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摘要集

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目　录

Centrifuge investigation on behavior of geosynthetic-encased stone column supported embankment under freeze-thaw cycles

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Abstract: In this paper, two centrifuge tests were conducted on geosynthetic-encased stone column (GESC) supported embankment to investigate the behavior under freeze-thaw cycles considering the effects of initial degree of consolidation and number of freeze-thaw cycles. The embankments with a height of 4.5 m supported by GESC-reinforced foundation with a thickness of 9 m in prototype were first consolidated to initial degrees of consolidation of 30% and 60%, respectively, and then subjected to three freeze-thaw cycles. The results showed that the foundation soil under the embankment toe experienced a higher degree of freezing than the soil outside the embankment with non-uniform frozen depths observed at different positions in soil under the embankment, and that multiple freeze-thaw cycles contributed to extra settlement in the foundation. Both the frost heave and thaw settlement appeared on GESCs prior to soil. During freezing, the stress on GESC increased first, while decreased rapidly when soil began freezing. The stress concentration ratio (SCR) reached nearly 1.0 before complete freezing. After the complete thawing of GESCs, the stress on GESC increased significantly. As the number of freeze-thaw cycles grew, the variation in settlement, stress and pore pressure was reduced. The final settlement on soil was greater in the foundation with lower initial degree of consolidation, as well as the SCR. The GESCs had larger deformation and showed outward bending under lower initial degree of consolidation, but inward bending appeared on GESCs under higher one.

Keywords: Centrifuge test, GESC, Freeze-thaw cycle, Initial degree of consolidation, Frost heave, Thaw settlement

Effect of temperature on critical strength of geosynthetic clay liner / textured geomembrane composite systems

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Abstract: The objective of this study was to evaluate the effect of temperature on the shear behavior and critical strength of composite systems comprising of a geosynthetic clay liner (GCL) and textured geomembrane (GMX). For this purpose, displacement-controlled internal and interface direct shear tests were performed at both room temperature (≈20 °C) and an elevated temperature of 80 °C on three GCL/GMX composite systems at normal stresses varying from 100 kPa to 2000 kPa. An increase in the test temperature resulted in peak shear strength reduction up to 45% in GCL internal shear tests and up to 46% in GCL-GMX interface shear tests. The large-displacement shear strength at the elevated temperature was also reduced by up to 32% in GCL internal shear tests and up to 48% in GCL-GMX interface shear tests.
Keywords: Direct shear, Geomembrane, Geosynthetic clay liner, Shear strength, Temperature

Assessment of pegged geogrid (PG) pullout performance in coarse-grained soils using PIV analysis

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Abstract: The paper examines the efficacy of using small, welded metal plates (pegs) in enhancing the pullout resistance of commercially available geogrids. Soil deformations and particle displacements at the soil-geogrid interface and in the vicinity of the pegs were investigated using the Particle Image Velocimetry (PIV) technique. Effects of the soil particle size, overburden pressure, and the height and locational arrangement of the pegs were examined. Results indicate the effectiveness of pegs in enhancing geogrid pullout resistance, which increases significantly with peg height and the distance from the pullout load. Meanwhile, the PIV images showed larger soil strains and particle displacements in coarser soils and under greater overburden pressures. Results also indicate that taller pegs are more effective in engaging the soil adjacent to the reinforcement layer, resulting in reduced particle displacements and increased passive resistance of a larger volume of soil, leading to greater pullout resistance. Findings of the study can be beneficial in practice where pegged-geogrids of reduced length could be used to meet design requirements while addressing space limitations and/or excavation costs, and thereby, help with the feasibility and cost-effectiveness of MSE walls and reinforced slopes in related projects.
Keywords: Pegged-geogrids, PIV, Pullout resistance, Soil-geogrid interaction

Hydraulic conductivity and multi-scale pore structure of polymer-enhanced geosynthetic clay liners permeated with bauxite liquors

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Abstract: A study was conducted to investigate the multi-scale pore structure-based mechanism controlling the hydraulic conductivity of polymer-enhanced geosynthetic clay liners (GCLs) prepared by the wet-mixed method to bauxite liquors (BLS and BLA). The multi-scale pore structures were evaluated using MIP and N_2GA tests quantitatively. Conventional GCL permeated with BLS had a larger flow path volume than with DI water (0.194 > 0.119 cm^3/g), attributed to the bentonite swelling inhibition and the montmorillonite dissolution, leading to the higher hydraulic conductivity ($3.0 \times 10^{-7} > 2.7 \times 10^{-11}$ m/s). Polymer-enhanced GCLs developed more micropores and had a smaller quantity proportion and volume of flow paths since polymer formed more micropores to clog pores, contributing to a lower hydraulic conductivity than conventional GCL to BLS. The hydraulic conductivity of polymer-enhanced GCL to BLS (ionic strength: 622.5 mM) was higher than that to BLA (156.9 mM) ($2.6 \times 10^{-9} > 6.0 \times 10^{-12}$ m/s), given that the coiled or contracted polymer conformation left a smaller quantity proportion (5.54% < 6.71%) and volume (0.0002 cm^3/g < 0.0035 cm^3/g) of micropores.

Keywords: Hydraulic conductivity, Multi-scale pore structure, Geosynthetic clay liner, Bauxite liquor, Polymer enhancement

Unlocking the sorption mechanism of perfluoroalkyl acids (PFAAs) on geosynthetics: Case of the geotextile components of geosynthetic clay liners

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Abstract: We present here an experimental investigation on the sorption of four perfluoroalkyl acids (PFAAs): namely, two perfluorocarbonic acids (PFCAs) – perfluorooctanoic acid (PFOA) and perfluorohexanoic acid (PFHxA); and two perfluorosulfonic acids – perfluorooctane sulfonate (PFOS) and, perfluorobutane sulfonic acid (PFBS) to polypropylene cover and carrier geotextiles commonly used in geosynthetic clay liners. The impacts of various operational parameters, such as sorbent mass, contact time, and initial PFAA concentration, were investigated. A bi-exponential adsorption model was observed to describe the adsorption kinetics for all PFAAs sufficiently. The model indicates two (probably physically) different types of adsorption sites involved in the PFAAs adsorption. The Freundlich and Langmuir equations well represented the adsorption isotherms. Furthermore, it was observed that PFAA sorption was strongly dependent on the end functional groups and perfluorinated carbon chain length of PFAAs. The maximum adsorption capacities for all PFAAs on geotextiles were consistent with results obtained for clay minerals, indicating that, in the absence of sufficient organic matter, sorption of PFAAs onto solids is mainly analyte and solution dependent. The results obtained and reported for the first time herein are imperative for understanding the fate and migration of PFAAs in modern geosynthetic composite liner systems.
Keywords: Geosynthetics, Geotextiles, GCLs, PFAS, Sorption

Geosynthetic reinforced rubble mound breakwater for mitigation of tsunami-induced damage

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Abstract: Several rubble mound breakwaters (RMB) were damaged and even collapsed during the past tsunamis. The main reasons for the failure of the breakwaters occurred due to the combined effects of seepage and scouring. Limited articles are available dealing with the behaviour of RMB during the tsunami. Furthermore, few available articles are related to developing countermeasures for the RMB against tsunamis. Therefore, an attempt has been made in the study to determine the exact behaviour of the RMB under the action of the tsunami. In addition, the main aim of the present study is to develop countermeasures to make the breakwater tsunami resilient. The present study proposes a novel geosynthetics-reinforced RMB to mitigate tsunami-induced breakwater damage. Based on the available information, this is the first time geosynthetics have been used in the RMB to mitigate tsunami-induced damage. Geogrid layers, geobags, sheet piles and crown walls (with shear keys) are adopted as countermeasure elements against the tsunami. Since the height of a tsunami can exceed its design tsunami height, tsunami waves were allowed to overflow the breakwater in physical model tests. Comparative analyses between the reinforced and unreinforced RMB were performed by conducting physical model tests, analytical tools, and numerical simulations.
Keywords: Geosynthetics, Rubble mound breakwaters, Tsunami, Geobag, Geogrid, Resilient breakwaters

Field tests on partially geotextile encased stone column-supported embankment over silty clay

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Abstract: Various researchers have highlighted that geosynthetic-encased stone columns could be used in place of stone columns (SCs) in very soft soil. In this study, field load tests are performed on individual partially geotextile-encased stone columns (pESCs), individual stone columns (SCs), and a field embankment reinforced with pESCs and SCs in silty clay. Although the material cost of pESCs is designed to be comparable to that of SCs, the tests reveal that pESCs display a higher allowable bearing capacity and stress concentration ratio and less residual settlement than SCs. The embankment reinforced by pESCs is found to incur fewer lateral displacements, while there is no improvement in the drainage performance during the construction period compared to the SCs. For the pESCs, 51–66% of the pressure acting on the top of the column propagates to a depth of z = 1.2 m, wheras, for the SCs, it is only 21–55%. Furthermore, to estimate group behaviour, the ultimate bearing capacity of an individual pile composite ground can be extrapolated. However, individual pESCs achieve much higher stress concentration ratios than the pESC group.

Keywords: Embankment, Field test, Geotextile, Partially geotextile-encased stone column, Stone column

Numerical investigation of the tensile behaviors of needle-punched nonwoven geotextiles

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Abstract: A numerical modeling method to reproduce the structures of needle-punched nonwoven geotextile based on the actual manufacturing process (web formation and web bonding) was developed. The geotextile model was built based on the statistical characteristics of the computed tomography (CT) observations, physical and mechanical properties of fibers, and physical parameters of the geotextile. A combination of the finite element model and pore network model method was proposed to obtain the pore size characteristics. The appearance and pore size characteristics before and under uniaxial tensile strains were investigated. It is shown that the method can simulate the geotextile manufacturing process satisfactorily. The pore size distribution (PSD) curves obtained from the model show good agreement with the CT-based results. Moreover, the method can reasonably simulate the tensile behaviors of geotextile under uniaxial tensile strain. The specimen necking phenomenon during the uniaxial tensile test was well reproduced. The PSD curves moved towards the direction of larger pore size with increasing uniaxial strain, and characteristic pore sizes (O_{98}, O_{95}, O_{50}, O_{30}, O_{10}) all show a relatively steady increasing trend.

Keywords: Nonwoven geotextiles, FEM, Numerical simulation, Uniaxial tensile, Pore size characteristics

Semi-analytical solution for two-dimensional electro-osmotic consolidation of double-layered soil

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Abstract: This study proposed a semi-analytical solution for 2D electro-osmotic consolidation of double-layered soil. The method of Laplace transform is employed to derive the solution in the frequency domain. Then the numerical approach of inverse Laplace transform is used to obtain the explicit solution in the time domain. A finite element simulation is conducted to validate the proposed solution's accuracy. The verification example shows excellent agreement between the two methods. Based on the parametric study, it is found that the value of soil parameters in the second layer has significant influences on the behaviour of electro-osmotic consolidation. The larger the electro-osmosis coefficient in the second layer, the smaller the excess pore pressure at a given time. Additionally, a higher coefficient of volume compressibility in the second layer results in higher excess pore pressure. Compared with the 1D case, the distribution of excess pore pressure at the steady state is non-linear with depth in the 2D electro-osmotic consolidation, rather than a linear distribution. Furthermore, the dissipation rate and steady-state excess pore pressure could be underestimated if the electro-osmotic consolidation is modelled as a 1D case.

Keywords: Electro-osmotic consolidation, Double-layered soil system, Two-dimensional model, Semi-analytical solution

Creep behavior and viscoelastic-plastic models for polymer-blend HDPE geocell sheets based on the stepped isothermal method

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Abstract: Polymer-blend High Density Polyethylene (PHDPE) sheet materials have been developed in China as an alternative to the High Density Polyethylene (HDPE) materials for the manufacture of geocells. It is necessary to evaluate the creep properties of the geocell-reinforced structures to provide a reference for design of their service life and improve their application potential. In this paper, the Stepwise Isothermal Method (SIM) based accelerated creep testing, in which the test temperature was gradually increased but the load was kept constant, was employed obtain the long-term creep behavior of PHDPE and HDPE geocell sheets. Conventional creep tests were also carried out to assess the accuracy of the creep prediction. Furthermore, the Modified Burgers (MB) model and the Mon-linear Three-component (NLTC) model were proposed to predict long-term creep deformations of the PHDPE geocell sheets. The experimental results indicated that SIM creep tests could predict long-term creep deformations. The creep resistance of all three PHDPE, PHDPE-A, PHDPE-B, and PHDPE-C, was better than that of HDPE due to the addition of nylon 6 for the polymer-blending modification in HDPE. Comparison of the experimental data with the predicted data also confirmed that the MB and NLTC models could accurately model the viscoelastic-plastic creep behavior of PHDPE geocell sheets.

Keywords: Geocell sheets, Accelerated creep tests, Stepped isothermal method, Prediction models

Test method and strain calculation effects on geomembrane strain from gravel indentations

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Abstract: The effects of test method and strain calculation method on strains from nominal 25 mm coarse gravel indentations are examined for a 1.5 mm thick HDPE geomembrane with full-scale physical modeling. Maximum principal strains were calculated using thin plate theory that considers lateral displacement effects and bending strain. Strains from index tests with no subgrade were found to be twice as large as those from performance tests with clay, while strains from index tests with rubber as the subgrade were only 40% of those with clay; neither index test is suitable for selecting protection layers to limit geomembrane strain. Strains from past index tests with idealized single-point loading need to be multiplied by a factor of at least 1.8 to reproduce the maximum strain from performance tests with coarse gravel. Limiting the average membrane strain to 0.25% was found to limit the maximum principal strain to less than 6%, but not to 3% as originally intended by the German standard. The maximum result of membrane plus bending strain of 3% was shown to be closer to a maximum principal strain of 4–6% because of large-displacement and three-dimensional effects. The geotextile protection layers tested (nonwoven, needle-punched, 1500 and 1800 g/m^2) were only able to limit the strain to 6% at a vertical pressure of 250 kPa and were unable to limit strain below 3%.

Keywords: Geosynthetics, Geomembrane, Geotextile, Strain, Puncture protection

Reliability analysis of geosynthetic-reinforced slopes under rainfall infiltration

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Abstract: The rainfall-induced instability of geosynthetic-reinforced is a time-dependent phenomenon owing to the infiltration process, and is influenced by rainfall patterns. Catering to the inherent uncertainty in soil properties, this study conducted a reliability analysis of three-dimensional (3D) vertical geosynthetic-reinforced slopes, in order to explore how the probabilistic stability of slope evolves over time under different rainfall patterns. A 3D horn-like mechanism incorporating the Conte-Troncone (CT) model is adopted as a framework for deterministic analysis. Through a Fourier transform-based theoretical reasoning, the CT model assesses the time-variable pore-water pressure of soils in response to any continuously varying rainfall intensity over time. Subsequently, the pore water pressure-driven changes in soil unsaturated strength and the corresponding extend power are integrated into the three-dimensional mechanism, enabling a rapid determination of the instantaneous safety factor at discrete time instants. To avoid the tedious computation generated by Monte Carlo simulation, a simplified Hasofer-Lind-Rackwitz-Fiessler (HLRF) algorithm is used to calculate the time-varying reliability indices. Using the implantation of the proposed method, the effects of rainfall pattern, slope width, and reinforcement tensile strength are investigated by parametric analysis.

Keywords: 3D reinforced slope, Rainfall infiltration, Time-dependent failure, Probabilistic analysis