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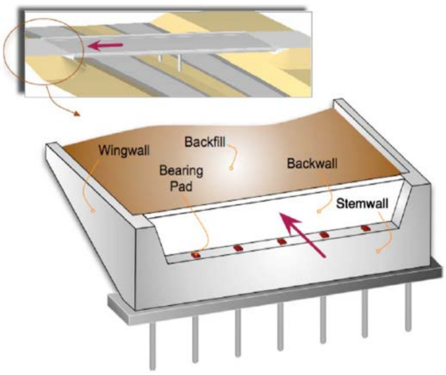

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(After M. Ramalakshmi and G. R.

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(After Maria P.S. Susunaga, Ennio M. Palmeira and Gregório L.S. Araújo, 2018)

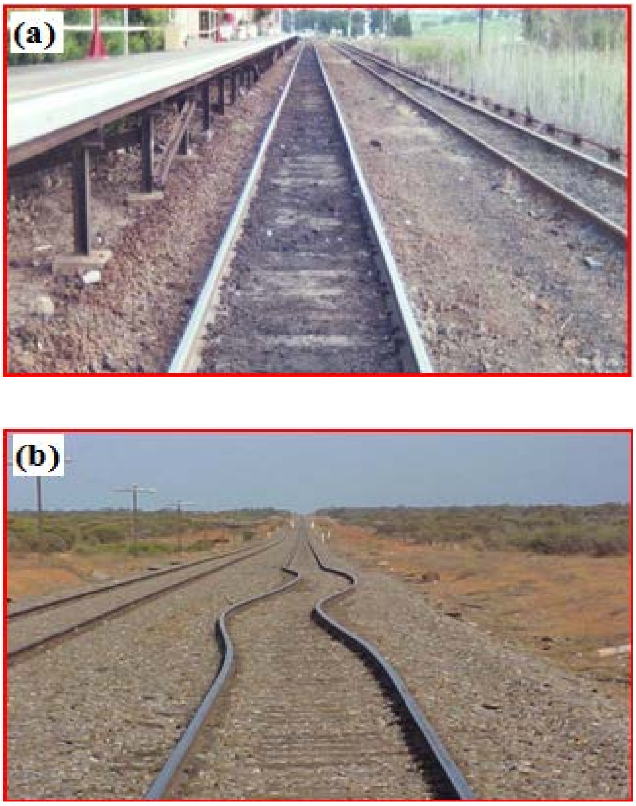

Figure 1 (a) Ballast breakage in a rail track
(b) Buckling of track due to insufficient lateral confinement (After Indraratna et al. 2011);
(Qouted by Syed Khaja Karimullah Hussaini, Buddhima Indraratna, and J. S. Vinod, 2018)

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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.

Finally the last paper sixteenth is by Tjie-Liong GOUW on Geosynthetics Application in Indonesia – A Case Histories: The first application of geosynthetics technology 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

Fifteen 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

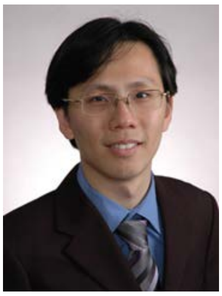
GEOTECHNICAL ENGINEERING

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.

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