance improvement due to geogrid was observed to be a function of the interface efficiency factor (α). Moreover, studies also established the additional role of geogrids in reducing the differential track settlements and diminishing the stresses at the subgrade level. The geosynthetics were found to be more beneficial in case of tracks resting on soft subgrades. Furthermore, the benefits of geosynthetics in stabilizing ballast were found to be significantly higher when placed within the ballast. The optimum placement location of geosynthetics has been reported by several researchers to be about 200-250 mm below the sleeper soffit for a conventional ballast depth of 300-350 mm. A number of field investigations and track rehabilitation schemes also confirmed the role of geosynthetics/geogrids in stabilizing the tracks thereby helping in removing the stringent speed restrictions that were imposed earlier, and enhancing the time interval between maintenance operations.

In the sixth paper on the Performance of Geosynthetic Reinforced Model Pavements under Repetitive Loading is by K. H. Mamatha, S. V. Dinesh and B. C. Swamy: In this paper, the effectiveness of geosynthetic reinforcement materials such as geogrids and geocells in improving the pavement performance is investigated by carrying out a series of repeated load tests on unreinforced, geogrid and geocell reinforced model pavement sections. The effect of properties of geogrids and geocells on the improved performance is also studied. The provision of geogrid/geocell at the interface of subgrade and sub-base course is found to reduce the plastic settlement significantly with geocells being very effective when compared with geogrids. The reduced plastic settlement results in reduced rutting at the surface leading to increased service life of the pavements and also increased ride comfort to the road users. The geocells reinforcement results in higher TBR values when compared with that of geogrid.

The seventh paper by M. Ramalakshmi and G. R. Dodagoudar is on Lateral Response Analysis of GRS Bridge Abutments under Passive Push: The objective of this study is to analyse the response of Geosynthetic Reinforced Soil (GRS) bridge abutments under lateral push towards the backfill. Hypoplastic constitutive model is adopted as the user defined material model in the subroutine, VUMAT, to represent the soil behaviour in finite element (FE) analysis. The unreinforced abutment and GRS abutments of eighteen different configurations are modelled using FE approach and analysed for static passive push up to a maximum lateral displacement of 0.3 m. The passive force-displacement curves are obtained to study the lateral response of the GRS abutments. The curves for different GRS configurations lie closer to each other

up to a lateral displacement of 0.1 m, beyond which their passive resistances vary. The GRS abutments with geogrid spacing, s = 0.2 m and geogrid length to abutment height ratio, L/h = 3 performed well as compared to the other cases.

The subsequent paper eight in the series is by H. Venkateswarlu and A. Hegde on Numerical Analysis of Machine Foundation Resting on the Geocell Reinforced Soil Beds: The foundation beds are often subjected to dynamic loads due to many circumstances, such as earthquakes, traffic loads, and the machine vibrations in the case of the machine foundations. Excessive vibrations caused by the dynamic sources can lead to the structural damage of the foundation soil. Over the years, geosynthetics have been effectively used in reducing the settlement of the foundations under static loads. However, the performance of geosynthetics is not fully analyzed under the dynamic loads. In the present study, the numerical analyses have been carried out to understand the performance of the machine foundations resting on the geocell reinforced beds. The analyses were carried out by using finite element software PLAXIS 2D. The hypothetical case of the circular machine foundation of 1 m diameter resting on the saturated silty sand was analyzed. Mohr-Coulomb failure criteria was used to simulate the behavior of the soil. Initially, the numerical model was validated with the existing results reported in the literature. The validated numerical model was further used to investigate the performance of the machine foundations. Three different cases, namely, unreinforced, geogrid reinforced and geocell reinforced were considered. The response of all the cases was studied by varying the frequency of dynamic excitation and maintaining the constant force amplitude. The depth of the placement of the geocell and geogrid was also varied. At the optimum location of geocell, 61% reduction in the displacement amplitude was observed as compared to unreinforced foundation bed. Similarly, as compared to geogrid, more than 50% reduction in the displacement was observed in the presence of geocell. In addition, 40% reduction in peak particle velocity was observed in the presence of geocell at the center of the footing. The resonant frequency was found to vary with the reinforcement system. Furthermore, 163% increase in the damping ratio of the soil was observed in the presence of geocell. In this way, the study highlights the possible new applications of geocell in supporting the machine foundations.

B. Giridhar Rajesh, S. K. Chukka, and A. Dey are the authors of the ninth paper on Finite Element Modelling of Embankment Resting on Soft Ground Stabilized with Prefabricated Vertical Drains: This paper presents the numerical modelling of embankment resting on soft soil improved by the use of prefabricated vertical drains (PVDs). The study has been validated with the field measurements of settlements and excess pore pressures for a trial embankment at the Krishnapatnam Ultra Mega Power Project (KUMPP) in Nellore, Andhra Pradesh, India. The paper elaborately highlights the intricate effect of various parameters such as the drain spacing, reduction of permeability due to smear, and the efficiency of floating drains. Two dimensional finite element modelling was carried out using PLAXIS 2D. In the analysis, classical axisymmetric solution for consolidation by vertical drains has been converted into an equivalent two-dimensional plane strain analysis. The comparatives reflect the agreements and differences between the field measurements and the results obtained from the numerical model. Based on the results, the state of smear prevailing in the field has been identified. The numerical study suggests that the optimal length of the partially penetrating drains (75-80% of the full penetration) would be efficient in aiding sufficient vertical consolidation of the soft soil site, thus making its usage more economical.

The tenth paper is by H. Rahardjo, N. Gofar, F. Harnas and A. Satyanaga on Effect of Geobags on Water Flow through Capillary Barrier System: Capillary barrier is a two-layer cover system consisting of fine over coarse materials designed to protect slope from rainfall-induced failure. Previous studies have shown that the capillary barrier system (CBS) is effective for protection of gentle slopes, but the application of CBS on steep slopes requires further study. The fine materials are wrapped with geobags before laying them on top of the coarse materials. In this case, the bags serve as the separator between the fine and coarse materials. This paper highlights the effect of geobags on the effectiveness of CBS consisting of fine sand (Sand) as the

fine material and reclaimed asphalt pavement (RAP) as the coarse material. Soil column tests were performed for two configurations (1) Sand overlying RAP (no-geo) and (2) Sand overlying RAP with geobags inserted at the interface (geo). The soil column was instrumented with tensiometer-transducer system, moisture sensors and electronic balance to measure pore-water pressures (PWP), volumetric water content (VWC) and outflow, respectively. Numerical simulations were carried out to support the findings from the soil column tests. Results of the soil column tests and numerical analyses on both configurations showed that the presence of geobags at the interface of Sand and RAP does not affect the effectiveness of CBS as slope protection from rainfall infiltration.

Sanjay Nimbalkar, Sujit Kumar Dash, and Buddhima Indraratna are the authors of the eleventh paper on Performance of Ballasted Track under Impact Loading and Applications of Recycled Rubber Inclusion: In this paper a review of the sources of impact loads and their effect on the performance of ballasted track is presented. The typical characteristics and implications of impact loading on track deterioration, particularly ballast degradation, are discussed. None of the procedures so far developed to design rail track incorporate the impact that dynamic loading has on the breakage of ballast and therefore it can be said to be incomplete. An intensive study on the impact of induced ballast breakage is needed in order to understand this phenomenon and then use the knowledge gained to further advance the design methodology. A stiff track structure can create severe dynamic loading under operating conditions which causes large scale component failure and increases maintenance requirements. Installing resilient mats such as rubber pads (ballast mat, soffit pad) in rail tracks can attenuate the dynamic force and improve overall performance. The efficacy of ballast mats to reduce structural noise and ground vibration has been studied extensively, but a few recent studies has reported how ballast mats and soffit pads reduce ballast degradation, thus obviating the necessity of a comprehensive study in this direction.

Twelfth in the series is the paper, Probabilistic Stability Analyses of Reinforced Slope Subjected to Strip Loading, by Koushik Halder and Debarghya Chakraborty. Studied herein is the effect of uncertainty associated with soil friction angle (ϕ) and soil unit weight (γ) on the stability of unreinforced and reinforced cohesionless soil slopes subjected to strip loading. The magnitude of *CoV* of ϕ and γ are varied to account uncertainties. The location of the footing on the top of the slope is also changed. Stability of both unreinforced and reinforced slopes is presented in terms of factor of safety (*FoS*). Deterministic *FoS* values are computed first by using a two-dimensional finite difference software FLAC. To perform probabilistic analyses, FLAC is combined with Monte Carlo simulations. The outcomes of the probabilistic analyses are presented in terms of probability of failure (p_F) and reliability index (β). The value of β obtained from the present study is compared with the guidelines provided by USACE. It is found out that with the increase in the value of *CoV*, p_F increases and β decreases. The failure probability of slope is found to be maximum, when footing is placed on the edge of the unreinforced slope. With the inclusion of a single layer of geotextile in the slope for the same footing position, p_F reduces drastically, and β increases significantly. As footing position shifts from the slope edge, p_F increases for a particular *CoV* value of ϕ and γ. The effect of uncertainty related to ϕ is found to be more prominent with compared to the uncertainty related to γ. The influence of cross-correlation between ϕ and γ is also studied. It is found that there is no significant change in the value of p_F with the change in the value of cross correlation coefficient. Though the present study is related to a simple slope stability problem, but using the same methodology, probabilistic analyses of complex slopes can also be performed.

The thirteenth paper by J. Scalia IV, C.A. Bareither, and C.D. Shackelford is on Advancing the Use of Geosynthetic Clay Liners as Barriers: Geosynthetic clay liners (GCLs) are effective barrier materials for liner and cover systems in waste containment applications. Exposure to non-standard chemical solutions can alter the chemical and mechanical properties of both the bentonite and geotextiles comprising a GCL. Considerable advances in laboratory testing and analysis of GCLs have occurred recently in regard to hydraulic conductivity, the existence and persistence of membrane behavior, and long-term shear strength of GCLs evaluated under stress-controlled conditions. The objective of this paper is to present a synopsis of advances in research related to GCLs that is focused on enhancing knowledge of GCLs used as hydraulic and chemical contaminant barriers.

G. Bräu and S. Vogt are the authors of the fourteenth paper on Field and laboratory tests on the bearing behaviour of unpaved roads reinforced by different geosynthetics**:** Field experiences have shown that the use of geosynthetics improves the trafficability of unpaved roads on soft subsoil. Furthermore, the height of the base course and therefore the amount of high quality geomaterials e.g. crushed gravel can be reduced. Until now, the design is mainly based on empirical approaches. The height of the base course is increased until the unpaved road reaches a proper bearing behaviour or it is decided to use a certain base course height that gives mostly conservative results. There are plenty of examinations shown throughout the literature, confirming the principle of bearing mechanism but mostly cover only individual effects. Therefore, they cannot be extended to an overall theory and design approach that account for all important variables. In a completed research, series of loading tests on geotextile reinforced unpaved roads were carried out both in laboratory and in field. Beside the bearing strength and stiffness respectively of the soft subsoil, the base course height as well as the type and hence strength of the geosynthetics were varied in the test series. This paper presents a brief summary of the experimental results that may be used to evaluate models that aim for the prediction of the bearing capacity of unpaved roads.

The fifteenth paper is by Maria P.S. Susunaga, Ennio M. Palmeira & Gregório L.S. Araújo on Performance of nonwoven geotextiles as separators for pavement applications**:** Geosynthetics can be used in several applications in geotechnical and geoenvironmental engineering, being geotextiles the most traditional and versatile type of geosynthetic. One of the applications of geotextiles is in separation between good and poor quality soils. This situation may occur in geotechnical structures such as roads and railways constructed on soft saturated subgrades. The presence of a geotextile separator avoids or minimize the contamination of the good quality base or ballast material with fines from the subgrade, increasing the life of the road and reducing maintenance costs. Despite its importance, very few studies on the behaviour of geotextiles in separation can be found in the literature compared to other applications of these materials. This paper investigates the performance of nonwoven geotextiles in separation. Laboratory tests on geotextiles with masses per unit area ranging from 200 g/m^2 to 600 g/m^2 were executed using an apparatus capable of applying repetitive loading to simulate traffic conditions. Measurements of surface displacements and pore pressures in the subgrade soil and the evaluation of geotextile mechanical damages at the end of the tests were carried out. The results obtained showed that the geotextiles were effective separators, avoiding contamination of the base soil and accelerating the dissipation of excess pore pressures in the subgrade soil.

The sixteenth paper is by Tjie-Liong GOUW on Geosynthetics Application in Indonesia – A Case Histories
The first application of geosynthetics technology in Indonesia was back in 1983, where a high strength geotextile of 200 kN/m was laid to help stabilize the highway built on swampy land toward Soekarno Hatta airport, the gateway to Indonesia. Since then, geosynthetics have been gaining popularity in solving challenging ground conditions for civil engineering development, e.g. stabilization of road development over peat deposits, accelerating consolidation of soft clay, stabilization of foundation over expansive clays, slope stabilization over clay shales formation, retaining walls, ponds lining, breakwater, shore protection and river bank stabilization, etc. This paper presents the author experiences in applying geosynthetics technology in building geotechnical construction over difficult ground condition such as peat, soft clay, expansive soils, and clay shales. It also presents the application of geosynthetics tubes (geotubes) to build containment dykes over soft marine clays.

Sujit Kumar Dash (Lead Editor),
Alfrendo,
Darren Chian &
San Shyan Lin

ACKNOWLEDGEMENT

Sixteen papers are contained in this issue. No doubt the material contained herein would be most valuable to our profession. The editors have adequately described the contributions in the preface. They are to be congratulated for these contributions.

Dr. Teik Aun Ooi
Dr. Sujit Kumar Dash
Prof. San Shyan Lin
Prof. Kwet Yew Yong
Dr. Noppadol Phienwej
Prof. A. S. Balasubramaniam

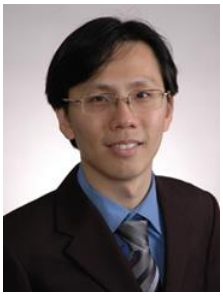
GEOTECHNICAL ENGINEERING

December 2018: Geosynthetics

Edited by: SUJIT KUMAR DASH (LEAD EDITOR), ALFRENDO, DARREN CHIAN & SAN SHYAN LIN

Sujit Kumar Dash

Dr. Sujit Kumar Dash is currently a faculty member in the department of civil engineering, Indian Institute of Technology Kharagpur, India. He is a geotechnical engineer by profession and obtained Ph.D. for his work on geocell reinforced foundations, in the year 2001, from the Indian Institute of Technology Madras. He was a visiting fellow at the Technical University of Munich, Germany and University of Wollongong, Australia. He has received the German Academic Exchange Service Fellowship and the Australian Endeavour Research Fellowship. Dr. Dash has published more than 80 papers in various journals and peer reviewed conference proceedings. His papers on geosynthetics and allied construction products have received the Indian Geotechnical Society best paper award.



Siau Chen Chian (Darren)

Dr. Chian is an Assistant Professor at the Department of Civil and Environmental Engineering, National University of Singapore. He received his PhD and BEng with gold medal from Cambridge University and Nanyang Technological University respectively. His research interests are in earthquake engineering and ground improvement. Dr. Chian's contribution in earthquake engineering lies in the field of damage vulnerability of underground structures in earthquake induced soil liquefaction. He was funded by the UK Engineering and Physical Sciences Research Council (EPSRC) to carry out reconnaissance missions at the 2009 Padang, 2011 Tohoku and 2016 Muisne earthquakes. Dr. Chian is also an enthusiast of recycling waste material to good use. He is actively involved in collaborative research projects with local government agencies to recycle unwanted and contaminated soils from underground construction projects and sea dredging as construction and fill materials. He is a nominated member of three International Technical Councils under the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE). Dr. Chian also sits in the technical committee of SPRING Singapore to oversee and provide advice on geotechnical engineering practices in Singapore. He is presently the Vice President of the Geotechnical Society of Singapore (GeoSS). Dr. Chian has been invited to speak in a number of international conferences in Singapore, Malaysia and India. Recently, Dr. Chian's research work at NUS led to his award of the prestigious Top 10 Innovators Under 35 in Asia by the MIT Technology Review in 2016. Other achievements include a 1st Prize in a National Technical Paper

Competition and the Best Young Researcher Award at the 8th International Conference on Urban Earthquake Engineering.

Alfrendo Satyanaga

Dr Alfrendo Satyanaga is currently a Senior Research Fellow at School of Civil and Environmental Engineering, Nanyang Technological University, Singapore. He has over 15 years of civil engineering experience as a geotechnical engineers, consultant and researcher in design, mathematical and numerical modelling as well as laboratory testing. His area of expertise includes unsaturated soil mechanics, slope stability analysis, foundation design, site investigation and soil characterization, geotechnical instrumentation and finite element analyses. He has served as a consultant on various projects to several engineering firms in Singapore, Australia and Indonesia. Dr. Alfrendo holds PhD degree from the Nanyang Technological University, Singapore and Master degree from the Newcastle University, United Kingdom. He has published and presented more than 40 technical papers in international journals and conferences. For innovation in developing a new system to optimize space and improve the liveability in Singapore using urban greenery, Dr Alfrendo has been conferred “the Minister (ND)'s R&D Award (Special Mention Category)” in June 2017.

San Shyan Lin

Prof. San-Shyan Lin graduated from Chung Yuan University with a BSCE degree in 1981. He then obtained his master degree from Utah State University, Logan, Utah in 1985 and his PhD from Washington University in St. Louis, Missouri in 1992. Before his teaching career at university, Dr. Lin served as an engineer at Taiwan Area National Expressway Engineering Bureau between1992 to1994. Dr. Lin has been serving at Department of Harbor and River Engineering (DHRE) of National Taiwan Ocean University (NTOU) since 1994. He was promoted as a full professor in 2000. Thereafter, he took some university duties by serving as the secretary-general at office of the secretariat between 2001 and 2003; the chairman of DHRE between 2005 and 2006; the acting dean of college of engineering in 2007 and the vice president of NTOU between 2006 and 2012.

Prof. Lin served as a committee member of committee A2K03-Foundations of Bridges and Other Structures of TRB, USA between 1995 and 2004. Currently, he is still serving as a committee member of TC-212 and ATC-1 of ISSMGE and as an editorial board member of four international journals. In addition, Dr. Lin also served as the president of Taiwan Geotechnical Society (2011-2013); Chairman of International Geosynthetics Society- West Pacific Regional Chapter (2002-2004); CEO of Sino-Geotechnics Foundation (2011-2014) etc. Dr. Lin received the distinguished alumnus award from Chung Yuan University in 2009 and the distinguish Engineering Professor Award from Taiwan Pavement Engineering Society in 2011. Prof. Lin’s research and practical experiences have been dealt with deep foundations and geosynthetics.

GEOTECHNICAL ENGINEERING

December 2018:

Edited by

SUJIT KUMAR DASH (LEAD EDITOR), ALFRENDO, DARREN CHIAN & SAN SHYAN LIN

TABLE OF CONTENTS

COVER PHOTOGRAPH

1. Figure 1. Typical seat type bridge abutment
(After M. Ramalakshmi and G. R. Dodagoudar, 2018)

2. Figure 1(a). Ballast breakage in a rail track (b) Buckling of track due to insufficient lateral confinement
(After Indraratna et al. 2011);
(Qouted by Syed Khaja Karimullah Hussaini, Buddhima Indraratna, and J. S. Vinod, 2018)

3. Figure 2(b). View of the equipment during one of the tests
(After Maria P.S. Susunaga, Ennio M. Palmeira and Gregório L.S. Araújo, 2018)