《Geosynthetics and Geomembranes》

(土工织物与土工膜)

<双月刊>

2021年第49卷第5期

摘要集

中国土工合成材料工程协会秘书处

目　录

Design of geocell reinforced roads through fragility modeling

Sundeep Inti[a], Vivek Tandon[b]
a Department of Technology, Illinois State University, Normal, IL, USA
b Department of Civil Engineering, The University of Texas at El Paso, El Paso, TX, USA

Abstract: Several studies have confirmed the geocell reinforcement system as potential road material. However, there is a wide gap between the number of research studies evaluating the geocell in the laboratory and those dealing with road design methods using the geocell. Due to this gap, the geocell system has not reached its full potential in highways. The present study proposes fragility modeling to design low volume roads by considering the geocell reinforced layer's modulus. A predictive model was developed to estimate the geocell layer's modulus using laboratory and finite element analysis results. The results indicate that geocell reinforcement reduces the stresses on the underlying road layers. The developed fragility approach is then used to examine three road designs for Texas's low volume road involving different geocell reinforced layers. The obtained fragility curves indicate the reliability of each of the three road designs against the traffic load and can thereby assist decision-makers in selecting the optimum design. By designing geocell reinforced roads via fragility modeling, highway officials will be able to integrate any uncertainties in the design inputs and check designs against road performance criteria such as rutting and fatigue cracking, and against decision criteria such as cost, emissions, etc.
Keywords: Geocell, Fragility curve, Modeling, Low volume roads

Performance enhancement of encased stone column with conductive natural geotextile under k0 stress condition

B.K. Pandey, S. Rajesh, S. Chandra
Department of Civil Engineering, Indian Institute of Technology Kanpur, Kanpur, 208016, India

Abstract: In this study, the performance of the stone column encased with conductive jute geotextile in improving the characteristics of soft clay under k0 stress condition was evaluated using a custom-designed large-scale consolidation test setup. The electrokinetic-encased stone column (e-ESC) was designed as a cathode, while mild steel rods were chosen as anodes, and by applying a voltage gradient of 0.1 V/mm between the electrodes, electrokinetic processes were initiated. The efficacy of using the e-ESC in improving the performance of soft clay was assessed by comparing the results with an ordinary stone column (OSC) and encased stone column (ESC) reinforced soft clay. The results from the study reveal that the inclusion of stiffer material like OSC and ESC in soft clay has significantly increased undrained shear strength and modulus of subgrade reaction of the composite ground with a reduction in settlement and compression index. Due to the application of the voltage gradient between the electrodes, the rate of consolidation settlement of composite ground has significantly increased when compared to the OSC/ESC case. Further, it was confirmed from the chemical and mineralogical analysis that the pH, chemical composition, mineral phases, and microfabric of soft clay were altered with the voltage gradient.

Keywords: Jute geotextile, Encased stone column, Soft clay, Electrokinetic-ESC, Settlement, Strength

Analytical solutions for geosynthetic-encased stone column-supported embankments with emphasis on nonlinear behaviours of columns

Yang Zhou[a], Gangqiang Kong[a,b], Junjie Zheng[c], Lei Wen[a], Qing Yang[d]
a Key Laboratory of Ministry of Education for Geomechanics and Embankment Engineering, Hohai University, Nanjing, 210098, China
b Key Laboratory of Geological Hazards on Three Gorges Reservoir Area of Ministry of Education, China Three Gorges University, Yichang, Hubei, 443002, China
c Institute of Geotechnical and Underground Engineering, Huazhong University of Science and Technology, Wuhan, 430074, China
d State Key Laboratory of Coastal and Offshore Engineering, Dalian University of Technology, Dalian, 116085, China

Abstract: This paper presents an analytical approach to predict the behaviours of geosynthetic-encased stone column (GESC)-supported embankments. The soil arching in the embankment and the nonlinear behaviours of stone columns are considered. Based on nonlinear elastic and elastoplastic constitutive models of stone columns, the nonlinear behaviours of GESCs, including settlement and radial deformation, are analysed. The deformations of GESCs, the surrounding soil, and the overlying embankment fill are compatible by applying stress continuity and volume deformation continuity at the bottom of the embankment fill. This method is verified via comparison with literature data and numerical analysis. The influences of parameters of the GESC, including encasement stiffness and column friction, on the performance of the embankment are investigated. Without considering the nonlinear behaviours of the column, the column-soil stress ratio is overestimated. It is more appropriate that the nonlinear characters of the column be considered in the analysis of GESC-supported embankments.
Keywords: Geosynthetics, Stone columns, Radial bulging, Embankment, Stress

The influence of geosynthetic reinforcement on the mechanical behaviour of soil-pipe systems

Ana C.G. Pires, Ennio M. Palmeira
University of Brasília, Department of Civil and Environmental Engineering, Faculty of Technology, 70910-900, Brasília, DF, Brazil

Abstract: Buried pipes may transport substances that can be harmful to people and the environment. These structures may be subjected to damages caused by soil movements and external interference, such as surcharges and excavations. Different applications of geosynthetics have demonstrated that they can be used to protect buried pipes and to minimize the consequences of pipe burst. This paper discusses results of largescale laboratory tests on a flexible pipe buried in unreinforced and geosynthetic reinforced soils subjected to surface surcharges. The pipes were buried in a cohesionless soil and different types of reinforcements were tested, with a wide range of tensile stiffness values. The results obtained show that the arrangement of the reinforcement enveloping the pipe reduced significantly pipe displacements and deflections. The efficiency of the reinforcement depended on its type and physical and mechanical properties. The open geogrid tested showed less reinforcement efficiency due to the passage of soil particles through its aperture during the tests. A theoretical solution available for pipes in unreinforced soils was extended to the reinforced situation with good agreement between predictions and measurements and showed that the presence of the reinforcement is equivalent to the pipe being buried in a significantly stiffer unreinforced soil.

Keywords: Geogrids, Geotextiles, Buried pipes, Pipe deflections, Surcharge

Hydraulic conductivity of bentonite-polymer geosynthetic clay liners to coal combustion product leachates

Binte Zainab[a], Christian Wireko[b], Dong Li[a], Kuo Tian[c], Tarek Abichou[b]
a Department of Civil and Environmental Engineering, George Mason University, Fairfax, VA, 22030, USA
b Department of Civil and Environmental Engineering, Florida A&M University- Florida State University College of Engineering, 2525 Pottsdamer St., Tallahassee, FL, 32310-6064, USA
c Department of Civil, Environmental and Infrastructure Engineering, George Mason University, Fairfax, VA, 22030, USA

Abstract: Hydraulic conductivity of seven geosynthetic clay liners (GCLs) to synthetic coal combustion product (CCP) leachates were evaluated in this study. The leachates are chemically representative of typical and worst scenarios observed in CCP landfills. The ionic strength (I) of the synthetic CCP leachates ranged from 50 mM to 4676 mM (TCCP-50, LRMD-96, TFGDS-473, LR-2577, HI-3179 and HR-4676). One of the GCLs contained conventional sodium bentonite (Na–B) and the other six contained bentonite-polymer (B–P) mixture with polymer loadings ranging from 0.5% to 12.7%. Hydraulic conductivity tests were conducted at an effective confining stress of 20 kPa. The hydraulic conductivity of the Na–B GCLs were >1 × 10− 10 m/s when permeated with all six CCP leachates, whereas the B–P GCLs with sufficient polymer loading maintained low hydraulic conductivity to synthetic CCP leachates. All the B–P GCLs showed low hydraulic conductivity (<1 × 10− 10 m/s) to low ionic strength leachates (TCCP-50, I = 50 mM and LRMD-96, I = 96 mM). B–P GCLs with P > 5% showed low hydraulic conductivity (<1 × 10− 10 m/s) up to HI-3179 leachates. These results suggest that B–P GCLs with sufficient polymer loading can be used to manage aggressive CCP leachates.

Keywords: Bentonite-polymer (B–P), Geosynthetic clay liners (GCLs), CCP leachates

Load-bearing performance of model GRS bridge abutments with different facing and reinforcement spacing configurations

Kianoosh Hatami, Ridvan Doger
School of Civil Engineering and Environmental Science, University of Norman, OK, USA

Abstract: The paper reports the construction and surcharge load-testing of three (3) large-scale (~2.50 m-tall) GRS bridge abutment models in an outdoor test station to investigate the influences that the facing type and reinforcement spacing could have on their load-bearing performance. The facing types examined included cored Concrete Masonry Units (CMU) in Model #1 and much larger solid concrete blocks in Models #2 and #3. Reinforcement spacing in the first two models was 0.20 m, whereas it was increased to 0.30 m in the third model. Results show that using large facing blocks in GRS abutments could lead to significant improvements in their load-deformation performance relative to those with the CMU facing alternative. This improvement was observed even in the case of model with increased reinforcement spacing. Therefore, use of larger facing blocks could also help reduce the cost of GRS abutments by reducing the need for tighter reinforcement.

Keywords: Geosynthetics, GRS-IBS, Bridge abutments, Large-scale model tests, Facing blocks, Reinforcement spacing

Two-dimensional consolidation analysis of geotextile tubes filled with fine-grained material

H.J. Kim[a], P.R. Dinoy[b]
a Department of Civil Engineering, Kunsan National University, Gunsan, 573-701, South Korea
b Department of Civil and Environmental Engineering, Kunsan National University, Gunsan, 573-701, South Korea

Abstract: In this study, a two-dimensional consolidation solution for geotextile tubes filled with fine-grained material was presented. The solution is based on a combination of various methods that were modified or extended to take into account the change in tube shape, the nonlinear interaction between the soil and geotextile, and the water content distribution of the tube during consolidation. Using the proposed solution, the effect of various necessary input parameters was investigated. Thereafter, numerous dewatering and consolidation properties of various combinations of geotextiles and fill materials were obtained from several tests such as the half cross-section test, hanging bag tests, and geotextile tube demonstration test. Results of the study have shown that the method presented in this study can well-represent the consolidation behavior of geotextile tubes filled with fine-grained material.

Keywords: Geosynthetics, Two-dimensional analysis, Dewatering, Geotextile tube, Fine-grained material, Waste disposal

Effect of wet-dry cycles on standard & polymer-amended GCLs in covers subjected to flow over the GCL

R. Kerry Rowe[a], Seba Hamdan[b]
a Barrington Batchelor Distinguished University Professor and Canada Research Chair in Geotechnical and Geoenvironmental Engineering, GeoEngineering Centre at Queen's – RMC, Department of Civil Engineering, Queen's University, Kingston, Canada, K7L 3N6, E
b GeoEngineering Centre at Queen's – RMC, Department of Civil Engineering, Queen's University, Kingston, Canada, K7L 3N6; E

Abstract: The performance of five different GCLs (two GCLs with standard sodium bentonite and three GCLs with polymer enhanced bentonite) subjected to three different climatic modes of wet-dry cycles simulating conditions to which a GCL might expose in cover systems over a prolonged time is reported. The wetting cycles lasted for 8 h, while the drying cycles varied between 16 h, seven days, and 14 days. It is shown that after around a year of accelerated aging, the hydraulic conductivity of the aged GCLs increased notably when permeated with tap water at an applied effective stress of 15 kPa for a range of heads (0.07, 0.14, 0.21, 0.49, and 1.2 m). The combined effects of the number and the duration of the wet-dry cycles, the GCL's mass per unit area, the carrier geotextile, the size and the number of the needle punch bundles, and the thermal treatment to bond the needle-punch bundles to the carrier geotextile are discussed. The poor hydraulic performance of the polymer-amended/modified bentonite GCLs is discussed.
Keywords: Geosynthetics, Geosynthetic clay liner, Wet-dry cycle, Cover, Polymer-amended bentonite, Hydraulic conductivity

Deformation of model reinforced soil structures: Comparison of theoretical and experimental results

Krystyna Kazimierowicz-Frankowska, Marek Kulczykowski
Institute of Hydro-Engineering, IBW PAN, ul. Ko´scierska 7, 80-328, Gda´nsk-Oliwa, Poland

Abstract: The problem of accurate prediction of deformations of reinforced soil structures under serviceable loading is discussed in this paper. First, a short overview of existing guidelines and methods is presented. Second, an analytical approach developed in IBW PAN to calculate horizontal and vertical deformations of such structures is described. Third, results of the verification of the proposed methodology are discussed. The modeling approach is validated against measured results from a literature review and an original laboratory program. Experimental studies under laboratory conditions were carried out to evaluate the accuracy of the proposed methodology. A model of a reinforced soil (RS) wall with a height of 0.5 m was constructed at a geotechnical laboratory and subjected to external loading. Horizontal deformations of the model RS wall were investigated at the end of construction and during the surcharge application (post-construction displacements). A theoretical analysis of the experimental results is elaborated on. A comparison of theoretical and experimental values of deformations is presented. The main conclusions are pointed out.
Keywords: Reinforced soil walls, Deformation, Serviceability limit state, Analytical methods

A multi-camera based photogrammetric method for three-dimensional full-field displacement measurements of geosynthetics during tensile test

Xiaolong Xia[a], Xiong Zhang[a], Chunmei Mu[b]
a Department of Civil, Architectural and Environmental Engineering, Missouri University of Science and Technology, 135 Butler Carlton Hall 1401 N. Pine Street, Rolla, MO, 65409-0030, USA
b College of Civil and Architectural Engineering, Guilin University of Technology, Guilin, Guangxi, 541004, PR China

Abstract: Conventional methods for measuring the deformational response of geosynthetics, such as the linear variable differential transformers (LVDTs), strain gauges, and extensometers have several limitations in fully determining the complete strain distribution in geosynthetics. This paper presents a multi-camera based photogrammetric method to track the 3D full-field displacements of geosynthetics during tensile tests. The proposed method extends the conventional one-camera based photogrammetry for static object measurements to multi-camera-based photogrammetry for object measurements with continuous movements or deformations. It is non-contact, cost effective, highly accurate, and capable of measuring the 3D full-field displacements of the geosynthetics. A tensile test on a geogrid specimen was performed to verify the effectiveness and accuracy of the proposed photogrammetric method. The results from the tensile tests using both the proposed method and conventional methods, such as machine-controlled displacement measurements and extensometer, were presented and compared. It was observed that the average absolute difference between the proposed photogrammetric method and the machine-controlled movements of the bottom clamp was 0.25%, and the average absolute error was 0.038 mm. The average difference in measurements made by the proposed method and extensometer was 0.07%. It was further found that the proposed method can provide more comprehensive input, such as the complete strain and modulus distributions in the geosynthetics, for a probability-based geosynthetics design.
Keywords: Geosynthetics, Multi-camera-based photogrammetric method, Full-field displacement measurement, 3D deformation, Dynamic tests

Use of geosynthetic clay liner as a remedial measure of claystone degradation in Lam Ta Khong hydropower plant

Suttisak Soralump[a], Avishek Shrestha[b], Apiniti Jotisankasa[a], Chinoros Thongthamchart[b], Rattatam Isaroran[b]

a Geotechnical Engineering Division, Department of Civil Engineering, Kasetsart University, Bangkok, 10900, Thailand

b Geotechnical Engineering Research and Development Center, Kasetsart University, Bangkok, 10900, Thailand

Abstract: In this study, the downstream slope of a dam impounding the upper reservoir of Lam Ta Khong (LTK) hydroelectric energy storage in Thailand was found to slide at a higher pace during the rainy season. After a thorough site investigation, laboratory tests, and numerical modeling to identify the main cause of the movement, it was found that as rainfall infiltrated the upper soil layer, the claystone of the downstream slope deteriorated when in contact with the water. As a remedial measure, 174,750 m2 of geosynthetic clay liner (GCL) was used to cover the entire downstream slope of the dam, and proved to be an effective and economical solution for reducing the ongoing movement. The GCL included a textured high-density polyethylene (HDPE) layer for improving the resistance and minimizing the slippage at the interface between the GCL and underlying rock. Before the dam's remediation, the settlement point demonstrated a movement of nearly 0.1 m/year. In contrast, after the placement of the GCL, almost all settlement points moved less than 0.1 m for a recorded period of more than 4 years.

Keywords: Geosynthetic clay liner, Ruzi grass, Claystone degradation, Lam Ta Khong

Pullout tests on diagonally enhanced geocells embedded in sand to improve load-deformation response subjected to significant planar tensile loads

Kazem Fakharian, Aref Pilban
Department of Civil & Environmental Engineering, Amirkabir University of Technology, Tehran, Iran

Abstract: This paper presents pullout test results on conventional (ordinary) and diagonally enhanced geocells under surcharge pressures of 3, 13, 23 and 33 kPa. Extensive pullout tests on scaled geocells embedded in silica sand are performed to investigate the effects of improvements on load-deformation response, strength and stiffness. Conventional web-shaped geocells are having a small stiffness when subjected to planar tension attributed to deformability of webs. Therefore, conventional geocells may not function properly when subjected to tensile forces along the main plane in service. A special geocell is fabricated in this study, similar to tendoned geocells, through adding diagonal members along the induced tensile load to overcome the shortcomings of conventional geocells. The test results have shown that both the stiffness and ultimate resistance of the diagonally enhanced geocells have significantly improved with respect to the conventional ones. Afterwards, three experiments were carried out on a small-scale shallow footing resting on sand reinforced with geocells, indicating improvement in bearing capacity as well as load-settlement response of footings supported by the diagonally enhanced geocells as compared to conventional geocells.

Keywords: Reinforced soil, Diagonally enhanced geocell, Geogrid, Pullout box, Interaction mechanism

Modified axial pullout resistance factors of geogrids embedded in pond ash

Bhargav Kumar Karnamprabhakara, Umashankar Balunaini
Department of Civil Engineering, Indian Institute of Technology Hyderabad, Kandi, Telangana, 502 285, India

Abstract: In the internal stability design of reinforced soil structures, the existing design provisions consider only axial pullout of the reinforcement. However, the kinematics of deformation clearly shows the reinforcement to be subjected to an oblique pull along the failure surface. The overall response due to oblique pull of reinforcement can be considered as cumulative individual responses of axial and transverse components of oblique pull. In the present work, the transverse pullout responses of four geogrids embedded in pond ash under three different normal stresses were studied. Geogrids considered varied in geometric and mechanical properties of the grids to study the effects of their tensile stiffnesses/strengths and opening sizes on transverse pull-displacement response. Based on extensive laboratory testing, transverse pullout resistance factors (Ft*) were proposed; additionally, empirical equations were proposed to estimate the transverse pullout resistances of geogrids in pond ash. F*t of the four geogrids in pond ash ranged between 0.08-0.31 and 0.21–0.99 at front-end transverse pullout displacements of 20 mm and 35 mm, respectively. Finally, sensitivity analysis was conducted to identify the parameters significantly influencing the transverse pullout resistance of geogrids. The effect of grid opening size on transverse pull of geogrid was observed to be minimal; while the tensile strength showed a significant effect.
Keywords: Transverse pullout, Oblique pullout, Modified pullout resistance factor, Pond ash, Waste management

Seismic behavior of geosynthetic-reinforced retaining walls backfilled with cohesive soil

I.E. Kilic[a], C. Cengiz[b], A. Edincliler[c], E. Guler[d]
a Department of Civil Engineering, Maltepe University, Istanbul, Turkey
b Ove Arup & Partners Int'l Ltd, 13 Fitzroy St, London W1T 4BQ, UK
c Kandilli Observatory and Earthquake Research Institute, Bogazici University, Istanbul, Turkey
d George Mason University, VA, USA

Abstract: This study investigates the seismic performance of geosynthetic-reinforced modular block retaining walls backfilled with cohesive, fine grained clay-sand soil mixture. Shaking table tests were performed for three ½ scaled (wall height 190 cm) and ¼ scaled model walls to investigate the effects of backfill type, the influence of reinforcement length and reinforcement stiffness effects. The El Centro and Kobe earthquake records of varying amplitudes were used as base acceleration. Displacement of the front wall, accelerations at different locations, strains on the reinforcements, and the visual observations of the facing and the backfill surface were used to evaluate the seismic performance of model walls. The model walls were subjected to rigorous shaking and the walls did not exhibit any stability problems or signs of impending failure. The maximum deformations observed on the models with cohesive backfill was less than half of the deformation of the sand model. The load transfers between the geogrid and cohesive soil was comparable to that of sand and hence the needed reinforcement length was similar as well. As a result; the model walls with cohesive backfills performed within acceptable limits under seismic loading conditions when compared with granular backfilled counterparts.

Keywords: Geosynthetics, Reinforced soil, 1-G shaking table test, Cyclic loading, Cohesive backfill

Water retention curves of a geosynthetic clay liner under non-uniform temperature-stress paths

Mayu Tincopa[a], Abdelmalek Bouazza[b]
a Universidad de Ingenieria y Tecnologia-UTEC, Jr. Medrano Silva 165, Barranco, Lima, Peru
b Department of Civil Engineering, 23 College Walk, Monash University, Vic, 3800, Australia

Abstract: This paper presents a novel suction-controlled chamber that permits the determination of the full water retention curves of geosynthetic clay liners (GCLs) under non-uniform temperature-stress paths. It investigates field conditions encountered in brine ponds (low confining stress settings) and heap leach pads (high confining stress settings) during construction and operation stages. Consequently, the analysis of the moisture dynamics in a GCL was defined under the wetting path (construction) and drying path (operation). High vertical stresses were found to facilitate a more rapid water uptake as capillarity is established faster than at low, confined stresses. In general, the drying curves increase the water desorption over the suction range investigated due to the low water viscosity caused by high temperatures. The wetting of the GCL at 20 ◦C and drying at 70 ◦C under either low, confined stress (2 kPa) or high confining stress (130 kPa) shows a reduction in the volumetric water contents. Furthermore, on the drying path, the coupled effect of elevated temperature and high confining stress accelerates water desorption leading possibly to potential desiccation.

Keywords: Geosynthetics, Geosynthetic clay liner, Water retention curves, Temperatures, Vertical stresses

Predicting the settlement of geosynthetic-reinforced soil foundations using evolutionary artificial intelligence technique

Muhammad Nouman Amjad Raja[a,b], Sanjay Kumar Shukla[c,d]
a Geotechnical and Geoenvironmental Engineering Research Group, School of Engineering, Edith Cowan University, Perth, Australia
b Department of Civil Engineering, School of Engineering, University of Management and Technology, Lahore, Pakistan
c Founding Research Group Leader, Geotechnical and Geoenvironmental Engineering Research Group, School of Engineering, Edith Cowan University, Perth, Australia
d Department of Civil Engineering, Delhi Technological University, Delhi, India

Abstract: In order to ensure safe and sustainable design of geosynthetic-reinforced soil foundation (GRSF), settlement prediction is a challenging task for practising civil/geotechnical engineers. In this paper, a new hybrid technique for predicting the settlement of GRSF has been proposed based on the combination of evolutionary algorithm, that is, grey-wolf optimisation (GWO) and artificial neural network (ANN), abbreviated as ANN-GWO model. For this purpose, the reliable pertinent data were generated through numerical simulations conducted on validated large-scale 3-D finite element model. The predictive power of the model was assessed using various well established statistical indices, and also validated against several independent scientific studies as reported in literature. Furthermore, the sensitivity analysis was conducted to examine the robustness and reliability of the model. The results as obtained have indicated that the developed hybrid ANN-GWO model can estimate the maximum settlement of GRSF under service loads in a reliable and intelligent way, and thus, can be deployed as a predictive tool for the preliminary design of GRSF. Finally, the model was translated into functional relationship which can be executed without the need of any expensive computer-based program.

Keywords: Geosynthetics, Reinforced soil foundation, Settlement, Finite element simulations, Predictive modelling, Artificial intelligence, ANN-GWO, Hybrid model

A rigorous numerical formulation for upper bound analysis of reinforced soils using second order cone programming

Shuai Yuan
School of Highway, Chang'an University, Xi'an, 710064, PR China

Abstract: A rigorous upper bound formulation is established for reinforced soils considering both the tensile rupture of the reinforcement and the relative slippage of the reinforcement-soil interface. To represent its finite tensile strength and negligible compressive strength, a novel strategy is proposed to calculate the plastic dissipation rate of the reinforcement without the incorporation of stress variables. Plastic dissipation rates of the soil, the reinforcement and their interfaces are obtained using only kinematic variables and all flow rules are expressed in terms of linear constraints and second order cones. The solution domain is then discretized using linear strain elements for the soil and constant strain elements for the reinforcement and the interface. Numerical examples are given to show the accuracy of the present formulation. The effect of design parameters such as the tensile strength, the length and the location of the reinforcement is discussed.
Keywords: Reinforced soil, Upper bound limit analysis, Second order cone programming

Critical length of encased stone columns

Marina Miranda[a], Jesús Fernandez-Ruiz[b], Jorge Castro[a]
a Department of Ground Engineering and Materials Science, University of Cantabria, Santander, Spain
b Department of Civil Engineering, University of La Coru˜na, La Coru˜na, Spain

Abstract: Encased stone columns are vertical inclusions in soft soils formed by gravel wrapped usually with a geotextile. Their critical length is the one where further lengthening of the column provides a negligible improvement and it is therefore not effective to build columns longer than it. This paper aims to obtain common values of the critical length using simplified two-dimensional axisymmetric and full three-dimensional finite element analyses. A uniform soft soil layer with a linear elastic perfectly plastic behaviour is considered for the sake of simplicity. For the studied cases, the critical column length is around 1.3–2.5 times the footing diameter for encased stone columns, and slightly lower for ordinary stone columns, namely around 1.1–1.9. The critical length of the encasement is found to be slightly lower than the critical column length. The value of the critical column length is related to the extent of plastic deformation and that may be used to decide the column length in the design phase without the need of parametric analyses. As a first approximation, a general value of the critical column length of 2 and 2.5 times the footing diameter may be considered for ordinary and encased stone columns, respectively.

Keywords: Geosynthetics, Geotextiles, Encased stone columns, Critical length, Settlement, Footing, Finite element analyses

The role of geosynthetics in reducing the fluidisation potential of soft subgrade under cyclic loading

Joseph Arivalagan[a,b], Cholachat Rujikiatkamjorn[a,b,c], Buddhima Indraratna[a,b,c], Andy Warwick[d]

a School of Civil & Environmental Engineering, University of Technology Sydney, NSW, 2007, Australia

b ARC Industrial Transformation Training Centre, ITTC-Rail, University of Wollongong, Wollongong City, NSW, 2522, Australia

c Transport Research Centre, University of Technology Sydney, NSW, 2007, Australia d National Sales and Marketing Manager, Polyfabrics Australasia Pty Ltd, Australia

Abstract: The instability of railway tracks including mud pumping, ballast degradation, and differential settlement on weak subgrade soils occurs due to cyclic stress from heavy haul trains. Although geotextiles are currently being used as a separator in railway and highway embankments, their ability to prevent the migration of fine particles and reduce cyclic pore pressure has to be investigated under adverse hydraulic conditions to prevent substructure failures. This study primarily focuses on using geosynthetics to mitigate the migration of fine particles and the accumulation of excess pore pressure (EPP) due to mud pumping (subgrade fluidisation) using dynamic filtration apparatus. The role that geosynthetics play in controlling and preventing mud pumping is analysed by assessing the development of EPP, the change in particle size distribution and the water content of subgrade soil. Using 3 types of geotextiles, the potential for fluidisation is assessed by analysing the time-dependent excess pore pressure gradient (EPPG) inside the subgrade. The experimental results are then used to evaluate the performance of selected geotextiles under heavy haul loading.

Keywords: Mud pumping, Track substructures, Geosynthetics, Heavy haul trains, Excess pore pressure gradient

Numerical study of geosynthetic reinforced soil bridge abutment performance under static and seismic loading considering effects of bridge deck

Mehdi Askari, Hamid Reza Razeghi **, Jaber Mamaghanian
School of Civil Engineering, Iran University of Science and Technology, Tehran, Iran

Abstract: Although the use of Geosynthetic Reinforced Soil (GRS) bridge abutments has been increasing, the seismic performance of such structures has remained a significant concern due to their unknown behavior in loadbearing and stress distribution under bridge load and seismic conditions simultaneously. This paper investigates the static and dynamic response of GRS bridge abutment. A series of numerical models representing the realistic field conditions of these structures, including two reinforced soil walls and a single span deck that restrains the top of walls, rather than equivalent surcharge load, was developed. The calibrated numerical model in FLAC program was used to evaluate the effects of horizontal restraint from the deck on the GRS wall displacements and reinforcement loads at the end of construction and under harmonic base acceleration up to 0.5 g. Results indicated that the restraint mobilized from the bridge deck presence, considerably affected the results at both the end of construction and after the dynamic load was applied. Moreover, a series of the parametric studies were performed to investigate the influences of backfill soil relative compaction, reinforcement stiffness, reinforcement length, and reinforcement vertical spacing on the response of GRS abutments at the end of construction and post dynamic state.

Keywords: Geosynthetics, GRS bridge abutment, Dynamic analysis, Geogrid, Numerical analysis, FLAC

Full-scale field study of using geofoam to reduce earth pressures on buried concrete culverts

Junqi Wang[a], Jie Huang[b]
a School of Water Resources and Hydropower Engineering, North China Electric Power University, 2 Beinong Rd., Changping District, Beijing, 102206, China
b The University of Texas at San Antonio, One UTSA Circle, San Antonio, TX, 78249, USA

Abstract: Applications of geofoam for buried culverts/pipes keep increasing; however, the design of such applications is still challenging due to lack of full-scale studies. Considering practice needs, a full-scale field study was carried out to investigate the effectiveness of different geofoams with different layouts to reduce overburden stresses on deeply buried, large-size culverts. Among the eight test sections, five were installed with two different of geofoams (7.5 and 15 kg/m3) in thicknesses of 300 and 600 mm and the remaining three were built with loose sand, lightly and normally compacted clay, respectively. The acquired data indicated that the geofoam can greatly reduce the overburden stress over the culvert. In general, higher compressibility of geofoam resulted in greater stress transfer but did not cause excessive settlement at the surface due to significant burial depth. However, due to its large span and dome shape, a secondary soil arching formed when the soil over shoulder settled more than that over the crown, which readjusted the stress and resulted in further reduction in the stress at the culvert shoulder but partially compromised the stress reduction at the crown. Such phenomenon shall be appropriately addressed to avoid unexpected damage to buried culverts or pipes.
Keywords: Geofoam, Culvert, Stress reduction, Overburden stress, Soil arching

Pullout resistance of inclined anchors embedded in geogrid reinforced sand

Sougata Mukherjee[a], Lucky Kumar[a], Awdhesh Kumar Choudhary[b], G.L. Sivakumar Babu[a]
a Department of Civil Engineering, Indian Institute of Science, Bangalore, 560012, India
b Department of Civil Engineering, National Institute of Technology Jamshedpur, Jamshedpur, 831014, India

Abstract: Transmission tower foundations experience large vertical uplift forces during their lifetime. These forces can be resisted by providing anchor foundations below the tower. In this study, laboratory experiments were conducted to investigate the pullout capacity of inclined plate anchors in dry sand. The capacity of inclined anchor significantly improved in the presence of geogrid reinforcement on top of the anchor plate. Besides, the pullout capacity increased with the inclination angle (30◦, 45◦, 60◦) both in unreinforced and reinforced soil. It was observed that the ultimate pullout load is significantly influenced by the embedment depth of the anchor plate and relative density of the backfill material. The experimental results were compared with a three-dimensional numerical model developed in FLAC3D. The comparison shows good agreement between the experimental and numerical results, and the numerical model can predict the pullout behaviour of the inclined anchor plate both in unreinforced and reinforced soil. Comparison of uplift resistance of pile and anchor foundations are shown through a design example of a transmission tower foundation. Results indicate that inclined anchors embedded in reinforced soil can resist the uplift forces at shallow depth compared to piles.

Keywords: Geosynthetics, Inclined anchor, Pullout capacity, Laboratory tests, Numerical analysis, Transmission tower

Mitigation of seasonal temperature change-induced problems with integral bridge abutments using EPS foam and geogrid

Hao Liu, Jie Han, Robert L. Parsons
Civil, Environmental, and Architectural Engineering (CEAE) Department, Univ. of Kansas, 1530 W. 15th St., Lawrence, KS, 66045-7609, USA

Abstract: Expansion of bridge girders in summer moves integral bridge abutments toward backfill, causing high lateral earth pressures behind the abutment. Some backfill material slumps downward and toward the abutment when the abutment moves away from the backfill due to bridge girder contraction in winter. Placement of geogrids within the backfill can increase stability of the backfill while placement of compressible inclusions (e.g., Expanded Polystyrene (EPS) foam) can reduce lateral earth pressures behind the abutment caused by bridge girder expansion. In this study, six physical model tests were conducted with 30 abutment top movement cycles due to simulated seasonal temperature changes to study the performance of integral bridge abutments with different mitigation measures. The test results showed that geogrid reinforcements caused higher maximum lateral earth pressures at the same abutment movement, but geogrids with wrap-around facing significantly reduced the backfill surface settlements. The combination of the EPS foam and geogrids could minimize lateral earth pressure increase and backfill settlement. The EPS foam reduced the abutment toe outward movement when the abutment top was pushed against the backfill; however, the mitigation effects by the EPS foam was limited due to its small thickness and relatively high elastic modulus in this study.

Keywords: Geosynthetics, Integral bridge abutment, EPS foam, Lateral earth pressure, Seasonal temperature change

Geogrid-soil interaction: A new conceptual model and testing apparatus

Jan Derksen[a], Martin Ziegler[b], Raul Fuentes[a]
a Institute of Geomechanics and Underground Technology, RWTH Aachen, Germany
b ZAI Ziegler und Aulbach Ingenieurgesellschaft mbH, Germany

Abstract: This paper provides a more realistic representation of the soil-geogrid interface in indirectly activated geogrids. A new testing apparatus is designed using transparent soil that allows an unobstructed observation of the interface to investigate the interaction occurring along the reinforcement. In this investigation, the reinforcement is indirectly activated by the deformations of the surrounding soil. Deformations were determined by digital image correlation (DIC) using a dot pattern attached to the geogrid and a laser speckle plane within the transparent soil. The interaction is derived from relative soil-geogrid displacements, deflections of geogrid transverse members, geogrid strain and force distributions as well as shear stresses acting at the interface. Three zones were identified corresponding to the distinct modes of interaction: pushout, pullout and interlocking, whereby a micromechanical conceptual model was validated. The geogrid force reaches its maximum at the intersection of the critical slip plane with the reinforcement. The results indicate that the pushout, pullout and interlocking areas cover 15%, 49% and 36% of the total geogrid length respectively. In this study, a transition area between the pushout and pullout zones was observed where the mobilised interface shear stress increases to a maximum value.
Keywords: Soil-geogrid interaction, Geogrid activation, Interface, Transparent soil, DIC

A large-scale shaking table model test for acceleration and deformation response of geosynthetic encased stone column composite ground

Fang Ou Yang[a,b], Gang Fan[c], Kaifeng Wang[d], Chen Yang[d], Wenqiang Lyu[e], Jianjing Zhang[f]

a BIM Technology Application Engineering Center, Hubei University of Education, Wuhan, 430205, PR China

b Hubei BIM Intelligent Construction International Science and Technology Cooperation Base, Hubei University of Education, Wuhan, 430205, PR China

c College of Water Resource and Hydropower, Sichuan University, Chengdu, 610065, PR China

d CSCEC Road and Bridge Group Co., Ltd., Shijiazhuang, 050001, PR China

e Rail Line & Station Design Institute, China Railway Siyuan Survey and Design Group Co., Ltd., Wuhan, 430063, PR China

f School of Civil Engineering, Southwest Jiaotong University, Chengdu, 610031, PR China

Abstract: Effective mitigation of seismic-induced ground hazards requires an improved understanding of ground response in terms of earthquake wave propagation and ground deformation. Here, this paper examines the effects of geosynthetic-encased stone columns (ESCs) and ordinary stone columns (SCs) on the acceleration amplitude and frequency content responses of sand profiles, and the deformation of the ground using a large-scale shaking table model test. The model was excited by 15 shaking events including El Centro motion, Wenchuan Qingping motion and Kobe motion with peaks ranging from 0.1 to 0.9 g. The results indicate that the ESCs more significantly amplify surface accelerations compared to the SCs in the frequencies ranging from 10 to 17 Hz and from 2.5 to 9 Hz. The horizontal peak acceleration values in the ESCs composite ground are approximately twice those of the SCs composite ground. The acceleration response of the ground is influenced by the applied acceleration peak and frequency content, reinforced type, and structure. After the seismic excitation, the ESCs composite ground develops much narrower surface cracks distributed in a larger area compared to the SCs.

Keywords: Geosynthetic encased stone column, Stone column, Composite ground, Shaking table model test, Earthquake motion

Shear strength behavior of clayey soil reinforced with polypropylene fibers under drained and undrained conditions

N.S. Correia[a], S.A. Rocha[a], P.C. Lodi[b], J.S. McCartney[c]
a UFSCar - Federal University of Sao Carlos, Department of Civil Engineering, SP, Brazil
b UNESP - S˜ao Paulo State University, School of Engineering at Bauru, SP, Brazil
c UCSD – University of California at San Diego, CA, USA

Abstract: The fundamental mechanisms controlling shear strength and deformability behavior of clay-fiber mixtures have still not been well established, nor the constraints that may affect their performance of shearing under different drainage conditions. This study aims to understand the behavior of a clay soil mixed with polypropylene fibers using results from drained and undrained triaxial compression tests, and to provide necessary calibration data for a shear strength prediction model. In drained tests, shear strength increased with fiber inclusion for a given mean effective stress, represented by an increase in apparent cohesion. In the undrained tests, the shear strength was not affected by pore water pressure generation. Results from the drained and undrained tests indicate that the fiber content had a greater influence on the apparent cohesion than on the friction angle. Drainage affected the improvement in the peak shear strength of fiber-reinforced soils, with superior improvement in the drained tests. As the percent improvement in shear strength decreased with increasing effective confining stresses for both tests, the difference in behavior in the drained and undrained tests was attributed to the strain at failure, with failure occurring at large strains in the drained tests but at smaller strains in the undrained tests.
Keywords: Polypropylene fibers, Clayey soil, Fiber reinforcement model, Triaxial compression, Drainage

A laboratory evaluation of reinforcement loads induced by rainfall infiltration in geosynthetic mechanically stabilized earth walls

F.H.M. Portelinha[a], M.C. Santos[a], M.M. Futai[b]
a Federal University of Sao Carlos, Civil Engineering Department, Washington Luis Rd., km 235, Sao Carlos, Sao Paulo, 13.565-905, Brazil
b School of Engineering, University of Sao Paulo, Prof. Almeida Prado Ave., 83, Sao Paulo, SP, 05508-900, Brazil

Abstract: A laboratory testing that simulates the mechanisms of a geosynthetic-reinforced layer was used to assess the impact of rainwater infiltration on reinforcement loads and strains in mechanically stabilized earth (MSE) walls. The testing device allows measuring loads transferred from a backfill soil subjected simultaneously to surcharge loading and controlled irrigation. Load-strain responses of geosynthetic-reinforced layers constructed with three different geosynthetics under a moderate rainfall are related to suction captured along the depth of reinforced layers. Results show infiltration leading to increases on strains and tensile loads mobilized by reinforcements. Rates of increases of both parameters were found to be dependent of global suction, geosynthetic stiffness and hydraulic properties. In addition, increases in water content at soil-geotextile interfaces due to capillary breaks also had a significant effect on mobilized loads. The loss of interaction due to the interface wetting was observed to affect the stress transference from soil to geosynthetic reinforcement. An approach suggested for calculation of lateral earth pressures in unsaturated GMSE walls under working stress conditions and subjected to rainfall infiltration demonstrated a reasonable agreement with experimental data.
Keywords: Geosynthetics, Infiltration, Suction, Tensile load, Reinforcement strain

Nonlinear consolidation analysis of soft soil with vertical drains considering well resistance and smear effect under cyclic loadings

Pyol Kim[a], Tong-Chol Kim[a], Yong-Gun Kim[b], Hak-Bom Myong[a], Kwang-Su Jon[a], Song-Hun Jon[c]

a Department of Hydrogeology, Faculty of Geology, Kim Il Sung University, Pyongyang, Democratic People's Republic of Korea

b Department of Hydrology, Faculty of Global Environmental Science, Kim Il Sung University, Pyongyang, Democratic People's Republic of Korea

c Faculty of Forest Science, Kim Il Sung University, Pyongyang, Democratic People's Republic of Korea

Abstract: In this paper, the nonlinear consolidation behavior of soft soil with vertical drains considering well resistance and smear effect under cyclic loadings was investigated. Using the variables separation method, a series of analytical solutions were derived to calculate the excess pore water pressure and the average degree of consolidation of the soil subjected to various cyclic loadings including trapezoidal cyclic loading, rectangular cyclic loading, triangular cyclic loading and haversine cyclic loading. The correctness of the proposed solutions was verified through degenerating into the existing solutions. Finally, the effects of different parameters on the nonlinear consolidation behavior of soil with vertical drains under cyclic loadings were analyzed.

Keywords: Cyclic loading, Nonlinear consolidation, Soft soil, Analytical solution, Vertical drain, Well resistance, Smear effect