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摘要集

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目　录

Vibration response of closely spaced footings protected by use of rubber sheet: An in-situ investigation

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Abstract: It is essential to protect sensitive equipment located in the vicinity of vibration sources (VS). As the well-known method of using wave barriers is ineffective to protect facilities that are located very close to a VS, in this study the effect of a thin rubber sheet to protect a nearby foundation (NF) was assessed. This was achieved experimentally at a site using a semi-large scale machine foundation model as the VS and a similar concrete foundation as the NF. The effects of the rubber sheet position (beneath the VS and NF) and of the rubber sheet thickness (6, 12, 18 and 24 mm) were assessed within the vibration frequency range 10-70 Hz and at various NF to VS distances (Distance/Foundation Width = 1 to 10). The testing illustrates that, by increasing the rubber sheet thickness beneath the VS/NF, there is a consequential resonant response frequency reduction at the NF. Moreover, it was found that placing the rubber sheet beneath the VS is more efficient at reducing the NF's resonant amplitude while placing the rubber sheet beneath the NF is more effective in protecting the NF from the resonant frequency variation. This is due to the dominance of the VS's resonant frequency.

Keywords: Geosynthetics, Rubber sheet, Vibration response, Spaced footings, In-situ investigation

Unveiling the reinforcement benefits of innovative textured geogrids

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Abstract: The smooth surface texture of the commercially available geogrids limits the shear strength mobilization at the interfaces. This study presents the design, manufacturing, and interface performance evaluation of innovative textured geogrids. Geogrids with square, triangular, and hexagonal apertures with and without inherent surface texture were manufactured through additive manufacturing (3D printing) technique, using PLA (Poly Lactic Acid) filament. The texture includes elevated pins of 3 mm height at the junctions and inherent diamond pattern of 1 mm height on the ribs. The individual and combined effects of surface texture and aperture shape on the stress–displacement relationship, dilation angle, and the thickness of shear zone are quantified using large-scale direct shear tests and Particle Image Velocimetry (PIV) analysis. Results showed that the textured geogrid with hexagonal aperture has exhibited the maximum interface coefficient of 0.96 with sand followed by the geogrids with triangular and square apertures. Irrespective of the aperture shape, provision of the surface texture resulted in an overall increase of interface shear strength by more than 13%. Further, PIV analysis revealed that the shear zone is 25% thicker for textured geogrids of different aperture shapes, suggesting higher interlocking and passive resistance offered by their textured surfaces.

Keywords: Geosynthetics, Textured geogrid, 3D printing, Interface coefficient,
Aperture shape, PIV

Improvements in vacuum-surcharge preloading combined with electro-osmotic consolidation on soft clayey soil with high water content

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Abstract: This study conducted laboratory tests on soft clayey soils to investigate the effectiveness of the combinations of vacuum-surcharge preloading and electro-osmotic treatment (EOC-VPM-SPM). To minimize the loss of vacuum pressure and mitigate clogging of the drainage system during the consolidation process, two improved methods were developed by optimizing technical characteristics and geometric layout of drainage boards. In the EOC-Alternate VPM-SPM method, alternate vacuum pressure was incorporated using two drainage boards with different lengths in the VPM system, combined with EOC to improve consolidation efficiency. In the multiple-electrodes EOC-VPM-SPM method, a new design of multiple drainage boards in a square tube layout fabricated through 3D printing was employed to provide efficient connections of the consolidation system. Furthermore, electrokinetic geosynthetics (EKG) was utilized as the cathode in the EOC system to minimize erosion and passivation of electrodes for the enhancement in consolidation efficiency. The properties of tested soils were analyzed to evaluate the feasibility of the improved methods. Test results indicated that the consolidation effects were significantly improved, with effectively mitigated clogging of the drainage system. Compared to the traditional method, the water content of the tested soil was reduced through the improved methods, resulting in increased uniformity of strength distribution.

Keywords: Electro-osmosis, Vacuum-surcharge preloading, 3D-printing, Soft clayey soil, EKGs, Improvement method

Analytical model and stress behavior of consolidated load bearing geotextile tubes

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Abstract: Accurately predicting stress-strain characteristics is crucial to ensuring the regulated capacity and controlled deformation of the tubes during and after construction. However, research on the shear strength of geotextile tubes under surcharge loading, especially after dewatering, is insufficient. This study proposes an analytical model with a Stress-State Boundary (SSB) and Yield Function to comprehensively describe the stress-strain behavior of Load-Bearing Geotextile Tubes (LGTs). The SSB is designed to predict the initial state of stress in the infill soil prior to load application, while the Yield Function is formulated to express the shear stress path experienced by the LGT before fabric failure. The model considers various factors that affect LGT behavior, including diverse soil mechanical parameters, nonlinear fabric stiffness, initial tension due to self-weight and principal stress axes rotation. Results show that a decrease in Poisson's ratio corresponds to an increase in failure stress. Moreover, it was demonstrated that the axial failure strain can be influenced by the geotextile linear or nonlinear behavior. Notably, the study highlights that tube height and inclination angle significantly affect the geotextile's confining effect. Beyond theoretical contributions, the analytical model serves as a valuable tool for optimizing geotextile tube design and execution, contributing to project success and longevity through enhanced structural stability.

Keywords: Stress-strain, Stress path, Analytical model, Geotextile tube,
Embankment structure, Non-linear stiffness

Application of the non-linear three-component model for simulating accelerated creep behavior of polymer-alloy geocell sheets

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Abstract: The polymer-alloy geocell sheets (PAGS) represent a novel geocell material developed to replace conventional geocell materials. Accelerated creep testing, a convenient and precise performance evaluation method, presents a viable alternative to traditional creep testing for obtaining long-term creep strains. Nonetheless, there is a lack of prediction and in-depth exploration of accelerated creep testing. This paper aims to assess the efficacy of using the non-linear three-component (NLTC) model to simulate the accelerated creep behavior of PAGS. The predictive accuracy of the NLTC model has undergone evaluation through a comparison between stepped isothermal method (SIM) accelerated creep experimental tests and numerical simulations. Subsequently, the validated NLTC model was employed to simulate the time-temperature superposition method (TTSM), time-stress superposition method (TSSM), and stepped isostress method (SSM) accelerated creep tests, thereby verifying its effectiveness in predicting all accelerated creep tests. The results indicate that the NLTC model can effectively simulate creep deformation induced by temperature increases, particularly the temperatures below 41 °C. Although some errors are observed at elevated temperatures, it is within the acceptable range of 17.4%. Numerical simulation results of TTSM, TSSM, and SSM tests also suggest the model's proficiency in simulating the accelerated creep behavior by temperature and creep load increasing.

Keywords: Geosynthetics, Geocell sheets, SIM accelerated creep tests, Numerical simulations

Freeze-thaw impacts on geocell-stabilized bases considering effects of water supply and compaction

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Abstract: Although Novel Polymeric Alloy (NPA) geocells have been applied to stabilize road bases against the freeze-thaw (F-T) damage in practice, the relevant research lags the application. A scarcity of research has been reported to comprehensively evaluate the benefits of geocell stabilization in enhancing the F-T performance of bases. This study aims to investigate quantitatively the F-T performance of geocell-stabilized bases, focusing on two influencing factors-i.e., water supply and degree of compaction in the bases. A series of model-scale experimental tests (19 tests) was conducted using an upgraded customized apparatus. The results showed that the inclusion of geocells was beneficial for reducing frost heave and thaw settlement as well as mechanical properties (i.e., stiffness and ultimate bearing capacity) of road bases. The benefit of geocells was more remarkable for the well compacted bases than for the poorly compacted bases. The benefit was more pronounced in the open system than in the closed system.

Keywords: Geocells, Model tests, Freeze and thaw cycles, Water supply,
Degree of compaction

Characteristics of electro-osmosis consolidation and resistivity evolution in soft clay reinforced with recycled carbon fibers

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Abstract: This study repurposed discarded carbon fiber fabric by mechanically cutting it into short-cut carbon fibers and utilized these fibers in electro-osmosis experiments with varying lengths (5 mm, 10 mm, and 15 mm) and mixing ratios (0.05%, 0.10%, and 0.25%). The results indicated that increasing the length and mixing ratio of recycled carbon fibers effectively reduced the soil resistivity. Furthermore, incorporating an appropriate amount of carbon fibers not only reduced the energy consumption coefficient but also enhanced the electro-osmotic drainage performance. Increasing the length and mixing ratio of carbon fiber also improved the vane shear strength after electro-osmosis consolidation. To promote the application of carbon fiber in electro-osmosis consolidation and to provide support for the development of electro-osmosis consolidation theory and numerical analysis, a resistivity calculation model of carbon fiber-reinforced soil during the electro-osmosis process was developed based on the Ohm's Law and tunneling transmission theory. The model elucidates that during the electro-osmosis process, soil resistivity is influenced by the increase in barrier thickness, which consequently raises the tunneling transmission resistance.

Keywords: Electro-osmosis consolidation, Recycled carbon fibers, Fiber length, Mixing ratio, Tunneling transmission, Resistivity

Microstructural characteristics and prediction of hydraulic properties of geotextile envelopes via image analysis and pore network modeling

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Abstract: In this study, the microstructural characteristics of geotextile envelopes were investigated via two-dimensional (2D) and three-dimensional (3D) image analysis. A pore network model was constructed to predict the hydraulic properties of the geotextile envelopes. Based on image analysis, the representative domain size of the geotextile envelopes was estimated and was further confirmed by pore network modeling. The results showed that while nonuniformity existed in geotextile envelopes, no noticeable difference was observed in porosity among samples of different sizes. The porosity derived from 3D image analysis was much closer to the theoretical value, with relative error less than 12%. The fibers of the geotextile envelopes were mainly distributed in the in-plane direction and were nearly uniform. The prediction of the permeability coefficient was optimal when hybrid cones and cylinders were considered as the geometric shapes and when the equivalent diameter, inscribed diameter, and total length were used as the geometric properties of the extracted pore network. The capillary pressure curves matched experimental values more closely when using the equivalent diameter for throat diameter. The representative domain size of geotextile envelopes was at least 3500 μm, but no meaningful length could be found along the through-plane direction.

Keywords: Geotextile envelope, Microstructural characteristics, Image analysis, Pore network model

Nonlinear creep consolidation of vertical drain-improved soft ground with time-dependent permeable boundary under linearly construction load

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Abstract: This paper presents an upgraded nonlinear creep consolidation model for VDI soft ground, incorporating a modified UH relation to capture soil creep deformation. Key novelties also include considering linear construction loads, TDP boundary conditions, and Swartzendruber's flow in the small strain consolidation domain. The system was solved using the implicit finite difference method, and numerical solutions were rigorously validated. A parametric analysis reveals that soil viscosity causes abnormal EPP increases under poor drainage conditions during early consolidation. Meanwhile, neglecting the time effect of the secondary consolidation coefficient delayed the overall EPP dissipation process and overestimated the settlement during the middle and late consolidation stages. Furthermore, TDP boundaries, Swartzendruber's flow, and construction processes significantly influence the creep consolidation process but not the final settlement. These findings offer fresh insights into the nonlinear creep consolidation of VDI soft ground, advancing the field.

Keywords: Nonlinear creep, Linear construction loads, Time-dependent permeable boundary, Swartzendruber's flow, Self-weight stress

Implications of single and double liners on the impact of PFOA in landfills on an underlying aquifer

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Abstract: The transport of perfluorooctanoic acid (PFOA) through the base of a municipal solid waste landfill lined by a single or double composite liner system underlain by an aquifer is examined. Experiments conducted to obtain permeation coefficients for PFOA (and other PFAS) through HDPE and a GCL at different stress levels are described and the results presented. Experimentally derived interface transmissivity and GCL hydraulic conductivity permeated by a PFAS solution are presented. The experimentally derived parameters for PFOA are then used together with finite element software to model diffusive and diffusive-advective transport of PFOA through holed wrinkles from a landfill. The peak concentrations of PFOA in the modelled aquifer are reported and compared to the maximum allowable drinking water regulations for PFOA in different jurisdictions. A sensitivity analysis is performed to assess the effect of different parameters on the degree of contamination of the aquifer. With no holes in the geomembrane (pure diffusive transport), all regulatory limits are met for both single and double-lined barrier systems. The amount of leakage through holed wrinkles required for PFOA to exceed regulatory limits varies depending on the initial concentration of PFOA and jurisdictional allowable limits. Most results showed that the single composite liner barrier system examined is unlikely to be sufficient to contain PFOA to an acceptable level. The double liner system is more likely to meet regulatory requirements if most of the leakage through the primary is collected.

Keywords: Contaminant transport, PFOA, PFAS, Diffusion, HDPE geomembranes, Geosynthetic clay liners, Double composite liner, Single composite liner, Finite element modelling, Impact assessment

New theoretical solution for soft soil consolidation under vacuum pressure via horizontal drainage enhanced geotextile sheets

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Abstract: Land reclamation is a major construction activity in Singapore and other Asian countries. When granular fills become scarce, soft materials have to be used for land reclamation. A new land reclamation and soil improvement method using vacuum preloading and horizontal drainage enhanced non-woven geotextile (HDeG) sheets for soft soil consolidation has been proposed to reduce consolidation time and save costs. This paper presents a new theoretical solution for analysing the consolidation process of soil under vacuum pressure via horizontal drainage enhanced geotextile sheets as such a solution is not available yet. To verify the proposed theoretical solution, model tests and finite element analyses (FEA) have also been conducted. The proposed analytical solution agrees well with the results from FEA and the model tests in settlement, average effective stress and degree of consolidation. Thus, this solution could be used for design and analysis for land reclamation with soft materials consolidated using vacuum preloading together with HDeG sheets or other horizontal drainage materials with an adequately high transmissivity. The prediction of the consolidation performance relies on the proper selection of the coefficient of consolidation based on the effective stress history of soil.

Keywords: Vacuum preloading, Soft soil, Horizontal drains, Horizontal drainage enhanced geotextile sheets, Theoretical solution, Finite element analyses

Multi-scale behaviour of sand-geosynthetic interactions considering particle size effects

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Abstract: The continuous evolution of digital imaging and sensing technologies helps in understanding the multi-scale interactions between soils and geosynthetic inclusions in a progressively better way. In this study, advanced techniques like X-ray micro-computed tomography (μCT) and profilometry are used to provide better understanding of the multi-scale interactions between sand and geosynthetic materials in direct shear interface tests. To cover the dilative and non-dilative interfaces and sands of different particle sizes, shear tests were carried out with a woven geotextile and a smooth geomembrane interfacing with three graded sands at different normal stresses. The shear response of different interfaces is analyzed in the light of 3D multi-scale morphology of particles and the roughness of tested geosynthetic surfaces to compare the peak and residual friction angles and shear zone thickness determined using Digital Image Correlation (DIC) technique. The average peak frictional efficiencies for sand-geotextile and sand-geomembrane interfaces are 0.84 and 0.52, respectively. The extent of the shear zone increased with the increase in particle size, with its average thickness ranging from 2.22 to 11.41 times the mean particle size. On a microscopic level, fine sands cause increased shear-induced changes on geomembrane surfaces because of their greater effective contact per unit area.
Keywords: Particle size, μCT, Profilometer, Shear zone,Geosynthetics,Shear strength

Biological clogging of geotextiles under discontinuous fermentation scenario

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Abstract: This article presents the effect of biological clogging on the hydraulic performance of geotextiles used for the construction of filter and drainage in landfills. Clogging tests were performed on specimens of woven and non-woven geotextiles in a discontinuous fermentation scenario using natural leachate and a nutrient solution. The consequences of biological clogging were assessed through experimental measurements of changes in the cross-plane hydraulic conductivity and the impregnation ratio of different geotextiles specimens at different immersion times. Porosity reduction was then back-calculated from the hydraulic conductivity results using the Kozeny-Carman equation. Additionally, the impact of an antibiotic and antifungal solution on biofilm development was evaluated. It was demonstrated that the cross-plane hydraulic conductivity of geotextile specimens decreases as biomass accumulation per unit area increases with immersion time. The application of an antibiotic and antifungal solution resulted in a porosity recovery of over 90% and a hydraulic conductivity recovery ranging from 78 to 83% for both woven and non-woven geotextiles. These results demonstrate that the clogging was primarily due to biological activity. Despite certain limitations in measurement and definition, the impregnation ratio proved to be a reliable parameter for the evaluation of biological clogging.

Keywords: Biological clogging, Leachate collection system, Filter layer, Drainage layer, Cross-plane hydraulic conductivity

Experimental study on deformation and failure mechanism of geogrid-reinforced soil above voids

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Abstract: Geosynthetic materials are crucial for reinforcing soil above subterranean voids. However, the complexities of load transfer mechanisms in reinforced structures remain elusive. This study investigates the deformation and failure mechanisms in geogrid-reinforced soil using trapdoor experiments. The particle image velocimetry (PIV) technique was utilized for detailed observation of soil deformation, while fiber optic strain sensing cables were used to monitor tensile strains within geogrids. Results indicate that soil arching redistributes loads across the trapdoor area, effectively transferring loads from subsiding to adjacent stable regions. As trapdoor displacement increases, the initial soil arch collapses, prompting the formation of another stable arch. This cycle of development and failure of soil arch continues until shear bands reach the ground surface. Soil arches are more prone to failure over shallower voids. Strain data reveal that the geogrid's tension varies with the tensile strain and is highest near the void's edges. For shallow voids, the tensioned membrane effect of the geogrid bears more of the overlying soil weight, whereas for deeper voids, soil arching plays a more significant role in load transfer. This study provides important insights into the interaction between soil arching and tensioned membrane effects, offering potential implications for optimizing geosynthetic design.

Keywords: Geogrid-reinforced soil, Soil arch, Tensioned membrane effect, Particle image velocimetry (PIV), Optical frequency domain reflectometry, (OFDR), Fiber optic sensor

DEM investigation on mechanical behavior of geogrid-sand interface subjected to cyclic direct shear

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Abstract: The cyclic properties of geosynthetic soil interface are crucial for reinforced soil structures subject to seismic loading. To investigate the mechanical geogrid-sand interface behavior under cyclic shear conditions, a series of numerical simulation cyclic shear tests were conducted using the discrete element method. The results revealed with increasing of shear cycles, dense sand sample gradually shrunk, exhibiting obvious softening characteristics. The vertical displacement of the sample under simulated 10 cyclic shear increases by 0.27 mm, which is 0.41 mm lower than that under 1 cyclic shear. Meanwhile, obvious dilation was observed in the shear band. As the number of cyclic shear increases, the region where the particle rotation occurs does not change significantly, ranging from 75 mm to 125 mm. Higher sample density made it more difficult for particles at geogrid-sand interface to rotate. Under the same number of cycles, denser samples had narrower shear bands, smaller shear strain shifts, and larger shear stiffness. The sand size is 0.5 mm, and the particle displacement concentrated in the 3 mm shear zone. After the completion of cyclic shear, dense sand had little effect on the porosity of the unreinforced sand affected zone, and the porosity after cyclic cycle was close to the initial porosity.
Keywords: Discrete element method, Cyclic shear, Geogrid-sand interaction, Mechanical behavior, Shear band

A 9-year study of the degradation of a HDPE geomembrane liner used in different high pH mining applications

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Abstract: The degradation of a HDPE geomembrane in heap leaching environments is evaluated using immersion tests at five temperatures. The incubation solutions had a pH of 9.5, 11.5, and 13.5, relevant to gold and silver pregnant liquor solutions. After 9.3 years, the geomembrane's mechanical properties had reached nominal failure at 95, 85, and 75 °C in all three solutions. It is shown that the pH 13.5 solution had the greatest effect on the antioxidant depletion (Stage I) and polymer degradation (Stage III), but was the least aggressive to initiate the degradation (Stage II) compared to the pH 11.5 and 9.5 solutions. Overall, the time to nominal failure (time to 50% of the initial or specified property value) in pH 13.5 was slightly shorter than the pH 9.5 and 11.5 solutions. Based purely on immsersion tests, the time to nominal failure of this specific geeomembrane at 30oC is predicted to be 150 years in the pH 9.5 and 11.5 solutions, and 140 years in the pH 13.5 solution. Assuming a good liner design that limits the tensile strains in the GMB, nominal failure in a composite liner configuration is predicted to exceed 260 years at 30 °C and the expected value could exceed 1000 years at 10 °C.

Keywords: Geosynthetics, Geomembrane, Mining, Heap leaching, Degradation, Nominal failure, Arrhenius

Modified approach for predicting seismic-induced deformation of landfills considering strength parameters of GMB-GCL interface within the liner system

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Abstract: This study presents an innovative methodology for predicting seismic-induced sliding displacement, a key determinant in evaluating the seismic stability of landfills. The novelty of this research lies in the incorporation of the softening characteristics of the geosynthetic interface within the liner system, a factor that has been largely overlooked in previous studies. A dynamic stability analysis was performed on a landfill using the ABAQUS software, with an emphasis on the impact of coupled parameters, particularly the strength of the interface. The results highlight PGA (Peak Ground Acceleration), PGV (Peak Ground Velocity), I_a (Arias Intensity), and residual interface shear strength (μ) as effective predictors. The study further identifies the combination of PGA and μ as the optimal parameter pairing for predicting the seismic permanent deformation of the landfill. A multi-dimensional data regression approach was employed to propose a calculation formula for seismic permanent deformation, taking into account liner damage. To enhance the seismic design methodology for landfills, the probability density function was integrated into the study. This innovative approach provides a new perspective on seismic stability assessment in landfill engineering and designs.

Keywords: Landfill, Earthquake, Liner system, Geomembrane, Seismically induced permanent displacement, Seismic design

Performance of unreinforced and geogrid-reinforced pile-supported embankments under localized surface loading: Analytical investigation

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Abstract: An analytical solution is proposed to identify the performance of unreinforced and geogrid-reinforcement pile-supported embankments under localized surface loading at working stress conditions based on the total efficacy and efficacy induced by soil arching alone, average strain of geogrid reinforcement, and average settlement of subsoil. This solution considered interactively soil arching within the embankment fill, the load-deflection behavior of geogrid reinforcement (if existed), and subsoil settlement. Specifically, the soil arching consisted of a structural arch with different stress states (evaluated by the elastoplastic state coefficient K) and a frictional arch. The load-deflection behavior of geogrid reinforcement was modeled by a membrane, with due consideration of the skin friction between the geogrid and soil. The subsoil was idealized as a one-dimensional compression model. The effectiveness of the proposed solution was verified by comparisons with results from the collected literature. It is shown that geogrid reinforcement improved the performance of embankments with low subsoil stiffness significantly more than that of those with high stiffness subsoil. A high tensile stiffness geogrid was found to be inefficient because its contribution to reducing the subsoil settlement and enhancing the load transfer efficacy was minimal. This paper provides a significant reference for optimizing these embankment design.

Keywords: Geosynthetics, Pile-supported embankments, Soil arching, Reinforcement, Load transfer, Localized surface loading

Effect of backfilling surface settlement trough on waste cover leakage

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Abstract: The effect of backfilling of a surface differential settlement trough to reduce leakage is explored both experimentally and numerically. The field experiment examined two lined sections each with an 11 mm-diameter hole in the liner on a nominally 4 horizontal:1 vertical slope. A 2 m by 3 m, 0.3 m deep depression was filled with a 50-50 sand-snow mixture in winter to give a continuous 4H:1V slope prior to covering with the liner and 0.3 m of cover soil. Spring thaw induced a differential settlement trough up to 0.14 m deep. A second section with a similar trough was backfilled with cover soil to reinstate the 4H:1V surface while the settlement depression in the liner remained. Over the 15 months of monitoring, the backfilling reduced leakage by 57% from a annual total of 565 L to 244 L (i.e., a 60% reduction in colder seasons, from 351.3 L to 137.8 L together with a 45% reduction in warmer seasons, from 141.8 L to 77.6 L). A 3D numerical model showed encouraging agreement with the experimental results. The model indicated an inverse relationship between leakage and slope gradient, and a direct relationship between leakage and depression depth and upgradient distance to the depression. The effect of cover hydraulic conductivity was complex.

Keywords: Geosynthetics, Geomembrane, Leakage, Hole, Repair, Differential settlement

Liquefaction and reliquefaction mitigation of sand specimen treated with prefabricated vertical drains: An experimental investigation

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Abstract: This study examines the performance of prefabricated vertical drains (PVD) against liquefaction and reliquefaction. A series of 102 shakings were performed using 1g shaking table apparatus on untreated and treated sand specimens prepared with 25% relative density. Sinusoidal waveform experimented with three different repeated shaking patterns and independent events for two different frequencies (2 Hz and 3.5 Hz) with 1-min duration. Two different installation methods; drainage alone method (PVD-D) and drainage along with densification (PVD-DD) were experimented. Durability of PVD were examined from geotextile tensile testing apparatus and digital image correlation. These experiments demonstrated excellent durability characteristics of PVD filter even after exposed to repeated shakings. Treated specimens improved the resistance to reliquefaction due to radial drainage offered by PVD which has retarded the excess pore pressure (EPP) generation. In addition, densification induced during the installation of PVD also contributed for restricting EPP, however, the induced sand densification achieved during repeated shaking events were not responsible for increased resistance against liquefaction/reliquefaction. Results indicate that the maximum pore pressure ratio in treated specimens were restricted within threshold design limit (≤0.60) for most of the events, even when the untreated specimens completely liquefied or generated a maximum value near unity.

Keywords: Prefabricated vertical drains, Reliquefaction, Drainage, Densification, Geotextile tensile testing, Digital image correlation

A large-size model test study on the consolidation effect of construction waste slurry under self-weight and bottom vacuum preloading

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Abstract: Bottom vacuum preloading (BVP) is the method of applying vacuum pressure at the bottom zone of soils to generate pore-water pressure difference between the top and bottom boundaries, thereby achieving the consolidation drainage. This study conducted a large-size model test to explore the engineering feasibility of combining self-weight and BVP to treat construction waste slurry (CWS). Through the treatment of the measures of self-weight consolidation (0–26 d) and BVP with a water cover (26–78 d), the average water content of CWS declined from 255.6% to 115.9%, and the volume reduction ratio reached 0.476. However, since these two measures could properly treat only the bottom CWS, the measures of BVP with the mud cover (78–141 d) and the natural air-drying (141–434 d) were performed to further decrease the CWS water content near the upper zone. The latter two-stage measures reduced the average water content of CWS to 84.9% and increased the volume reduction ratio to 0.581. Moreover, the measurements suggested that the treated CWS largely exhibited a shear strength of 10 kPa or more. Overall, the proposed approach appeared some engineering feasibility to treat CWS, and the performed test study could act as a reference for the practical treatment of CWS.

Keywords: Large-size model test, Construction waste slurry, Bottom vacuum preloading, Consolidation effect, Engineering feasibility

Seismic response and mitigation measures for T shape retaining wall in liquefiable site

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Abstract: Focusing on a T-shape cantilever retaining wall in a liquefiable site, a series of shaking table model tests were conducted to investigate the seismic stability characteristics of the wall when using EPS composite soil isolation piles (WEP), EPS composite soil isolation walls (WEW), and backfilled natural fine sand from Nanjing (WSS). The seismic response characteristics of the model ground soil and the retaining wall for the three models were comparatively analyzed regarding the acceleration, displacement, dynamic earth pressure and excess pore water pressure ratio. Moreover, the seismic performance of anti-liquefaction measures in the liquefiable ground with EPS composite isolation structures were discussed from the view of the phase characteristics and energy consumption. The results indicate that under the same peak ground acceleration, the excess pore water pressure in the WEP and WEW models is significantly lower than that in the WSS model. Different from WSS, WEP and WEW exhibit a segmented distribution with the buried depth in acceleration amplification factors. The embedding of isolation structures in liquefiable sites can reduce the wall sliding and rotational displacements by approximately 25%–50%. In addition, the out-of-phase characteristics of dynamic earth pressure increment are evidently different among WEP, WEW and WSS. There is an approximate 180° phase difference between the dynamic earth pressure behind the wall and the inertial force in the WEP and WEW models. EPS composite soil isolation structures show good energy dissipation characteristics, and especially the isolation wall is better than isolation pile. The displacement index of WSS retaining wall is significantly larger than that of WEW and WEP, indicating that EPS composite isolation piles and wall play an important role in the mitigating damage to the retaining wall. This study can provide references for the application of isolation structures in the liquefiable ground soil regarding the seismic stability.

Keywords: Cantilever retaining wall, EPS composite soil, Liquefiable ground, Shaking table test, Seismic response, Isolation structure

Stress-strain responses of EPS geofoam upon cyclic simple shearing: Experimental investigations and constitutive modeling

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Abstract: This paper investigates the cyclic simple shearing behaviors of Expanded Polystyrene (EPS) geofoams considering influences of the shear strain amplitude (γ_a), number of shear cycles, shear rate, vertical stress (σ_n), and EPS density (ρ_{EPS}). The experimental results demonstrate that the cyclic shear stress (τ)-shear strain (γ) relationships of EPS are not sensitive to the shear rate. As the γ exceeds 2%, the EPS yields and its τ-γ relationships and backbone curve become nonlinear. There are linear relationships between the elastic modulus E, elastic shear modulus G_e, and plastic shear modulus G_p. They increase linearly with an increase in the ρ_{EPS}. The G_e and G_p are not sensitive to the γ_a. The cyclic shear stiffness G increases while the equivalent damping ratio D of EPS decreases with an increase in the σ_n and ρ_{EPS}. The G decreases while the D increases nonlinearly as the γ_a increases. Empirical models were developed to describe the variations of the G_e, G_p, G, and D with σ_n, ρ_{EPS}, and γ_a. A modified Hardin-Drnevich model was proposed to describe the backbone curves and τ-γ loops upon cyclic simple shearing, which has achieved good agreement with the experimental measurements and the testing results from the literature.

Keywords: EPS geofoam, Cyclic simple shearing, Backbone curves, Stress-strain loops, Damping ratio

Experimental study on vacuum preloading combined with intermittent airbag pressurization for treating dredged sludge

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Abstract: The PVD-vacuum preloading method combined with airbags is a new soft ground treatment technology that can provide additional consolidation pressure and reduce lateral deformation towards the improvement area caused by traditional PVD-vacuum preloading. However, continuous airbag pressurization tends to create large cavities in the soil, and the optimal timing for airbag loading is also unclear. To address the aforementioned issues, this paper proposes an intermittent airbag pressurization method, adding small-diameter airbags between adjacent PVDs and intermittently inflating the airbags. Through indoor model test, the water discharge characteristics, improvement effect, improvement mechanism, and foundation settlement characteristics under intermittent airbag pressure were studied, proving that intermittent airbag pressure can significantly reduce early soil rebound. A calculation method for the airbag expansion diameter was proposed, and its feasibility was verified through experimental results. Finally, the optimal time period for intermittent airbag loading was clarified.

Keywords: Dredged soil, PVD-vacuum preloading, Airbag pressurization, Intermittent pressure, Settlement prediction, Pressurization timing

Prediction method for lateral displacements of geosynthetic-reinforced soil walls with segmental block facings

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Abstract: Predicting the performance of geosynthetic-reinforced soil walls with segmental block facings in service is a challenging task due to their complex interaction mechanisms. This paper proposes a semi-analytical method to estimate the performance of such walls by considering a prescribed reduction factor. Rough back of the wall and unreinforced zone effects can be taken into account. It also incorporates an empirical formula to consider reinforcement stiffness to accurately characterize the nonlinear interaction between geosynthetics and soil. Seven full-scale tests and three robust numerical simulations were employed to evaluate the proposed method. The results demonstrate satisfactory estimations of lateral displacement and reinforcement force location with a rational reduction factor. Additionally, the physical significance of the reduction factor is identified, and a method for its determination based on data analysis is proposed. This method eliminates the need for sophisticated numerical analyses to determine lateral displacements. Further investigation is required to explore the correlation between the reduction factor and various design parameters, aiming to establish a more generalized formula for predicting the performance of GRS segmental walls.

Keywords: Deformation, Geosynthetics, Reinforced soils, Segmental block,
Differential evolution

Bearing capacity of strip footings in unsaturated soils reinforced with layered geogrid sheets using upper bound method

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Abstract: A frequently overlooked aspect in previous research on bearing capacity of reinforced foundations is the prevalent unsaturated properties of soils. This paper provides an analytical framework for evaluating the bearing capacity of strip footings with single-layer and double-layer reinforcement in unsaturated soils. Four classical nonlinear expressions are used to determine the additional cohesion induced by matric suction. Solutions for the reinforcement layer undergoing tensile failure and sliding failure are provided separately. In the former case, where the bearing capacity depends on the reinforcement's tensile strength, the Prandtl mechanism is employed. In the latter case, where the bearing capacity is influenced by the characteristics of the reinforcement-soil interface, a multi-block mechanism is adopted. Additionally, sliding failure exhibits different mechanisms depending on the reinforcement's embedded depth. By comparing the results of different failure mechanisms, accurate upper bound solutions for bearing capacity are obtained. In the case of sliding failure, the optimal reinforcement depths that maximize the bearing capacity are identified for both single-layer and double-layer reinforcement. To facilitate engineering use, the optimum depths and corresponding bearing capacity factors are given in tabular form. The effectiveness of the framework is demonstrated through comparisons with previous theories, experiments, and finite element simulation results.

Keywords: Upper bound method, Reinforced strip footings, Bearing capacity, Unsaturated soils

Full-scale testing and monitoring of geosynthetics-stabilized flexible pavement in Alberta, Canada

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Abstract: Freeze-thaw (F-T) cycles are a primary contributor of pavement damages in seasonal frost regions. Geosynthetics stabilization has been a promising solution for enhancing the roadways performance in cold regions. However, in comparison with the practical applications, research on the geosynthetics stabilization in cold-region roads is scarce and its efficacy is yet to be quantified. This study presents the full-scale test on geosynthetics-stabilized sections in a flexible pavement in Sturgeon County, Alberta. It focused on the investigation of three separate test sections with bases stabilized by two types of geocells and one geogrid composite, each fully instrumented with earth pressure cells, thermocouples, and moisture sensors. This experimental program consisted of plate loading tests and trafficking tests on each test section before and after the first F-T season, and monitoring of soil temperatures, moisture contents, and loads transferred to subbases while the sections were open to general traffic. The results showed seasonal F-T cycles resulted in increased pavement settlement, decreased load transfer ratio, and increased stress distribution angle under the plate loading. The traffic-induced stress on the subbases increased during the spring thaw but decreased afterwards.

Keywords: Geocell, Geogrid composite, Pavement, Full-scale test, Field monitoring, Freeze and thaw

Rate-dependent tensile response of Polyvinyl Chloride geomembranes

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Abstract: One of the challenge that face the effectiveness of Polyvinyl Chloride geomembranes (PVC GMs) as a hydraulic barrier is the capacity to withstand unexpected mechanical actions, particularly tensile forces, during installation and throughout their lifespan. These forces pose risks of premature failure and impermeability degradation. In this study, the characterization of the short and long-term mechanical response of PVC GMs to uniaxial tensile forces has been investigated. Uniaxial tensile test have been performed for tensile rates spanning several orders of magnitude. Analysis of the true stress-strain curves reveals a significant decrease in tensile modulus, strength, and strain at failure at low strain rates, which are relatively close to those applied in situ. Long-term investigations have been conducted as well, through relaxation tests. Our key results unveil two distinct characteristic times in stress relaxation, with the fast relaxation occurring over the first 4 h. During this phase, the pre-relaxation loading rate affects the relaxation behavior. Beyond this phase, the relaxation behavior becomes independent from the pre-relaxation loading rate. Burger's rheological model is proposed to measure the stress relaxation at different rates. The model's results validate the existence of two characteristic times.
Keywords: PVC geomembrane, Uniaxial tensile test, Tensile speeds, Tensile properties, Stress relaxation

Microscale analysis of geomembrane–geotextile interface cyclic shear behavior using DEM

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Abstract: Given that the material-wearing process is the key factor influencing the dynamic shear strength at the interface between the geomembrane (GMB) and nonwoven geotextile (NWGT), this study investigates the cyclic shear behavior of the GMB–NWGT interface from a microscale perspective using the three-dimensional discrete element method (DEM). The textured GMB is simulated with breakable asperities and the thermally bonded NWGT is generated by spatially randomly distributed fibers which could be stretched and untangled. The established model is validated against the experimental data. The wearing process during cyclic loading is evaluated by quantifying the embedded depth of GMB asperities and fiber breakage within NWGT. The simulation results demonstrate that the maximum asperity embedment (inter-embedding effect), affected by the normal stress and displacement amplitude, induces the hook and loop interactions between asperities and fibers (inter-locking effect), accounting for the cyclic shear resistance at the interface. The inter-locking effect dominates the strain-hardening behavior of the GMB–NWGT interface when the percentage of inter-fiber bond breakage is less than 22% and the maximum asperity embedment ratio is lower than 60%; otherwise, the inter-embedding effect dominates the strain-softening behavior of the interface.

Keywords: Geomembrane, Geotextile, Discrete element method, Interfacial shear strength, Landfills

Hydro-mechanical behaviour of omposite-geosynthetic-reinforced soil walls with marginal lateritic backfills through instrumented model tests

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Abstract: To examine the hydro-mechanical behavior of Geosynthetic Reinforced Soil Walls (GRSW) backfilled with locally available marginal lateritic soils, physical model tests were conducted during construction, surcharge loading, and rainfall infiltration. Various reinforcements were tested, including a conventional geogrid (GG) and two types of composite geosynthetic reinforcements (CGR) with equivalent stiffness but different configurations. The results showed that suction was maintained throughout surcharging, but during rainfall infiltration, the GG model lost suction after 12,240 min, while both CGRs retained it. Strain evaluations indicated that all reinforcements remained within serviceability limits during surcharging, but the GG model exceeded these limits during rainfall, while the CGRs stayed within acceptable limits with minimal strain increases. Additionally, the GG model showed a 61% increase in facing deformation during rainfall, exceeding serviceability limits, whereas the CGRs remained within permissible limits. The study emphasizes the importance of cautious use of marginal soils in backfill applications. These soils can still be suitable for GRSW when reinforced with composite geosynthetics, especially CGR made of polyester geogrids with non-woven geotextile bonded longitudinally to the polyester strips. This configuration demonstrated superior performance by reducing facing deformation through better drainage and improved soil-reinforcement interaction.

Keywords: Geosynthetics, GRS wall, Marginal backfill, Rainfall, Lateritic soil, Suction