《Geotextiles and Geomembranes》

(土工织物与土工膜)

<双月刊>

2025年第53卷第6期

摘要集

中国土工合成材料工程协会秘书处

目　录

Effect of geomembrane texturing method on geomembrane-dry GCL interface shear behavior

Juan Hou [a,b,*] , Xuelei Xie [a] , Craig H. Benson [b,c]

a School of Mechanics and Engineering Science, Shanghai University, Shanghai, 200444, China

b School of Engineering, University of Virginia, Charlottesville, VA, 22904, USA

c Geological Engineering, University of Wisconsin-Madison, Madison, WI, 53706, USA

Abstract: Effect of geomembrane texturing method on interface shear behavior between textured geomembranes (GM) and the nonwoven side of a dry geosynthetic clay liner (GCL) was evaluated using large-scale direct shear tests conducted using geomembranes with four different types of texturing and a range of asperity heights: impinged texturing (GMTI), coextruded texturing (GMTC), low asperity embossed texturing ($GMTE_L$), and high asperity embossed texturing ($GMTE_H$). The GCL contained granular bentonite between woven and nonwoven geotextiles bonded by needlepunching. Tests were conducted on the dry GCL to isolate GM-GCL interface behavior from other factors. All interfaces exhibited similar strain-softening shear behavior. Type of texturing had a strong influence on GM-GCL interface behavior. Comparable shear-displacement curves involving direct surface engagement between the texturing asperities and geotextile fibers were obtained with GMTI and GMTC. GMTI texturing delaminated during shear, reducing geotextile combing compared to GMTC. The $GMTE_L$ engaged the geotextile on the GCL via tip penetration and surface friction, as evinced by striations on the GCL surface, resulting in the lowest interface strengths of the textured GMs. $GMTE_H$ engaged deep into the interior of the GCL, resulting in dilation, tearing of the geotextile, furrows in the bentonite, and the highest interface strength of those tested.

Keywords: Geosynthetic clay liner, Interface shear behavior, Geomembrane, Texturing, Impingement, Coextrusion, Embossing, Asperity height, Direct shear tests

Geogrid stabilization effectiveness – Comprehensive assessment through multiscale experiments with bender element sensor technology

Han Wang [a,*] , Youngdae Kim [a], Mingu Kang [b], Erol Tutumluer [a], Heather Shoup [c]
a Civil and Environmental Engineering Department, The Grainger College of Engineering, University of Illinois Urbana-Champaign, Illinois, USA
b School of Engineering, University of St. Thomas, Minnesota, USA
c Central Bureau of Material, Illinois Department of Transportation, Illinois, USA

Abstract: Geogrids are commonly used in pavement structures to mechanically stabilize unbound aggregate layers to improve structural performance and extend lifespan. Geogrids stabilize aggregate particles by restraining their lateral movements through mechanisms such as interlocking and friction. This paper presents a multiscale experimental study conducted on extruded and welded geogrids, having different aperture shapes and properties, for their stabilization effectiveness through quantifying modulus enhancement using the bender element (BE) sensor technology. The study examines geogrid-stabilized aggregates both in a large-scale testbed with three embedded BE field sensors and in a repeated load triaxial device with geogrid coupons installed at midheight and embedded BE sensor pairs above geogrids. The large-scale testbed allowed lateral pressure measurements under a series of loading and unloading stages. Small strain moduli from the shear wave measurements determined from both experiments quantified geogrid stiffened zones when tested with the same dense-graded aggregates. All four geogrids showed modulus enhancements in both test setups when compared to control test results. The geogrid mechanical stabilization influence zone was observed to be as large as 6 in. (15 cm) above one extruded geogrid. Such quantified modulus enhancements and influence zones are essential for incorporating geogrid into mechanistic-empirical (M-E) pavement design framework.
Keywords: Geogrid, Unbound aggregate, Large-scale testbed, Triaxial testing, Bender element, Small strain shear modulus

Laboratory validation of seismic damage assessment in reinforced soil models based on sensor-enabled piezoelectric geogrids (SPGG)

Jun Wang , Zhiqiang Xiang , Hongtao Fu , Yu Rao * , Ziyang Gao , Junfeng Ni
College of Civil Engineering and Architecture, Wenzhou University, 586 Meiquan Street, Ouhai District, Wenzhou, Zhejiang, 325035, China

Abstract: Earthquakes are common geological disasters, and slopes under seismic loading can trigger coseismic landslides, while also becoming unstable due to accumulated damage caused by the seismic activity. Reinforced soil slopes are widely used as seismic-resistant geotechnical systems. However, traditional geosynthetics cannot sense internal damage in reinforced soil systems, and existing in-situ distributed monitoring technologies are not suitable for seismic conditions, thus limiting accurate post-earthquake stability assessments of slopes. This study presents, for the first time, the use of a batch molding process to fabricate self-sensing piezoelectric geogrids (SPGG) for distributed monitoring of soil behavior under seismic conditions. The SPGG's reinforcement and damage sensing abilities were verified through model experiments. Results show that SPGG significantly enhances soil seismic resistance and can detect soil failure locations through voltage distortions. Additionally, the tensile deformation of the reinforcement material can be quantified with sub-centimeter precision by tracking impedance changes, enabling high-precision distributed monitoring of reinforced soil under seismic conditions. Notably, when integrated with wireless transmission technology, the SPGG-based monitoring system offers a promising solution for real-time monitoring and early warning in road infrastructure, where rapid detection and response to seismic hazards are critical for mitigating catastrophic outcomes.

Keywords: Sensor-enabled geosynthetics (SEG), Reinforced soil, Failure localization, Failure quantification, Seismic simulation

Evaluation of water removal capability of wicking nonwoven geotextiles

Minghao Liu [a], Jiming Liu [a], Sam Bhat [b], Rishi Gupta [a], Cheng Lin [a,*]
a University of Victoria, 3800 Finnerty Road, Victoria, British Columbia, V8P 5C2, Canada
b Titan Environmental Containment, 777 Quest Blvd, Ile des Chenes, MB, Canada, R0A 0T1

Abstract: Water accumulation in road bases and subgrade is one of the primary causes of road distress. To counteract this adverse impact, this study introduces a novel geosynthetic composite, consisting of biaxial polypropylene geogrids heat-bonded to wicking nonwoven geotextiles (WNWGs). This new composite integrates wicking capabilities with reinforcement. Unlike wicking woven geotextiles (WWGs), which rely on deep-grooved fibers for wetting and wicking, the wicking mechanism of WNWGs is primarily based on the microstructure and unique fiber orientation of the nonwoven geotextile component, further enhanced by proprietary chemical treatment to convert the fibers from hydrophobic to hydrophilic. This modification allows WNWGs to exhibit rapid wetting and wicking properties while preserving the large lateral drainage functionality of conventional nonwoven geotextiles. To assess the wicking performance of this material, a series of wicking tests were conducted in both water and saturated soils under controlled temperature and relative humidity. Additionally, contact angle measurements and microscopic analyses using Scanning Electron Microscopy (SEM) were conducted to elucidate the underlying wicking mechanisms. The results confirmed that the WNWGs possessed superior spontaneous and forced wetting and wicking capabilities compared to traditional nonwoven geotextiles. The findings offer valuable reference for evaluating the performance of the WNWG-geogrid composite.

Keywords: Geotextile-geogrid composite, Wicking nonwoven geotextile, Wetting and wicking, Contact angle, Capillary forces

Investigation on the effect of interface temperature on soil-reinforcement interaction mechanism by pullout test

Huaxin Han [a], Chengzhi Xiao [a,*] , Jianguang Yin [a], Yonghua Cao [b]
a School of Civil and Transportation Engineering, Hebei University of Technology, Tianjin, 300401, China
b Tianjin Port Engineering Institute, Co., Ltd. of CCCC First Harbor Engineering Co., Ltd., Tianjin, 300202, China

Abstract: To investigate the effect of interface temperature on the soil-reinforcement interaction mechanism, a series of pullout tests were conducted considering different types of reinforcement (geogrid and non-woven geotextile), backfill (dry sand, wet sand, and clay), and six interface temperatures. The test results indicate that at interface temperatures of 0 °C and above, reinforcement failure didn't occur during the pullout tests, whereas it predominantly occurred at subzero temperatures. Besides, the pullout resistance for the same soil-reinforcement interface gradually decreased as the interface temperature rose. At a given positive interface temperature, the pullout resistance between wet sand and reinforcement was significantly higher than that of the clay-reinforcement interface but lower than that of the dry sand-reinforcement interface. Compared with geotextile reinforcements, geogrids were more difficult to pull out under the same interface temperature and backfill conditions. In addition, the lag effect in the transfer of tensile forces within the reinforcements was significantly influenced by the type of soil-reinforcement interface and the interface temperature. Finally, the progressive deformation mechanism along the reinforcement length at different interface temperatures was analyzed based on the strain distribution in the reinforcement.
Keywords: Geosynthetics, Pullout test, Interface temperature, Soil-reinforcement interaction, Progressive deformation mechanism

Case study: Design optimization and field tests of a large geotextile mat cofferdam combined with steel sheet piles

Yupeng Ren [a], Shuaidong Yang [b,c], Mi Zhou [d,*] , Xihong Zhang [e,] Jinhui Li [f], Yinghui Tian [g]
a State key laboratory of subtropical building and urban science, South China Institute of Geotechnical Engineering, South China University of Technology, 381 Wushan Rd., Guangzhou, 510640, Guangdong, China
b College of water Conservancy and Hydropower Engineering, Hohai University, Nanjing, 210098, Jiangsu, China
c Hydraulic Engineering Research Institute, Pearl River Water Resources Research Institute, Guangzhou, 510640, Guangdong, China
d State key laboratory of subtropical building and urban science, School of Marine Science and Engineering, South China University of Technology, 381 Wushan Rd., Guangzhou, 510640, Guangdong, China
e School of Civil and Mechanical Engineering, Curtin Univ., Kent St., Bentley, 6102, Western Australia, Australia
f Department of Civil and Environmental Engineering, Harbin Institute of Technology (Shenzhen), Shenzhen, 518055, Guangdong, China
g Department of Infrastructure Engineering, University of Melbourne, Parkville, 3010, Victoria (VIC), Australia

Abstract: A case study on a large geotextile mat cofferdam combined with steel sheet piles was conducted using field testing and numerical simulation to optimize the design and assess its performance. The failure mechanism and overall stability were investigated by numerical simulation, considering potential influence factors, including pile length, width ratio (W_2/W_1), water level, and excavation depth. The width ratio was identified as a critical influencing factor. Specifically, an optimized ratio of (W_2/W_1) =0.6 demonstrated the best overall performance. When the steel sheet pile intersects the potential failure surface, the stability improvement is most significant, particularly with a length of 15 *m* in the current case. Field tests were employed to examine the performance of the optimized cofferdam design. Water level fluctuations, surface displacements, and both horizontal and vertical displacements at various depths were monitored to assess the cofferdam's behavior. Results from both numerical simulations and field monitoring conclusively affirm the cofferdam's capability to meet stringent safety criterion during the construction and operational phases. This work fills gaps in standardization of large geotextile mat cofferdam design by providing guidance on geometric configuration, reinforcement integration, and soft soil risk management, thereby advancing engineering practices for similar projects.
Keywords: Geotextile mat cofferdam, Steel sheet pile, Field tests, Excavation, Water level, 2D numerical analysis

Consolidation analysis of staged-filled soil slurry with combined grid-horizontal and vertical drains system under vacuum preloading

Ding-Bao Song [a,b,**] , Yu Pan [a], Jian-Hua Yin [a,*], Zhen-Yu Yin [b], He-Fu Pu [a]
a College of Civil and Transportation Engineering, Shenzhen University, Shenzhen, Guangdong, China
b Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Kowloon, Hong Kong, China

Abstract: This study presents a combined method utilizing grid-horizontal drains assisted by vacuum preloading for initial treatment, and vertical drains with vacuum preloading for further enhancement, aimed at the beneficial reuse of dredged marine sediments as fill material. A novel method for analyzing the consolidation of staged-filled soft soils with grid-horizontal and vertical drains under vacuum preloading is established, and a numerical model, called Combined-drains Consolidation Settlement (CCS), is developed. CCS accounts for staged filling, drain combinations, creep strains, hydraulic conductivity anisotropy, vertical and radial flows, smear effects, time-dependent surcharge and/or vacuum loading, and variable compressibility and hydraulic conductivity throughout the consolidation process. A large-scale laboratory consolidation test is presented, focusing on staged-filled marine sediments treated by the combined system, demonstrating beneficial reuse potential of high-water-content dredged sediments. Settlement and water content predictions using CCS agree well with experimental results. The effects of paving rate (lateral spacing) and the number of grid-horizontal drain layers (vertical spacing) are evaluated using the CCS model. Based on these results, cost-effective design recommendations are proposed. Comparison of treatment efficiency shows the combined method significantly enhances improvement by enabling earlier application of vacuum consolidation than the PVD-only method.
Keywords: High-water-content dredged materials, Large strain consolidation, rid-horizontal drain, Vertical drain, Large-scale laboratory test, Numerical model

Analytical solution of freeze-thaw pretreatment combined with step vacuum preloading for sludge consolidation and dewatering

Xudong Zhang [a], Zhenggao Xu [a], Yajun Wu [a,*], Peng Ye [b], Xueke Zang [c], Jinhong Wu [c]
a School of Mechanics and Engineering Science, Shanghai University, Shanghai, PR China
b Institute of Geotechnical Engineering, School of Transportation, Southeast University, Nanjing, PR China
c Shanghai Yaxin Urban Construction Co., Ltd, Shanghai, PR China

Abstract: A significant amount of sludge is generated worldwide every day, characterized by its high moisture content. This study investigates the impact of freeze-thaw cycles and step vacuum preloading on sludge dewatering and volume reduction. It also analyzes the effects of different loading methods to address challenges associated with sludge dewatering. Based on Hansbo's consolidation theory, equations for excess pore water pressure and the degree of consolidation under step vacuum loading are derived, and the experimental results are predicted. A conversion coefficient, r, was introduced to measure the degree of clogging in the drainage board. The results indicate that step vacuum loading is more effective for sludge drainage and volume reduction. Additionally, the theoretical predictions accurately reflect the experimental outcomes, providing a solid theoretical foundation for the feasibility of employing step vacuum preloading in engineering applications.
Keywords: Freeze-thaw, Sludge settlement and drainage, Step vacuum loading, Step radial consolidation theory

Optimization and performance analysis of novel waste EPS bead-sand composite cushions for rockfall mitigation: An integrated experimental and numerical study

Hani Meree [a], Dongpo Wang [a], Shuaixing Yan [a], Stéphane Lambert [b], Yanhao Chen [a], Qi Dong [a]

a State Key Laboratory of Geohazard Prevention and Geoenvironment Protection, Chengdu University of Technology, Chengdu, 610059, PR China

b Univ. Grenoble Alpes, INRAE, CNRS, IRD, Grenoble INP, IGE, Grenoble, 38000, France

Abstract: Orthogonal Experimental Design (OED) and Response Surface Methodology (RSM) optimized waste Expanded Polystyrene (EPS) bead-sand composite cushions, identifying an optimal EPS content of 38.79 % by volume for superior energy absorption and load distribution. The novel SE-S-F layered configuration (EPS-sand mixture over pure sand) reduced RC slab tension damage by 79.7 % compared to traditional sand cushions and crack width by 92.3 % relative to the EPS-sand mixture, surpassing monolithic designs. It minimized transmitted forces, accelerations, and energy dissipation while promoting flexural cracking for enhanced structural protection. Validated numerical simulations accurately modeled impact dynamics, enabling reliable performance predictions. Successive impact tests confirmed the SE-S-F configuration's multi-impact resistance, achieving a non-dimensional factor (Ω) of 1.47 by the fifth impact, outperforming geofoam-based designs. Repurposing waste EPS, this approach delivers lightweight, sustainable, and cost-effective rockfall protection systems, enhancing safety in mountainous regions and transportation corridors.

Keywords: EPS-Sand mixture, Waste material utilization, Orthogonal experimental design (OED), Response surface methodology (RSM), Layered configuration

The effect of physical-chemical combined clogging on the area density and permeability of geotextile envelopes for subsurface drainage systems in arid regions

Shuai Qin [a], Chenyao Guo [a,*], Jingwei Wu [a,**], Shuai He [b], Haoyu Yang [a], Chenzhi Yao [a], Xinman Jiang [a], Hang Li [a]

a State Key Laboratory of Water Resources Engineering and Management, Wuhan University, Wuhan, Hubei, 430072, China

b Xinjiang Academy of Agricultural and Reclamation Science, Shihezi, 832000, China

Abstract: This study investigates the morphological characteristics, development process, and impact on permeability of physical-chemical combined clogging on geotextile envelopes, through laboratory experiments involving particle flow coupled with chemical precipitation. The results show that there is a synergistic effect between physical clogging caused by soil particle accumulation and chemical clogging due to salt precipitation. Chemical precipitation exacerbates physical clogging, while physical clogging promotes the formation of chemical precipitation. The chemical precipitates on the upstream of the geotextile envelope binds the particles to each other and to the fibers of the geotextile envelope, while on the downstream, precipitates tends to encapsulate the fibers, with less physical clogging. After combined clogging, the permeability coefficient of the geotextile envelope decreases rapidly with the increasing of the clogging material, and then decreases slowly. When the area density of the clogging material is less than 91.02 g/m^2, it shows a linear decrease, and then followed by a logarithmic decrease. Physical-chemical combined clogging is more severe than single physical or chemical clogging. After the permeability stabilizes, for the same clogging mass, the decrease in permeability caused by combined clogging is 1.2 times and 2 times greater than that caused by physical and chemical clogging, respectively.

Keywords: Subsurface drainage, Geotextile envelope, Physical-chemical combined clogging, Arid region

Filtration characteristics and mechanism of geotextile filters under cyclic flow

Feifan Ren [a, b, *], Zhipeng Hu [c], Yuan Gao [d], Qiangqiang Huang [c], Xiaorui Qian [c]
a Key Laboratory of Geotechnical and Underground Engineering of the Ministry of Education, Department of Geotechnical Engineering, Tongji University, Shanghai, 200092, China
b State Key Laboratory of Disaster Reduction in Civil Engineering, College of Civil Engineering, Tongji University, Shanghai, 200092, China
c Department of Geotechnical Engineering, College of Civil Engineering, Tongji University, Shanghai, 200092, China
d School of Automotive Studies & Clean Energy Automotive Engineering Centre, Tongji University, Shanghai, 200092, China

Abstract: Geotextile filter layers are extensively utilized in revetment structures for riverbanks, floodwalls, and dams. These structures are often located in complex hydraulic environments, so geotextile filter layers may be subject to long-term cyclic flows. In this study, based on a self-developed gradient ratio test device, a series of gradient ratio tests under different hydraulic gradients and normal stresses were carried out to investigate the filtration characteristics and mechanisms of soil-geotextile systems under cyclic flow. The results show that the risk of particle erosion under cyclic flow is greater than the risk of system clogging, and the magnitude of hydraulic gradient and normal stress have an important influence on the filtration behavior. The boundary scour effect caused by the cyclic flow is proportional to the hydraulic gradient, while the normal stress enhances the retention of the soil through the benign geotextile blockage effect. The corresponding visual inspection analyses reveal that stable arching structures can be formed near the filter interface under cyclic flow, thus mechanically enhancing the stability of the system. These mechanisms suggest that strategic adjustments of the overburden pressure can optimize the structural stability of the soil-geotextile system in flood-prone environments.
Keywords: Geotextile, Filter, Filtration characteristics, Cyclic flow, Soil erosion

Experimental and numerical analysis of wrapped geogrid-stabilized high-fill embankment: Seismic response and composite reinforcement mechanisms

Weiting Deng [a], Xuanming Ding [a], Chunyan Wang [a,*], Changwei Yang [b], Zhenhua Ren [c], Qiang Ou [a], Ren Wang [a, d]

a College of Civil Engineering, Chongqing University, Chongqing, 400045, China

b MOE Key Laboratory of High-speed Railway Engineering, College of Civil Engineering, Southwest Jiaotong University, Chengdu, 610000, China

c Hunan Provincial Key Laboratory of Intelligent Disaster Prevention-Mitigation and Ecological Restoration in Civil Engineering, Hunan Institute of Engineering, Hunan, 411104, China

d Beijing Urban Construction Design & Development Group Co., Limited, Beijing, 100037, China

Abstract: This study investigated the seismic response and reinforcement mechanism of high-fill embankment reinforced with geogrid and pile-slab structure through shaking table tests and numerical method. Experimental results demonstrated that the geogrid-reinforced composite embankment can still maintain structural integrity under high-intensity seismic loading (PGA ≥0.8g), exhibiting only surface cracking and localized soil extrusion. The acceleration amplification factor (AAF) exhibited both "elevation effect" and "surface tendency effect", while strain distribution in the pile-slab structure followed characteristic arch-shaped and M-shaped patterns. Geogrid reinforcement effectively constrained soil deformation and redistributed stresses, delaying the development of pile bending moment and embankment displacement. Its reinforcement efficiency increased with seismic intensity. Validated numerical models reproduced shear strain localization-induced cracking at both embankment surfaces and embankment-accumulation interfaces. Shear strain propagation exhibited a progressive inward expansion from the embankment surface under seismic excitation. Parametric studies further revealed that reducing geogrid spacing can improve constraint effects, minimize displacement, and mitigate internal shear deformation. These findings underscore the synergistic role of geogrids and pile-slab structures in redistributing seismic thrust forces, offering critical insights for optimizing reinforcement strategies in seismically active regions.

Keywords: Shaking table test, Wrapped geogrid, High-fill embankment, Seismic behavior, Composite reinforcement mechanism

Experimental analysis of the influence of drainage board diameter coefficient on sludge treatment combining horizontal drain-vacuum preloading with geomembrane bags

Jun Wang [a, b, c], Chenglong Gu [a, b, c], Xiaobing Li [a, b, c], Hongtao Fu [a, b, c, *], Junfeng Ni [a, b, c], Ziyang Gao [a, b, c], Long Wang [a, b, c]

a College of Architecture and Civil Engineering, Wenzhou University, Wenzhou, Zhejiang, 325035, China

b Key Laboratory of Engineering and Technology for Soft Soil Foundation and Tideland Reclamation, Wenzhou University, Wenzhou, Zhejiang, 325035, China

c Collaborative Innovation Centre of Tideland Reclamation and Ecological Protection, Wenzhou, Zhejiang, 325035, China

Abstract: In the combined method of horizontal drainage board vacuum preloading and sealed geomembrane bags, the horizontal drainage board serves as the sole drainage channel, making its diameter coefficient critical in determining the appropriate filling height. Based on the theoretical model for vertical drainage boards, this study analyzes the influence range of a horizontal drainage board using the sealed geomembrane bag method. Model tests show that the maximum influence diameter coefficient of the horizontal drainage board lies between 24.6 and 25.3. By referencing the minimum influence diameter coefficient typically used for vertical drains, the applicable range for horizontal drainage boards in sealed geomembrane bags is suggested to be 15.0 to 25.3. Results also reveal that the upper slurry layer drains more efficiently than the lower layer due to gravity-assisted downward flow. In contrast, upward drainage in the lower zone is less effective. Adding a drainage board at the bottom creates a direct flow path and improves consolidation in the lower zone. To mitigate clogging during testing, the drainage board was embedded in geotextile, which reduced clogging to some extent. However, as clogging is difficult to avoid in practice, the proposed coefficient does not account for its effects.

Keywords: Geomembrane bags, Horizontal drainage boards, Vacuum preloading, Consolidation, Slurry

Experimental study on the wicking performance of a wicking geotextile in coarse-grained soils under freezing-thawing actions

Zhilang You [a, b], Jian Xu [a, b, *], Hua Liu [a, b], Zhichao Zhang [a], Yang Peng [a c]
a School of Civil Engineering, Xi'an University of Architecture and Technology, Xi'an, Shaanxi, 710055, China
b Shaanxi Key Laboratory of Geotechnical and Underground Space Engineering, Xi'an University of Architecture and Technology, Xi'an, Shaanxi, 710055, China
c China Energy Engineering Group Shaanxi Electric Power Design Institute Co., Ltd, Xi'an, Shaanxi, 710054, China

Abstract: The effectiveness of a self-developed wicking geotextile under different freezing-thawing cycles (0, 1, 3, 5, 10) in draining water from the coarse-grained railways soils with varying initial water contents (12 %, 15 %, 18 %, and 21 %) and fine contents (5 %, 10 %, 15 %, 20 %, 30 %) was evaluated using a series of vertical wicking tests. Results show that: 1) the wicking geotextile demonstrated efficient vertical water drainage from coarse-grained soils, with its performance significantly influenced by soil properties (initial water content and fine content) and freezing-thawing cycles; 2) the maximum liquid vertical wicking heights (LVWHs) of the wicking geotextiles in the coarse-grained soils increased with the increasing initial water contents but decreased with the increasing fine contents; 3) with the increase in freezing-thawing cycles, the maximum LVWHs of the wicking geotextiles in coarse-grained soils demonstrated a two-stage decline (first decreasing rapidly, then slowing down) before stabilizing at a constant value. Based on the microstructures, the mechanisms by which the initial water contents, fine contents, and freezing-thawing cycles affected the wicking performance were qualitatively analyzed and discussed. This study contributes to frost heave prevention of coarse-grained soils in cold regions.

Keywords: Wicking geotextiles, Coarse-grained soil, Wicking performance, reezing-thawing cycle, Fine content, Initial water content

Investigation on dewatering and reinforcement of dredged clay treated with SAP and PVD under vacuum preloading

Yupeng Cao [a,b], Xinzhuang Cui [c], Zhehao Qiu [d], Jie Yin [d,*] , Pengfei Qi [a], Shuo Sun [a]
a College of Civil and Transportation Engineering, Weifang University, Weifang, 261061, China
b School of Architecture and Engineering, Yancheng Polytechnic College, Yancheng, 224005, China
c School of Civil Engineering, Chongqing University, Chongqing, 400044, China
d Department of Civil Engineering, Faculty of Civil Engineering and Mechanics, Jiangsu University, Zhenjiang, 212013, China

Abstract: This study investigates the dewatering and reinforcement performance of high-water-content dredged slurry using vacuum preloading combined with superabsorbent polymer (SAP) as a flocculant. Preliminary sedimentation experiments were conducted to compare the dewatering performance of different flocculants, and SAP was identified as the most effective additive for enhancing sedimentation. Laboratory vacuum preloading model tests were conducted on dredged clay treated with SAP and prefabricated vertical drain (PVD), to evaluate the effectiveness of SAP in enhancing the dewatering process. Results show that SAP enhances vacuum efficiency, leading to higher and faster vacuum pressure stabilization near the PVD. SAP-treated samples exhibited more rapid pore water pressure dissipation and accelerated water content reduction, particularly in the early stages. Post-treatment water content increased with distance from the PVD, but SAP improved overall drainage uniformity. Vane shear strength decreased with distance from the PVD but remained higher in SAP-treated samples, showing a linear correlation with normalized water content. SAP also influenced soil column formation, expanding its effective radius and reducing stabilization time. Two quantitative models were developed to predict shear strength and soil column radius variations under vacuum preloading with and without SAP. The radius of the soil column formed during vacuum preloading varied with depth, decreasing towards the bottom and increasing towards the surface. These findings provide valuable insights for optimizing vacuum preloading in dredged material treatment and soft soil improvement.
Keywords: SAP, PVD, Dredged clay, Water content, Vane shear strength

Mitigating washboard effect: A study on geocells as soil reinforcement for unpaved roads

Laura Ibagón [a,b], Bernardo Caicedo [b,*], Juan P. Villacreses [a], Fernando López-Caballero [c]
a Universidad San Francisco de Quito, Diego de Robles y Via Interoceanica, College of Science and Engineering, Quito, Ecuador
b Universidad de Los Andes, Department of Civil and Environmental Engineering, Bogotá, Colombia
c Université Paris-Saclay, CentraleSupélec, CNRS, ENS Paris-Saclay LMPSLaboratoire de Mécanique Paris-Saclay, 91190, Gif-sur-Yvette, France

Abstract: Washboard or corrugation is characterised by undulating patterns that emerge on unpaved roads as vehicles pass over. Soil properties, vehicle velocity, and mass influence these undulations. This study investigates the use of a cellular confinement system (geocells) placed at the road surface as a method to increase soil shear resistance. This approach aims to mitigate the formation of washboard undulations. A multi-pass experimental setup was employed to evaluate the reinforcement effect on the washboard phenomenon. The setup consists of a rotating wheel that traverses a sandy path, both with and without geocell reinforcement. Reinforced and non-reinforced results were compared under various scenarios, including wheel velocities and masses. Additionally, the effect of geocell confinement was compared with the effect of apparent cohesion using the theoretical model proposed by Ibagón et al. (2025). Findings showed that ripple formations are significantly reduced due to the geocell reinforcement. This suggests that geocells placed at the road surface may improve the durability and stability of unpaved roads under repeated vehicular loads.
Keywords: Washboard effect, Soil wheel interaction, Corrugation, Soil undulations, Unpaved roads, Soil reinforcement, Geocells

Centrifuge modelling of EPS geofoam behind integral bridge abutments

Douglas G. Morley [a,*] , Gopal SP. Madabhushi [a] , Dennis Sakufiwa [b]
a Schofield Centre, Dept. of Engineering, Univ. of Cambridge, Cambridge, CB3 0EF, UK
b National Highways, Leeds, LS11 9AR, UK

Abstract: This research investigates the extent to which geosynthetic compressible inclusions can be used to improve the performance of integral bridges. Geotechnical centrifuge modelling was used to simulate thermal movements acting on a 9 m abutment on a spread foundation, with and without a 1.2 m thick EPS geofoam inclusion. The compressible inclusion was found to significantly reduce the earth pressures behind the abutment generated over a 120-year design life of thermal cycles without undergoing notable permanent deformation. This resulted in the bridge deck axial force and peak abutment bending moment reaching only a third and two-thirds, respectively, of the values without the geofoam. Backfill settlement increased slightly when the compressible inclusion was used, although the peak settlement immediately behind the abutment face remained similar at around 100 mm. Through the application of extreme displacement amplitudes, it was found that the performance of EPS geofoam was not overly sensitive to permanent deformation, which was concentrated behind the top half of the abutment. By providing partial isolation, rather than accommodating thermal movements in their entirety, these results suggest that EPS geofoam can improve integral bridge performance even when subjected to large thermal movements.

Centrifuge modeling on the geosynthetic-reinforced soil (GRS) abutments with different combinations of reinforcement spacing and tensile stiffness

Qingming Wang [a], Chao Xu [b,*] , Geye Li [c,**], Panpan Shen [d], Chongxi Zhao [a]
a Department of Geotechnical Engineering, College of Civil Engineering, Tongji University, Shanghai, 200092, China
b Key Laboratory of Geotechnical and Underground Engineering of the Ministry of Education, Department of Geotechnical Engineering, College of Civil Engineering, Tongji University, Shanghai, 200092, China
c School of Environment and Safety Engineering, North University of China, Taiyuan, Shanxi, 030051, China
d Shanghai Investigation, Design & Research Institute Co., Ltd., Shanghai, 200434, China

Abstract: Three centrifuge model tests were conducted to investigate the performance of geosynthetic reinforced soil (GRS) abutments with modular block facing under localized vertical loads. This study examined the effects of different combinations of reinforcement spacing S_v and tensile stiffness J on the behavior of GRS abutments. In this study, river sand and woven geotextiles were used as the backfill soil and reinforcement material, respectively. Test results show that under the same ratio of $J/S_v = 3.7$, using the combination of smaller S_v and lower J was more effective in minimizing the beam seat settlements and the lateral facing displacements induced by localized vertical loads than the combination of larger S_v and higher J. Meanwhile, smaller additional vertical stresses transferred from the applied loads within the GRS abutment and smaller reinforcement tensile forces were also observed for the combination of smaller S_v and lower J. Furthermore, the maximum tensile forces in each layer occurred under the beam seat for the upper reinforcement layers and near the facing for the lower layers for all three tests. A more uniform distribution of the reinforcement tensile force was found for the combination of smaller S_v and lower J.

Keywords: Geosynthetics, Geosynthetic reinforced soil, Abutment, Centrifuge model test, Reinforcement spacing, Tensile stiffness

Degradation of polyethylene geomembranes exposed to different mine tailings pore waters

Rodrigo A. e Silva , R. Kerry Rowe * , Fady B. Abdelaal
GeoEngineering Centre at Queen's-RMC, Queen's University, Ellis Hall, Kingston, ON, Canada, K7L 3N6

Abstract: The chemical durability of three 1.5 mm geomembranes (GMBs) – two made from high-density polyethylene (HDPE) and one from a blended polyolefin resin – was examined over 3 years in synthetic tailings pore water solutions. The immersion solutions included a pH 4.0 solution simulating pore water from oxidized copper-zinc mine tailings (PW-4), pH 7.0 (PW-7) and 8.0 (PW-8) solutions simulating arsenic-bearing pore waters from saturated gold mine tailings, and a pH 9.5 solution (PW-9.5) simulating pore water affected by cyanide complexes and/or chemicals from a cyanidation plant. Both HDPE GMBs reached nominal failure in stress-crack resistance at 85 °C, followed by reductions in melt index and, in some cases, tensile strength. The blended GMB showed no degradation. PW-7 was the most aggressive solution in terms of degradation of mechanical properties of the HDPEs, while PW-9.5 was the most aggressive for antioxidant depletion for all three GMBs. The relative performance of the three GMBs in different tailings pore waters could not be predicted from the GMBs' initial properties or the solutions' chemistry. Overall, results highlight the importance of conducting immersion tests for applications involving complex chemical environments.

Keywords: Geomembranes, HDPE, Blended, Tailings storage facilities, Pore water hemistry, Degradation, Heap leaching, Arrhenius, Mining

The role of boundary normal stiffness in the micromechanical behavior of geomembrane-sand interface: A numerical study

Haibo Wang [a], Ge Gao [a,*], Mohamed A. Meguid [b], Nasser Khalili [c], Lulu Zhang [d]

a State Key Laboratory of Ocean Engineering, Shanghai Key Laboratory for Digital Maintenance of Buildings and Infrastructure, School of Ocean and Civil Engineering, Shanghai Jiao Tong University, Shanghai, 200240, China

b Department of Civil Engineering, McGill University, 817 Sherbrooke St. W., Montreal, QC, H2A 0C3, Canada

c School of Civil and Environmental Engineering, University of New South Wales (UNSW Sydney), Civil Engineering Building (H20) Level 4, Room CE404, Kensington Campus, Australia

d State Key Laboratory of Ocean Engineering, Collaborative Innovation Center for Advanced Ship and Deep-Sea Exploration, Shanghai Key Laboratory for Digital Maintenance of Buildings and Infrastructure, School of Ocean and Civil Engineering, Shanghai Jiao Tong University, Shanghai, 200240, China

Abstract: Three-dimensional discrete element method (DEM) is employed to investigate how boundary normal stiffness influences the shearing behavior at the soil-geomembrane interface. A robust and efficient algorithm was developed and implemented into direct shear numerical models, effectively capturing the key aspects of the sand-geomembrane interface behavior across a wide range of boundary normal stiffness values. The numerical model was validated by comparing the bulk responses of interface shear stress and volume change versus shear displacement with experimental data. At the microscale, particle displacements, rotations, contact network evolution, coordination number, redundancy factor and elastic stiffness tensor were investigated to shed light on the impact of normal stiffness on the interface response. The micromechanical insights, such as the development of higher level of geometrical and mechanical anisotropy, stronger interface interlocking to resist sliding and rolling of sand particles, and increased local density and bulk stiffness, are connected to the macroscopic response, explaining how higher boundary normal stiffness enhances interface shear strength and normal stress during shearing.

Keywords: Sand-geomembrane interface, Volume change boundary condition, Constant normal stiffness (CNS), Discrete element method (DEM), Microscale characterization

Dynamic properties of sand reinforced with non-woven geotextile sheets using resonant column and bender elements tests

Sandyapogu Peddaiah , Jyant Kumar *
Civil Engineering Department, Indian Institute of Science, Bengaluru, 560012, India

Abstract: This study examines an inclusion of non-woven polypropylene geotextiles sheets on dynamic properties of dry sand. Resonant column (RC), bender and extender elements (BE, EE) tests were conducted on sand reinforced with different numbers of geotextile sheets (N_{gts}) under varying confining pressures. The inclusion of geotextile sheets significantly increases not only the shear modulus (G) but also the damping ratio (D) of the reinforced sand specimen. As compared to the data reported in literature, although geotextiles with lesser tensile strength were being employed in the current research, the percentage increases in the values of G were, however, found to be relatively greater. The inclusion of geotextile also leads to a reduction in the amplitude of the shear strain (γ). The values of shear and Young's moduli (G_0, E_0) determined respectively from BE and EE tests also confirm the improvement in moduli values for sand reinforced with geotextile sheets. The improvement in Young's modulus is found to be, however, relatively smaller. The effect of an inclusion of geotextile sheets on (i) percentage increase in G_0 and percentage decrease in γ_{min} increases continuously with an increase in σ_3, and (iii) percentage increase in D_{min}, however, reduces with an increase in σ_3.

Keywords: Geotextiles, Resonant column, Bender and extender elements, Shear modulus, Young's modulus, Damping ratio, Shearing strain

Experimental and numerical investigation of the unsaturated behavior of conventional and wicking non-woven geotextiles

J. Jarjour *, A. Ibrahim , M.A. Meguid
Department of Civil Engineering, McGill University, 817 Sherbrooke St. W., Montreal, QC, H3A 0C3, Canada

Abstract: Non-woven geotextiles play a crucial role in transportation embankments, including roadways and railways, by providing separation, filtration, and drainage. These embankments typically remain unsaturated, with soil voids containing both air and water. Understanding their behavior in unsaturated conditions requires analyzing water retention curves. Conventional non-woven geotextiles effectively drain gravitational water but struggle in unsaturated conditions, leading to moisture accumulation and potential distress.

To address this limitation, a novel wicking non-woven geotextile has been developed, featuring hydrophilic and hygroscopic properties achieved through chemical treatment. This study investigates the unsaturated behavior of this wicking non-woven geotextile compared to conventional non-wicking geotextiles using laboratory experiments, including capillary rise, hanging column, and pressure plate tests, to determine geotextile water retention curves (GWRC) across a suction range of 0–1000 kPa. Numerical studies further explore its working mechanism and drainage performance under varying conditions, such as rainfall and groundwater fluctuations. A validated numerical model, based on wetting front propagation tests, simulates the wicking geotextile's behavior in soil. Results confirm its higher drainage capacity under unsaturated conditions, mitigating moisture-induced distress. These findings highlight the potential of wicking geotextiles in mitigating moisture-induced distress in transportation embankments and enhancing geotechnical performance.

Keywords: Geosynthetics, Matric suction, Unsaturated soil, Wicking geotextiles, Non-woven geotextiles, Numerical modeling

Laboratory evaluation of water absorption and drainage performance of a new wicking geotextile in loess-sand mixtures

Zhilang You [a,b], Jian Xu [a,b,*], Hua Liu [a,b], Yang Peng [a,c], Zhichao Zhang [a]
a School of Civil Engineering, Xi'an University of Architecture and Technology, Xi'an, Shaanxi, 710055, China
b Shaanxi Key Laboratory of Geotechnical and Underground Space Engineering, Xi'an University of Architecture and Technology, Xi'an, Shaanxi, 710055, China
c China Energy Engineering Group Shaanxi Electric Power Design Institute Co., Ltd, Xi'an, Shaanxi, 710054, China

Abstract: Climatic warming and humidification in Northwest China have led to frequent extreme rainfall events, triggering numerous geohazards along linear infrastructure such as highways in the Loess Plateau region. A self-developed wicking geotextile with fibers featuring an irregular cross-section (14 μm in major axis, 7 μm in minor axis) was first introduced to facilitate drainage in loess-sand mixtures, thereby enhancing the strength and stability of foundations. Capillary effect and drainage tests were conducted to evaluate its water absorption and drainage performance of loess-sand mixtures with various ratios of poorly graded sand with silt. Additionally, evaporation tests were performed to assess the evaporation rate of the wicking geotextiles under different environmental conditions, including variations in temperature and humidity. The results showed that: 1) the maximum liquid vertical wicking heights of the wicking geotextiles in loess-sand mixtures increased with both sand contents and initial water contents; 2) the evaporation rate decreased with increasing humidity, but increased with increasing temperature; 3) Under simulated extreme rainfall, the drainage efficiency of the wicking geotextile improved with greater sand content. The drainage mechanisms of the wicking geotextiles in loess-sand mixtures were analyzed based on fibers' microstructure. This study contributes to geohazard mitigation in the Loess Plateau.

Keywords: Wicking geotextile, Loess-sand mixture, Water absorption and drainage, Sand content

Impact of test speed on the thermo-mechanical behavior of various types of geomembranes

Hamza Tahir *, Guillaume Stoltz , Guillaume Veylon , Laurent Peyras
INRAE, Aix Marseille Universit´e, RECOVER, Aix-en-Provence, France

Abstract: Geomembranes in hydraulic structures are often in exposed conditions; the ambient temperature can vary significantly and hence influence their mechanical behavior. To determine their tensile behavior at various temperatures, unidirectional tensile tests can be performed in temperature-controlled chambers. However, the test speeds recommended by the main standards are high. Considering the elasto-visco-plastic behavior of geomembranes, the test speed has a double effect; the first comes from the viscous component and the second comes from temperature variation, due to the self-heating of the tested specimen during test. This study aims to investigate the effect of the test speed on the mechanical behavior of various geomembranes by decoupling the viscous effect and the self-heating effect. Through various unidirectional tensile tests performed on a wide range of test speeds, from 0.01 mm/min to 500 mm/min, it was found that for various tested geomembranes (HDPE, EPDM, PVC, FPO, Bituminous), the higher the test speed, the greater the tensile force at various strain levels and the greater the change in internal temperature of the specimen. Regarding the temperature effect, it was shown that for test speeds less than or equal to 10 mm/min, no self-heating of the specimen was observed for all geomembranes.

Keywords: Geomembranes, Uniaxial tensile test, Test speed, Tensile behavior, Internal temperature change, Viscosity

Chemical-enhanced electrokinetic geosynthetics (EKG) electro-osmosis combined with vacuum preloading for consolidation and copper remediation in contaminated dredged sludge

Yang Shen [a], Nihao Wei [a], Kewei Fan [a,*] , Wencheng Qi [a], Jianting Feng [a], Zhiqiang Lai [b,c,**]
a Key Laboratory of Ministry of Education for Geomechanics and Embankment Engineering, Hohai University, Nanjing, 210098, China
b Yellow River Institute of Hydraulic Research, Yellow River Conservancy Commission, Zhengzhou, 450003, China
c Key Laboratory of Lower Yellow River Channel and Estuary Regulation, Ministry of Water Resources, Zhengzhou, 450003, China

Abstract: Chemical-enhanced electrokinetic geosynthetics (EKG) electro-osmosis combined with vacuum preloading was employed to simultaneously consolidate and remediate copper-contaminated dredged sludge. Five chemical additives—citric acid, tartaric acid, hydrogen peroxide, rhamnolipids, and sodium chloride—were systematically evaluated via model tests. Results show that all additives improve both drainage and copper removal, with sodium chloride exhibited the enhancement in dewatering performance, while rhamnolipid achieved the highest copper removal efficiencies. Mechanistic analysis revealed that chemical additives improved sludge dewatering by enhancing pore water migration—through modifying soil structure, increasing ionic conductivity, or reducing surface tension. They also promoted copper removal by altering speciation: acidic chelating agents reduced pH and stabilized Cu^{2+} in soluble complexes, suppressing precipitation, while in near-neutral conditions, cathodic OH^- dissolved $Cu(OH)_2$ into mobile species, facilitating transport. Energy analysis confirmed that chemical-enhanced systems improved the energy efficiency of copper removal. These findings support the integrated use of EKG electro-osmosis combined with vacuum preloading, coupled with appropriate chemical agents, as a viable and energy-efficient strategy for the remediation of heavy metal-contaminated dredged sludge.

Keywords: Electrokinetic geosynthetics, Electro-osmosis, Vacuum preloading, Contaminated dredged sludge, Chemical activities, Consolidation, Copper remediation

Field performance of erosion control on Lamtakong dam slopes using geocell and ruzi grass cover: A case study

Nuttawut Thanasisathit [a], Supphanut Chuenjaidee [b], Panich Voottipruex [c], Pornkasem Jongpradist [d], Patara Kalayasri [e], Pitthaya Jamsawang [f,*]

a Department of Civil Engineering, King Mongkut's University of Technology North Bangkok, Thailand

b Department of Civil Engineering, King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

c Department of Teacher Training in Civil Engineering, King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

d Construction Innovations and Future Infrastructures Research Center, Department of Civil Engineering, Faculty of Engineering, King Mongkut's University of Technology Thonburi, Bangkok, Thailand

e Civil Maintenance Department, Electricity Generating Authority of Thailand (EGAT), Bangkok, Thailand

f Soil Engineering Research Center, Department of Civil Engineering, King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

Abstract: This study investigates the field performance of an integrated erosion control system combining geocell reinforcement and Ruzi grass cover on 30°, 45°, and 60° slopes at Lamtakong Dam, Thailand. Simulated rainfall intensities of 100, 130, and 170 mm/h were applied to assess the effects of geocell coverage patterns and vegetation maturity on runoff and sediment transport. Results show that full geocell coverage (C100) achieved the highest erosion resistance, reducing runoff and sediment by up to 90 % and 98 %, respectively. Partial coverage (C60 and C80) also proved effective, achieving comparable reductions (RRR of 60–75 % and SRR of 65–78 %) while offering cost-saving potential. Ruzi grass alone reduced sediment concentration by up to 75 % after 8 weeks, emphasizing the importance of vegetation maturity. Discontinuous geocell layouts performed similarly to continuous ones at equivalent coverage, indicating that total coverage area, not pattern, governs performance. A multiple regression model was developed to predict sediment reduction based on geocell coverage, Ruzi grass age, slope angle, and rainfall intensity, confirming the dominant influence of geocell coverage and vegetation maturity. The findings support the integrated system as a sustainable and scalable solution for erosion-prone slopes under varying environmental conditions.

Keywords: Bioengineering, Geosynthetics, Land protection, Sediment control, Soil stabilization

Influence of initial water content and voltage gradient on electroosmotic dewatering of ultra-fine soils using novel electrokinetic geosynthetics

Nilan Jayasiri [a,*] , Andy Fourie [a] , Cristina Vulpe [b]
a Department of Civil, Environmental and Mining Engineering, The University of Western Australia, Perth, WA, 6009, Australia
b Department of Mechanical Engineering, The University of Western Australia, Perth, WA, 6009, Australia

Abstract: Electroosmotic (EO) dewatering has gained substantial attention as an alternative method for improving weak soil deposits. One aspect that has not received sufficient attention in this approach is the influence of initial water content and voltage gradient on the EO treatment. This study aimed to provide a comprehensive understanding of the key operational parameters and post-dewatering performance metrics of EO treatment with varying initial water contents and voltage gradients. A number of electrical, hydraulic and soil water retention parameters were monitored during the treatment process, and the material response to the EO treatment was evaluated by assessing various geotechnical and physiochemical parameters. The results indicate that, regardless of the voltage gradients, overall, the EO dewatering led to a reduction of at least one-third of the original water content. The EO treatment resulted in a sevenfold, ninefold and twentyfold relative increase in undrained shear strength for the experiments with the lowest, intermediate and highest initial water contents, respectively, indicating an exponential increase as the initial water content of the slurry increases. The implications of the findings to improve the viability of EO treatment for large-scale applications using electrokinetic geosynthetics are also discussed.
Keywords: Electroosmotic dewatering, Consolidation, Electrokinetic geosynthetics, Undrained shear strength, Ultra-fine soils

A settlement calculation method for soft ground subjected to air-boosting vacuum preloading

Fang Xu [a,b], Wenqian Hao [a,b], Qichang Wu [a,b,*], Junfang Yang [a,b], Qi Yang [a,c]
a School of Civil Engineering, Central South University, Changsha, China
b Mechanics Teaching Experiment Center, Central South University, Changsha, China
c National Engineering Research Center of High-speed Railway Construction Technology, Changsha, China

Abstract: The air-boosting vacuum preloading (AVP) method effectively enhances the treatment performance of soft ground compared to conventional vacuum preloading. The air-boosting mechanism primarily exerts dewatering, de-structuring, and mitigating apparent clogging around drains, among which the dewatering is closely related to variations in pore water pressure within the soil. Through systematic analysis of pore water pressure variations during the preloading process, a computational framework for quantifying settlement increments induced by dewatering effect is established. By integrating the proportional contribution of dewatering to the total air-boosting effects, the settlement amplification mechanism attributable to air-boosting was characterized. These findings, in conjunction with vacuum consolidation theory, culminated in the development of a settlement calculation method for AVP-treated soft ground. The proposed method was validated through its application to two case histories, demonstrating favorable computational efficiency and satisfactory alignments between predicted and measured settlements. It also effectively reflects the evolution of ground settlement under air-boosting. Furthermore, the variations of the soil e-lg(p) compression curve under AVP treatment were investigated, facilitating the identification of an approximate shifted e-lg(p) curve. Finally, the primary factors affecting the settlement of AVP-treated soft ground were clarified. These findings offer valuable insights for the analysis and design of AVP-treated soft ground.

Keywords: Air-boosting vacuum preloading, Soft ground, Dewatering effect, Settlement, Calculation method

Full-scale experiment and numerical studies on vertical impact characteristics of reinforced embankment

Bo Chen [a], Liang Lu [b,c,*], Zongjian Wang [d], Shuwen Ma [e], Katsuhiko Arai [f]
a School of Civil Engineering and Transportation, Northeast Forestry University, Harbin, Heilongjiang 150040, China
b School of Civil Engineering, Chongqing University, Chongqing 400045, China
c State Key Laboratory of Safety and Resilience of Civil Engineering in Mountain Area, Chongqing 400045, China
d College of River & Ocean Engineering, Chongqing Jiaotong University, Chongqing, 400074, China
e Dept. of Architectural and Engineering, Chongqing Industry Polytechnic College, Chongqing, 401120, China
f University of Fukui, Fukui, 9108507, Japan

Abstract: Reinforced embankments offer advantages including reduced settlement, environmental friendliness and substantial protection against rockfall hazards. However, current research primarily focuses on the impact response of the upstream facing of reinforced embankments against rockfalls, while neglecting the influence of vertical rockfall impacts on embankment design and analysis. This study investigates deformation characteristics and load transfer mechanisms of reinforced embankment under vertical rockfall impacts through a full-scale experiment. Furthermore, based on the full-scale experiment, a validated numerical model was developed, enabling a parametric analysis of the effects of reinforcement cross-sectional configurations, rock shapes, impact energy and impact points on embankment performance. The findings indicate that reinforced embankments exhibit excellent impact resistance, exhibiting two distinct deformation patterns upon impact that are primarily influenced by impact point, impact energy and reinforcement cross-sectional configuration. Rockfalls with smaller aspect ratios tend to achieve greater penetration depths while causing limited disturbance to the embankment. When maintaining equivalent aspect ratios, flatter rock geometries generate stronger impact forces and cause more significant damage to the embankment structure. The insights from this study provide a basis for verifying and improving the current impact-resistance design of reinforced embankments, offering significant implications for enhancing the safety and functionality of such structures.
Keywords: Reinforced embankment, Full-scale experiment, Impact loading, Deformation, Stress distribution

A simple 3D orthotropic model for the tensile response of geogrids: In-isolation and soil–geogrid interaction applications

Lucas Paiva [a,*] , Margarida Pinho-Lopes [a], Robertt Valente [b], António Miguel Paula [c]
a CERIS, Department of Civil Engineering, University of Aveiro, Campus Universitário de Santiago, Aveiro, 3810-193, Portugal
b TEMA, Department of Mechanical Engineering, University of Aveiro, Campus Universitário de Santiago, Aveiro, 3810-193, Portugal
c GiCos, Instituto Politécnico de Bragança, Campus de Santa Apolónia, 5300-253 Bragança, Portugal

Abstract: The short-term tensile response is one of the key aspects in designing geogrid-reinforced soil structures. In this paper a simple data-driven 3D orthotropic model for the short-term tensile response is proposed. The Hill48 yield model is chosen to represent the orthotropic behaviour of the geogrid, and a procedure to obtain the necessary parameters, from simple tensile test data, is presented. The model is then implemented in ABAQUS, and validated against a realistic problem where the geogrid is embedded in soil. The influence of the orthotropy (against isotropy) on both the reinforcement and the overall soil–geogrid structure is evaluated. The results show that the orthotropic model can accurately predict the tensile response of the geogrid in different directions, with the orthotropy having a significant influence on the reinforcement and the overall structural response, especially in highly orthotropic materials. The study further examined stress redistribution capabilities in geogrids with notches, revealing enhanced stabilization performance using the orthotropic model. Parametric tests indicated that traditional isotropic assumptions might underpredict or overpredict reinforcement performance, emphasizing the advantages for accurate orthotropic characterization. The proposed 3D framework provides a robust, straightforward method for evaluating and optimizing geogrid designs, enabling better prediction of reinforced soil behaviour in geotechnical applications.
Keywords: Geogrids, ABAQUS, Numerical modelling, Plasticity, Orthotropy, Damage

Methods for mitigating effect of apparent clogging in vacuum consolidation and analysis technics – a review

Jinchun Chai [a,b,*], Yafei Qiao [a], Wenqi Ding [a], Liangjin Li [a], Takenori Hino [b]
a Department of Geotechnical Engineering, College of Civil Engineering, Tongji University, Shanghai, China
b Faculty of Science and Engineering, Saga University, Honjo 1, Saga, 840-8502, Japan

Abstract: To increase the efficiency and design accuracy of vacuum consolidation of clayey slurries with prefabricated vertical drains (PVDs) or prefabricated horizontal drains (PHDs), methods for mitigating apparent clogging around PVDs/PHDs, and consolidation solutions considering the effect of the apparent clogging are reviewed/analyzed. Methods for mitigating the effect of apparent clogging has been clarified as thermal, physical and chemical ones. For each method, its work mechanism is explained and its effectiveness is evaluated qualitatively/quantitatively. Recently published solutions for a PVD/PHD unit cell consolidation considering mechanical and/or geometrical non-linearities are summarized. Except technics adopted for modelling the non-linearities, other options considered in the solutions are: (i) Darcian or non-Darcian flow; (ii) equal strain or free strain; (iii) considering creep or not; and (iv) time dependent load or constant load. Further, an incremental imaginary time method has been described in certain detail for solving non-linear PVD/PHD unit cell consolidation with time dependent loads. It has been demonstrated that the method is a pragmatic and versatile one.
Keywords: Vacuum consolidation, Clayey slurry, Apparent clogging, PVD, PHD

Reinforcement effectiveness of stacked prefabricated vertical drain (S-PVD) vacuum preloading method: A case study

Huayang Lei [a,b,c,d], Jiankai Li [a], Shuangxi Feng [a,c,d,*], Tianlu Ma [a], Guoqing Zhang [a], Shengpeng Yu [e]

a Department of Civil Engineering, Tianjin University, Tianjin, 300350, China

b Department of Civil Engineering and Architecture, Guangxi University, Guangxi, 530004, China

c Key Laboratory of Coast Civil Structure Safety of the Ministry of Education, Tianjin University, Tianjin, 300354, China

d Key Laboratory of Comprehensive Simulation of Engineering Earthquake and Urban-Rural Seismic Resilience, CEA, Tianjin, 300354, China

e China Railway 20th Bureau Group Corporation Limited, Shanxi, 710016, China

Abstract: To address the issue of vacuum pressure attenuation in traditional vacuum preloading ground reinforcement methods, this study proposes a stacked prefabricated vertical drain (S-PVD) vacuum preloading method based on the stratified sealing drainage technology. A comprehensive field test was conducted to comparatively analyze the reinforcement effectiveness of three vacuum preloading approaches: conventional prefabricated vertical drains (PVDs), reverse prefabricated vertical drains (R-PVDs), and the novel S-PVDs. Test results demonstrate that the S-PVD method not only significantly enhances the ground reinforcement effect, effectively increasing surface settlement and vane shear strength of the soil, but also improves the uniformity of the reinforced soil, with only a 4.6 % difference in the vane shear strength between the top and bottom of the drainage board. In addition, the S-PVD method can meet the unloading criteria in less than 30 days, reducing the consolidation period by 34.1 %. The optimized S-PVD system demonstrates notable cost-effectiveness through energy-efficient operation and accelerated consolidation, achieving 26.5 % reduction in unit area cost of materials and electricity compared to conventional vacuum preloading. These findings suggest that the S-PVD method represents a promising innovation in deep soil stabilization technology, offering a technically and economically viable solution for soft ground improvement in coastal regions.

Keywords: Vacuum preloading, Stacked prefabricated vertical drain, Reinforcement effect, Case study

Experimental study on reinforcement and remediation of nickel-contaminated sludge using grouting vacuum preloading combined with electroosmosis

Peng Wang [a,b,c], Ming Li [a], Zhuoxuan Wu [a], Jun Wang [a,b,c], Guohui Yuan [a,b,c,*] , Xianfeng Huang [d], Jianfeng Wu [e]

a College of Civil Engineering and Architecture, Wenzhou University, Wenzhou, Zhejiang, 325035, China

b Key Laboratory of Engineering and Technology for Soft Soil Foundation and Tideland Reclamation of Zhejiang Province, Wenzhou 325035, China

c International Cooperation Base for Science and Technology on Ultra-soft Soil Engineering and Smart Monitoring, Wenzhou 325035, China

d College of Life and Environment Science, Wenzhou University, Wenzhou, Zhejiang, 325035, China

e Zhejiang Digital Intelligent Transportation Design Institute Co., Ltd., Hangzhou, Zhejiang, 310000, China

Abstract: Traditional vacuum preloading, electroosmotic techniques face challenges such as poor removal efficiency, reinforcement and high energy consumption when treating contaminated sludge with high water content. This study investigates the reinforcement and remediation of nickel (Ni)-contaminated sludge with high water content using an approach combining grouting, vacuum preloading, and electroosmosis (GVE). Through laboratory model tests, the effects of grouting agents, vacuum preloading, and voltage loading modes on Ni removal efficiency, soil reinforcement, and energy consumption were evaluated. The results demonstrate that the grouting of sodium alginate can chelate Ni^{2+} in the soil, facilitating the removal of heavy metal ions during the electroosmosis process. The GVE combined with vacuum preloading significantly enhances Ni removal rates, achieving up to 94.52 % compared to 65.11 % with electroosmosis alone. Additionally, GVE reduced soil water content to 30.34 % and increased shear strength to 98 kPa, indicating improved soil reinforcement. The step loading further reduced energy consumption by over 35 % compared to constant voltage loading while enhancing both soil remediation and reinforcement. This study concludes that GVE, particularly with step loading and intermittent loading, is an effective and energy-efficient method for remediating and reinforcing heavy metal contaminated sludge.

Keywords: Sludge, Vacuum preloading, Electroosmosis, Remediation, Reinforcement

Effect of temperature on geogrid-facing connection force and lateral earth pressure based on innovative testing method

Huaxin Han [a], Chengzhi Xiao [a,*] , Jianguang Yin [a], Nan Zhu [b,c,d]
a School of Civil and Transportation Engineering, Hebei University of Technology, Tianjin, 300401, China
b Tianjin Port Engineering Institute Co., Ltd. of CCCC First Harbor Engineering Co., Ltd., Key Laboratory of Port Geotechnical Engineering, Ministry of Transport, China
c Key Laboratory of Port Geotechnical Engineering of Tianjin, Key Laboratory of Geotechnical Engineering, CCCC, Tianjin, 300222, China
d CCCC First Harbor Engineering Co., Ltd., Tianjin, 300461, China

Abstract: Conventional geosynthetic-reinforced soil (GRS) retaining wall design guidelines focus on the horizontal reinforcement tensile force calculated based on lateral earth pressure under constant backfill temperature, while giving insufficient attention to the actual connection mechanism between the wall facing and the reinforcement. This limitation may impact the service life of retaining walls. In this study, a novel testing method was developed to simulate the differential settlement between the backfill and the facing within walls, enabling a new approach to quantify the reinforcement-facing connection force under various temperature conditions. Test results demonstrated that this connection force significantly exceeds the measured horizontal reinforcement tensile force under high vertical stress, and the ratio tends to increase with rising temperature under the same vertical stress. Additionally, the lateral earth pressure exerted on the wall back increases with the reinforcement stiffness, but it remains lower than the Rankine active earth pressure. At low temperatures, the conventional estimation method based on Rankine theory was shown to significantly underestimate the actual connection force. The study provides insights for the modification of the current GRS wall design guidelines.

Keywords: Geosynthetics, Connection force, Temperature, Lateral earth pressure, Down-drag, GRS retaining walls

Mitigating frost damage in cold region canals: performance evaluation of a two-layer geomembrane lining structure

Jianrui Ge [a,b], Yuncheng Yuan [a], Haoyuan Jiang [b,c,*], Zhengzhong Wang [b,c], Yi Wang [d], Min Xiao [e]

a College of Energy and Power Engineering, Lanzhou University of Technology, Lanzhou, 730050, China

b State Key Laboratory of Cryospheric Science and Frozen Soil Engineering, Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences, Lanzhou, 730000, China

c College of Water Resources and Architectural Engineering, Northwest A&F University, Yangling, Shaanxi, 712100, China

d Nanjing Hydraulic Research Institute, Nanjing, 210024, China

e Jiangxi Science and Technology Normal University, Nanchang, 330038, China

Abstract: To address frost damage to canal lining structures in arid and cold regions, this study proposes the use of a two-layer composite geomembranes (TLCGs) as a frost-heaving composite lining structure. To assess the performance of the two-layer geomembrane lining structure (TLCGLS), field tests were conducted. Considering the interaction between TLCGs and lining structure and canal foundation soil, a calculation model of canal frost heave is established based on the water-heat-force coupling theory of foundation soil. The stress of canal lining with single-layer composite geomembrane (SLCG), frictionless two-layer composite geomembranes (FTLCGS), and TLCGs under frost-heaving conditions is analyzed. The results indicate that TLCGLS can enhance the temperature of canal foundation soil by 7 % and decrease the water content by 12 %, thereby effectively mitigating canal deformation by 38 %. The TLCGs cushion under the canal lining can effectively release the tangential freezing constraint, so that the lining structure has certain flexibility, so as to prevent frost damage. Therefore, the reasonable use of TLCGs with appropriate friction and the setting of flexible structural joints can prevent frost damage.

Keywords: Two-layer composite geomembranes, Water-heat-force coupling, Field experiment, Numerical simulation, Cold region canals, Frost heave