《Geosynthetics International》

（国际土工合成材料）

<双月刊>

2025年第32卷第4期

摘要集

中国土工合成材料工程协会秘书处

目　录

Stress level dependent behavior of sand-rubber mixtures

D.-Y. Liu[1], M.-T. Wang[2], Y.-B. Li[3] and C. Wang[4]

1 Research Assistant Professor, Department of Civil & Environmental Engineering, The Hong Kong University of Science and Technology, Hong Kong, China, E-mail: deyunliu@ust.hk

2 Research fellow, UCL Bartlett School of Sustainable Construction, University College London, London, UK, E-mail: ucbqmtw@ucl.ac.uk

3 Associate professor, School of Geological Engineering and Geomatics, Chang'an University, Xi'an, China, E-mail: liyubai@chd.edu.cn

4 Associate professor, Key Laboratory of In-fiber Integrated Optics, Harbin Engineering University, Harbin, China, E-mail: 2520210429@hrbeu.edu.cn (corresponding author)

Abstract: This study investigates the mechanical behavior of sand-rubber mixtures, focusing on the influence of stress levels. Quantitative analysis reveals significant effects of stress levels on void ratio and coordination number, which become more pronounced with increasing rubber content. Small-strain stiffness could be affected by stress level by demonstrating unified relationships between small-strain stiffness and conventional state variables, with the coefficients of determination for fitted relationships increasing from 0.66 to 0.95 as rubber content increases from 0% to 80%. This is attributed to the impact of stress levels on conventional state variables. Alternative state variables that exclude rubber materials more effectively describe the small-strain characteristics of sand-rubber mixtures, suggesting that rubber materials should be excluded when considering these characteristics in practical engineering for conservation purposes. The stress level effect is also evident in the variation of stress ratios with axial strain, particularly when rubber content exceeds 25%, showing that higher stress levels restrict the mobilization of stress ratios for rubber materials. This study highlights the importance of considering stress level effects in the mechanical analysis of sand-rubber mixtures, which exhibit unique characteristics compared to natural sands in both compression and shearing behavior.

Keywords: Geosynthetics, Discrete element method, Sand-rubber mixtures, Stress level dependent, State variables

Numerical simulation of effects of previous PVD treatment on second vacuum-PVD improvement

D. T. Bergado[1], T. Nghia-Nguyen[2], P. Jamsawang[3], N. Kovittayanon[4], J. Rementilla[5] and K. C. Chao[6]

1 Emeritus Professor, Asian Institute of Technology, Klong Luang, Pathumthani, Thailand, E-mail: dbergado@gmail.com

2 Lecturer, Faculty of Civil Engineering, Ho Chi Minh City Open University, Ho Chi Minh city,
Vietnam, E-mail: nghia.nt@ou.edu.vn (corresponding author) (Orcid:0000-0001-9954-8452)

3 Professor, Soil Engineering Research Center, Department of Civil Engineering, King Mongkut's University of Technology North Bangkok, Bangkok, Thailand, E-mail: pitthaya.j@eng.kmutnb.ac.th

4 Project Director, Ceteau (Thailand) Co. Ltd., Bangkok, Thailand, E-mail: ntp@ceteau.co.th

5 Design Engineer, Ceteau (Thailand) Co. Ltd., Bangkok, Thailand, E-mail: jansen@ceteau.co.th

6 Associate Professor, Asian Institute of Technology, Thailand, E-mail: geoffchao@ait.ac.th

Abstract: The influence of the initial improvement through prefabricated vertical drains (PVD) and surcharge embankment on the second improvement by vacuum PVD has not been comprehensively explored in the existing literature. The expansion of the Second Bangkok International Airport (Suvarnabhumi Airport) underwent initial treatment with PVD and surcharge, followed by further soft ground improvement with vacuum PVD, which serves as a valuable case study for understanding the impact of the initial PVD improvement. This study highlights the effects of the initial PVD improvement through a comparison of two case studies: the first improvement by vacuum PVD on Taxiway Extension D at Zone 27 and the second vacuum PVD improvement on the Third Extension North at Zone 7. Extensive back analysis results reveal significantly higher flow parameters and reduced settlements for the second improvement at Zone 7 compared to the first improvement at Zone 27. The water contents, void ratios, and compression indices decreased while the undrained shear strengths and maximum past pressures increased. These results demonstrated the effectiveness of the vacuum PVD improvement with a modified field-distributed air-water separation system. Numerical studies further corroborated these findings and confirmed the observed crack patterns at the surface resulting from inward lateral movement.

Keywords: Geosynthetics, Consolidation, Ground improvement, Embankments, UN SDG 11: Sustainable cities and communities

Load transfer mechanism of floating pile-supported embankments under cyclic loading

C.-B. Xu[1], Y.-Y. Zhao[2], J. Zhang[3], J.-J. Zheng[4], W.-D. Deng[5], Z.-L. Yan[6] and Y. Zheng[7]

1 Ph.D. Candidate, School of Civil Engineering, Wuhan University, Wuhan, Hubei, China, E-mail: xucb21@whu.edu.cn (Orcid:0009-0003-9548-5476)

2 Assistant Engineer, Yellow River Engineering Consulting Co., Ltd., Zhengzhou, China, E-mail: 15890674590@163.com

3 Chief Engineer, Shanxi Transportation Technology Research & Development Co., Ltd., Key Laboratory of Highway Construction and Maintenance Technology in Loess Region, Taiyuan, China, E-mail: zj_sxjt@hotmail.com

4 Professor, School of Civil Engineering, Wuhan University, Wuhan, Hubei, China, E-mail: zhengjunjie@whu.edu.cn (corresponding author) (Orcid:0000-0001-9679-4914)

5 Researcher, China Merchants Chongqing Communications Research and Design Institute, Ltd., Chongqing, China, E-mail: 654617315@qq.com

6 Researcher, China Merchants Chongqing Communications Research and Design Institute, Ltd., Chongqing, China, E-mail: yanzongling@cmhk.com

7 Professor, School of Civil Engineering, Wuhan University, Wuhan, Hubei, China, E-mail: yzheng@whu.edu.cn (Orcid:0000-0001-9038-4113)

Abstract: Pile-supported embankments are one of the most commonly used techniques for ground improvement in soft soil areas. Existing studies have mainly focused on embankments supported by end-bearing piles under static loading, with limited research on floating pile-supported embankments under cyclic traffic loading. In this study, model tests for unreinforced floating, unreinforced end-bearing, geosynthetic reinforced floating, and geosynthetic reinforced end-bearing pile-supported embankments were conducted. Cyclic traffic loading was simulated using a three-stage semi-sinusoidal cyclic loading. Comparative analyses and discussions are performed under floating and end-bearing conditions to investigate the influence of floating piles on the soil arching evolution and membrane effect under cyclic loading. The results indicate that floating piles result in earlier stabilization of surface settlement. There is less arching and membrane effect induced by floating piles, and the arching does not continue to degrade under cyclic loading. Less membrane effect in floating pile-supported embankments results in less geosynthetic and pile strain. The degree of membrane effect in floating pile-supported embankment largely depends on the pile-end condition.

Keywords: Geosynthetics, Pile-Supported Embankment, Floating Pile, Cyclic Loading, Load Transfer Mechanism

Design, fabrication, and application of graphene sensor for geogrid strain measurement

C. Y. Hong[1,2,3], S. Yuan[4,5,6,7], W. B. Chen[8,9,10], J. Zhang[11,12,13], X. F. Xie[14] and D. C. Wang[15]

1 Associate Professor, College of Civil and Transportation Engineering, Shenzhen University, Shenzhen, China

2 Key Laboratory of Coastal Urban Resilience Infrastructure (Shenzhen University), Ministry of Education, Shenzhen, China

3 National Engineering Research Center of Deep Shaft Construction, Shenzhen, China, E-mail: cyhong@szu.edu.cn

4 Master Student, College of Civil and Transportation Engineering, Shenzhen University, Shenzhen, China

5 Key Laboratory of Coastal Urban Resilience Infrastructure (Shenzhen University), Ministry of Education, Shenzhen, China

6 National Engineering Research Center of Deep Shaft Construction, Shenzhen, China

7 Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hong Kong, China, E-mail: laurel199907@163.com

8 Assistant Professor, College of Civil and Transportation Engineering, Shenzhen University, Shenzhen, China

9 Key Laboratory of Coastal Urban Resilience Infrastructure (Shenzhen University), Ministry of Education, Shenzhen, China

10 National Engineering Research Center of Deep Shaft Construction, Shenzhen, China, E-mail: wbchen@szu.edu.cn; jerrychenweibin@163.com

11 College of Civil and Transportation Engineering, Shenzhen University, Shenzhen, China

12 Key Laboratory of Coastal Urban Resilience Infrastructure (Shenzhen University) Ministry of Education,Shenzhen, China

13 National Engineering Research Center of Deep Shaft Construction, Shenzhen, China, E-mail: jianzhang2022

14 Guangzhou Construction Engineering Co., Ltd. Guangzhou, Guangdong, China, E-mail: xiexf@189.cn

15 Guangzhou Construction Engineering Co., Ltd. Guangzhou, Guangdong, China, E-mail: chu_627@qq.com

Abstract: In this study, a flexible vertical graphene (VG) strain sensor was developed for monitoring geogrids deformation. The VG material was fabricated using radio frequency plasma-enhanced chemical vapor deposition, followed by spin-coating a polydimethylsiloxane (PDMS) solution for film curing, resulting in a flexible sensor within a PDMS substrate. The VG sensor was integrated with a wireless Bluetooth data acquisition system for automated and remote strain measurement. The stability performance of VG sensors was examined and effectively improved through cyclic loading tests in the laboratory. The drift ratio of electrical resistance before cyclic loading tests is 37.01%, which is reduced to only 0.5% after cyclic loading tests. Calibration tests show that the maximum measurement resolution and maximum measurement range of VG sensors is 0.7 micro-strain and 40000 micro-strain, respectively, indicating that VG sensors are highly effective for both high-strain resolution identification and large-strain measurement. Pullout tests demonstrate an average error of 5.67% between VG sensors and fiber Bragg grating sensors, suggesting that VG sensors are a promising alternative for large strain, wireless, and long-term geogrid monitoring.

Keywords: Geogrid, Geosynthetics, Strain sensor, Strain measurement, Vertical graphene

Measuring pore sizes of nonwoven geotextiles by X-ray CT images: a comparative evaluation

M. W. Khan[1], A. R. Dawson[2], A. M. Marshall[3] and R. Chaudhry[4]

1 Formerly PhD candidate, Department of Civil Engineering, University of Nottingham, University Park, Nottingham, UK, E-mail: khan.mw@outlook.com (corresponding author) (Orcid:0000-0002-0342-4699)

2 Associate, Nottingham Transportation Engineering Centre, University of Nottingham, University Park, Nottingham, UK, E-mail: andrew.nottingham@aol.com (Orcid:0000-0002-7048-2776)

3 Professor of Geotechnical Engineering, Department of Civil Engineering, University of Nottingham, University Park, Nottingham, UK, E-mail: alec.marshall@nottingham.ac.uk (Orcid:0000-0003-1583-1619)

4 Formerly PhD candidate, Department of Civil Engineering, University of Nottingham, University Park, Nottingham, UK, E-mail: drabiya.chaudhry@outlook.com

Abstract: This paper focuses on evaluating the pore sizes of four nonwoven geotextile specimens with different pore size distribution techniques. The paper introduces a bubble analysis technique to find the two-dimensional (2D) pore size distribution of geotextile specimens. A new method is also introduced to determine the three-dimensional (3D) constriction sizes of nonwoven geotextiles from X-ray CT images. The digital image concept and image processing methods for the 2D image analysis and 3D constriction size measurement of geotextile specimens are explained. Finally, the paper compares the 3D constriction sizes with those measured from 2D image analysis, mercury intrusion porosimetry, manufacturer-reported opening size values based on the wet sieving method, and pore sizes calculated from theoretical equations. The results show that the largest pore opening sizes measured from the 3D constriction size method are in good agreement with the theoretical equations. The values measured from the wet sieving method were found to be the smallest, indicating the limitations of the wet sieving method to determine the largest pore opening size of nonwoven geotextiles. As it is the constriction size which must control filtration behaviour, the 3D constriction size method is recommended for assessing the reference porometry.

Keywords: Geosynthetics, Geotextiles, Imaging Techniques, X-Ray CT, Constriction Size, Pore Size Distribution

Soil behavior near the PVD filter and interpretation of clogging during vacuum preloading

Q. Y. Dong[1], X. H. Ren[2], X. Y. Ge[3], P. Wang[4] and H. Z. Liu[5]

1 Associate professor, College of Architecture and Civil Engineering, Wenzhou University, Wenzhou, China, E-mail: dongqy@zju.edu.cn

2 Master’s Degree Candidate, College of Architecture and Civil Engineering, Wenzhou University, Wenzhou, China, E-mail: 642086113@qq.com

3 Engineer, Zhejiang Yueqing Bay Lin’gang Economic Development Zone Management Committee, Wenzhou, China, E-mail: 564598411@qq.com (corresponding author)

4 Professor, College of Architecture and Civil Engineering, Wenzhou University, Wenzhou, China, E-mail: geowangpeng@163.com

5 Engineer, State Power Economic Research Institute, Jinan, China, E-mail: eiyuezhi@126.com

Abstract: Clogging near the prefabricated vertical drain filter during vacuum preloading reduces the efficiency of ground treatment, and existing research has yet to agree on the cause. This study conducted a small model test to comprehensively examine the soil’s water content and particle size distribution at different distances from the filter and tailwater for different preloading durations. The results showed that the particle size distribution of the soil at different selected points exhibited a slightly irregular difference. This indicates that no measurable migration of particles occurs, which was further confirmed by the particle size distribution of the soil after the one-dimensional consolidation test. The application of vacuum pressure did not significantly change the soil particle composition and, thus, its compressibility and permeability properties. The particle size distribution of tailwater revealed that a small number of fine particles with a mean size of 3–4 μm rapidly discharged with tailwater during the initial stage of vacuum preloading, which was much less than the mean size of the slurry and pore size of the filter. The decrease in water content and permeability indicates non-uniform consolidation, and the increase in the permeability coefficient ratio suggests the formation and development of the clogging zone.

Keywords: Geosynthetics, Vacuum Preloading, Clogging, Particle Migration, Nonuniform Consolidation

Environmental impacts of mechanically stabilised earth walls

M. Lee[1] and D. Basu[2]
1 Assistant Professor, Department of Civil and Environmental Engineering, University of Windsor, Windsor, ON, Canada, E-mail: mina.lee@uwindsor.ca (Orcid:0000-0001-8800-066X)
2 Professor, Department of Civil and Environmental Engineering, University of Waterloo, Waterloo, ON, Canada, E-mail: dipanjan.basu@uwaterloo.ca (Orcid:0000-0002-7358-2123)

Abstract: Mechanically stabilised earth (MSE) walls have gained widespread popularity in North America because of their cost-effectiveness and reliable performance. Although the use of carbon-intensive materials for MSE walls is significantly lower compared to conventional retaining walls like concrete gravity walls and cantilever walls, heavy earthwork and transportation activities are involved in the construction of MSE walls, which increase their carbon footprint. The intensity of construction and transportation activities need particular attention because these are heavily reliant on the combustion of fossil fuels. In this study, the environmental impacts of MSE walls, reinforced by two common types — steel strips and geogrid — are quantified using life cycle assessment (LCA). A parametric study is conducted to investigate the effects of (i) soil properties, (ii) material properties of reinforcement, (iii) applied load, (iv) design parameters, and (v) hauling distances of materials on the global warming impact of MSE walls. Based on the study, reference charts are developed for the purpose of quick estimation of global warming impact of MSE walls based on design dimensions, applied load, and site conditions.
Keywords: Geosynthetics, Life Cycle Assessment, Environmental Impacts, Mechanically Stabilised Earth Wall, Retaining Walls, Sustainability, Carbon Footprint

3-Dimensional numerical analysis of geosynthetic double-encased annulus stone columns

M. S. Abid[1], D. Rathod[2] and S. K. Vanapalli[3]
1 Research Scholar, Department of Civil Engineering, National Institute of Technology, Tiruchirappalli, Tamilnadu, India, E-mail: mdshakeelabid@gmail.com
2 Associate Professor, Department of Civil Engineering, National Institute of Technology, Tiruchirappalli, Tamilnadu, India, E-mail: deendayal@nitt.edu (corresponding author)
3 Professor, Department of Civil Engineering, University of Ottawa, Ottawa, ON, Canada, E-mail: Sai.Vanapalli@uottawa.ca

Abstract: A geosynthetic double-encapsulated annulus stone column technique is proposed in this study to overcome limitations associated with conventional stone columns, such as limited lateral load-bearing capacity and potential issues related to aggregate dispersion in soft soils. Geosynthetic double-encapsulated annulus stone columns are consistent with conventional stone columns besides being confined in and around the surrounding soil. The performance of geosynthetic double-encapsulated annulus stone columns is primarily dependent upon their outer-to-inner diameter ratio. For this reason, comprehensive 3-dimensional numerical studies were carried out to evaluate the optimum outer-to-inner diameter ratio of the annulus stone column. The results suggest that the ultimate load-carrying capacity of an annulus stone column increases with an increasing ratio of outer to inner diameter until an optimum value. In addition, the double encapsulation enhances confinement, improving shear stiffness and reducing lateral bulging. However, the load-carrying capacity was substantially reduced beyond the critical outer-to-inner diameter ratio. A simple analytical model extending the theory of thin cylinders is also introduced to estimate the accumulated stresses and strains in the geosynthetic encasement. The proposed model operates within a simplified framework of elastic solutions that facilitate practising engineers to design and optimize geosynthetic encasements for enhanced structural performance.
Keywords: Geosynthetics, Annulus stone column, Double encapsulation, Outer to inner diameter ratio

Durability of non-woven geotextiles produced from recycled polyethylene terephthalate (PET)

Nahid Attarchian[1], Gholamhosein Tavakoli Mehrjardi[2], Marzieh Zahaki[2] and Ali Akbar Yousefi[3]

1 Road, Housing and Urban Development Research Center, Tehran, Iran

2 Department of Civil Engineering, Faculty of Engineering, Kharazmi University, Tehran, Iran

3 Dept. of Plastics Engineering, Faculty of Polymer Processing, Iran Polymer and Petrochemical Institute, P.O. Box. 14965-115, Tesshran, Iran

Abstract: Achieving the goals of sustainable development and circular economy requires recycling and reusing plastic materials. In this research, the durability of five needle-punched nonwoven geotextiles were experimentally studied. The geotextiles were made of recycled PET (rPET), virgin PET (vPET), and combinations of rPET and vPET fibers. The samples were hydrolyzed for a period of 14, 28, and 56 days and the retained tensile strength and puncture resistance of the samples were determined at the end of each interval. Moreover, this study took the benefits from the capability of differential scanning calorimetry (DSC), Fourier transforms in infrared spectroscopy (FTIR) analysis, and scanning electron microscopy (SEM) images to interpret the results acquired. Testing on as-received products, it was understood that the recycling process could increase crystallinity of the fibers, increasing the fibers' fragility, reducing the tensile strength and elongation capacity of rPET fibers. Moreover, considering the borderline value of 50% retained strength, a shorter service life (up to 30%) of rPET products in comparison with vPET products, due to higher degradation rates, was observed.

Keywords: Geosynthetics, Recycled PET, Non-Woven Geotextile, Durability, Hydrolysis

Angle-based residual strength estimation of geotextile/textured geomembrane interface

G. Xu[1], J. Shi[2], Z. Liu[3], H. Zhang[4] and Y. Gu[5]

1 Ph.D. Student, Key Laboratory of Ministry of Education for Geomechanics and Embankment Engineering, Hohai University, Nanjing, China, E-mail: xugaojie@hhu.edu.cn

2 Professor, Key Laboratory of Ministry of Education for Geomechanics and Embankment Engineering, Hohai University, Nanjing, China, E-mail: soft-ground@hhu.edu.cn

3 Ph.D. Student, Key Laboratory of Ministry of Education for Geomechanics and Embankment Engineering, Hohai University, Nanjing, China, E-mail: liu_zhanlei@hhu.edu.cn(corresponding author)

4 Assistant Engineer, China Design Group Co, Ltd, Nanjing, China, E-mail: 949128201@qq.com

5 Assistant Engineer, Nanjing Rail Transit Construction Engineering Quality and Safety Supervision Station, Nanjing, China, E-mail: 1360230180@qq.com

Abstract: Geotextile and geomembrane are widely used in landfill liner systems, but the relationship between geomembrane roughness and geotextile/geomembrane interface residual shear strength remains to be studied. In this paper, by using a large-scale ring shear apparatus, a series of ring shear tests of geotextile/geomembrane interfaces were conducted, and the profile inclined angle distributions of the textured geomembrane surfaces were obtained by a profilometer. The experiment results showed that the geotextile/geomembrane interface reached residual strength after a shear displacement of 3 m, and the average inclined angle of the textured geomembrane was close to zero. With the increase of geomembrane asperity height, the interface residual strength increases. Through force analysis and statistical analysis, quantitative relationships between residual shear strength of geotextile/co-extruded geomembrane and geotextile/cone-shape structured geomembrane interfaces and inclined angle distribution were established. The model was validated by test results and case analysis. This study helps to understand the mechanism that causes the textured geomembrane to generate high interface residual strength.

Keywords: Geosynthetics, residual strength, ring shear, geomembrane, geotextile, inclined angle