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摘要集

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目　录

Effect of fabric structure on in-plane and through-plane hydraulic properties of nonwoven geotextiles

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Abstract: The intrinsic in-plane (IP) permeability ($K_{\parallel}$) and through-plane (TP) permeability ($K_{\perp}$) of nonwoven geotextiles were measured experimentally. Also, the realistic 3D images of the samples were acquired by the nondestructive μCT technique and their microstructural characteristics were measured. This information was used to simulate virtual fibrous structures resembling the microstructure of geotextiles. The flow of fluid was then simulated through realistic and virtual structures and $K_{\parallel}$ and $K_{\perp}$ were calculated. The experimental and predicted results were compared with each other and those of some empirical, analytical and numerical studies. A non-linear relation between both the $K_{\parallel}$ and $K_{\perp}$ and geotextile porosity was observed. It was found that for the same porosity, coarser fibers provide higher $K_{\parallel}$ and $K_{\perp}$ and this is more pronounced at higher porosity values. It was observed that by increasing the IP fiber orientation in the flow direction, $K_{\parallel}$ increases exponentially, while $K_{\perp}$ is independent of IP fiber orientation. The anisotropic permeability ratios $\lambda = K_{\parallel}/K_{\perp}$ of samples were calculated and it was established that nonwoven geotextiles show highly anisotropic behavior with λ tending to unity with the increase of geotextile porosity. It was shown that $K_{\perp}$ increases with the increase of fiber orientation through the thickness direction.

Keywords: Nonwoven geotextile, Fiber orientation, In-plane permeability, Through-plane permeability, Pore size, Porosity

Vibration response of machine foundations protected by use of adjacent multi-layer geocells

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Abstract: The response of soil beds reinforced with multi-layer geocell systems that support machine foundations is investigated by laboratory testing that incorporates vertical machine vibrations of a square concrete foundation (400 × 400 *mm*) resting on soil that is unreinforced or reinforced with single-, double- or triple geocell layers. The tests are performed under three different vibration moment levels and three static force levels using a mechanical oscillator and concrete blocks, respectively. The vibration responses are studied in terms of resonant amplitude, resonant frequency, shear modules and damping coefficient. The results reveal that the resonant amplitude significantly reduced in the presence of geocell reinforcement whereas the resonant frequency, shear modulus and damping coefficient increased. In the range of applied vibration load and frequency, and hence the induced amplitude, maximum improvement (i.e., the greatest reduction in vibration amplitude) was observed in the presence of the triple-layer geocell reinforcement. Since the rate of improvement decreases steadily with an increase in the number of geocell layers, thus, further geocell layers would deliver little further benefit. The optimum placement depth of the first geocell layer and vertical spacing of the geocell layers were found to be 0.1 and 0.05 of the foundation's width respectively.

Keywords: Machine foundation, Vertical vibration, Multilayered geocell, Dynamic response, Shear modulus, Damping coefficient

DIA of centrifuge model tests on geogrid reinforced soil walls with low-permeable backfills subjected to rainfall

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Abstract: Geogrid reinforced soil walls (GRSWs) constructed using low-permeable backfills often experience failures when subjected to rainfall. The objective of this paper is to employ centrifuge modelling to investigate the effect of geogrid types on the performance of GRSW models constructed with low-permeable backfill, when subjected to rainfall intensity of 10 mm/h. A 4.5 m radius large beam centrifuge facility was used, and rainfall was simulated using a custom-designed rainfall simulator at 40 gravities. Digital Image Analysis (DIA) was employed to understand the deformation behaviour of GRSWs with low stiffness geogrid layers with and without drainage provision subjected to rainfall. Additionally, the effect of varying stiffness of geogrid reinforcement layers across the height of GRSW was also investigated. The interpretation of DIA helped to quantify displacement vector fields, face movements, surface settlement profiles and geogrid strain distribution with depth. Irrespective of drainage provision, GRSWs reinforced with low stiffness geogrid layers experienced a catastrophic failure at the onset of rainfall. However, GRSW reinforced with geogrid layers of varying stiffness was observed to perform well. This study demonstrates the effective use of DIA of GRSWs subjected to rainfall along with centrifuge-based physical model testing.
Keywords: Geosynthetics, Geogrid reinforced soil walls, Low-permeable backfill, Rainfall, Centrifuge modelling, Digital image analysis (DIA)

Effect of gas-oil contamination on the mechanical behavior of sand-woven geotextile interface: Experimental investigation and constitutive modeling

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Abstract: The accurate estimation of the frictional resistance of interfaces between soils and geosynthetics plays a central role in stability and serviceability of geosynthetic reinforced earth structures. Contamination with hydrocarbons generally impairs soil geotechnical properties; however, its effect on the behavior of soil-geosynthetic interfaces has seldom been examined precisely. For this reason, an extensive series of direct shear tests was performed to investigate the consequence of gas-oil contamination on the mobilization of shear strength and volume change response of gas-oil contaminated angular sand in contact with woven geotextile (WGTX). Complementary tests on the interfaces between glass beads as a replicate for sands with high degree of sphericity and roundness in contact with WGTX were also performed to explore the effect of particle shape. Gas-oil contamination is observed to causes decrease of the peak and critical state friction and dilation angles in both the sand-WGTX and glass bead-WGTX interfaces. However, gas-oil contamination-induced decrease in the frictional efficiency in the glass bead-WGTX interfaces was greater than that in the angular sand-WGTX interfaces. Calibration of a state-dependent sand-structure interface model against the laboratory data of gas-oil contaminated soils-WGTX interfaces results in a reasonable agreement between the model simulations and the laboratory data.
Keywords: Geosynthetics, Contamination, Dilation, Friction, Gas-oil, Sand, Woven geotextile

Effects of transverse members on geogrid pullout behavior considering rigid and flexible top boundaries

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Abstract: Geogrid pullout tests have been regarded as the most direct and effective way to describe the interfacial behavior between geogrid and soil. To investigate the coupled effects of geogrid transverse members and top-loading boundaries on the geogrid-soil interaction, numerical simulations of geogrid pullout tests using the Discrete Element Method (DEM) were carried out in this study. The rigid top boundary was simulated by a rigid wall, while the flexible top boundary was modeled with a string of bonded particles that could rotate and move up and down freely. The coupled effects of geogrid transverse members and top boundary conditions on the geogrid-soil interaction under pullout loads were visualized not only by the force distributions along the geogrids and in the specimens but also by the displacements of soil particles and geogrids. Additionally, the quantitative geogrid force and strain distributions along the geogrids, the lateral force distributions on the front walls, and the vertical displacements of top boundaries also showed the influence of transverse members on the geogrid pullout behavior considering the rigid and flexible top boundaries. The DEM investigation results of this study may provide helpful guidelines for regulating the geogrid pullout test apparatus and methods.

Keywords: Geosynthetics, Geogrid–soil interaction, Pullout load, Transverse member, Boundary condition, Discrete element method (DEM)

Effect of geosynthetic component characteristics on the potential for GCL internal erosion

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Abstract: Experiments quantifying GCL permittivity and the ultimate water head the GCLs can sustain before the initiation of internal erosion when underlain by a 50 mm angular to subangular gravel subgrade are conducted. The influence of different geotextiles over the subgrade, water heads, hydration periods before testing, masses per unit area of bentonite within the GCL, and ionic strengths of the solution (cation exchange) are considered. Test results show that GCL with the scrim-reinforced nonwoven geotextile over the subgrade has the best hydraulic performance against internal erosion, followed by the woven geotextile coated with a 110 g/m^2 polypropylene film. A woven or nonwoven is the least useful for preventing internal erosion, with the corresponding threshold water head initiating internal erosion >39 m for scrim-reinforced nonwoven, 21 m for lightly coated woven, 4–5 m for woven and nonwoven alone, respectively. Cation exchange, length of hydration, and mass per unit area of bentonite do not notably affect the threshold water head for the subgrade examined. Once internal erosion occurs, there is a 3-order of magnitude increase in permittivity. The practical implications are discussed.
Keywords: Geosynthetics, Geosynthetic clay liner, Internal erosion, Permittivity, Gravel subgrade

Sand-geogrid interfacial shear response revisited through additive manufacturing

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Abstract: Though it is known that the geometric features of geogrids are crucial for deriving optimal interface shear strength, not much work is done to optimize the size and shape of the apertures relative to the particle size of the soils in contact. Most of the commercial geogrids have rectangular or square apertures, which are many times bigger than the soil particles. The present study explores the effects of aperture size and shape of geogrids relative to the size of the sand particles on their interface shear response through direct shear tests and digital image analysis. Geogrids of different aperture sizes and shapes were manufactured using a 3D printer. Shear tests were carried out on three sands of different grain sizes interfacing with geogrids of five different aperture sizes and three different aperture shapes. Through these tests, interface shear response with a wide range of aperture ratio and different shapes of geogrids is understood. Shear zone thickness of different sand-geogrid interfaces was computed through Particle image velocimetry (PIV). Based on the tests and analyses, triangular apertures are found to be more efficient compared to other apertures. The optimal range of aperture ratio is found to be 2–11.29.
Keywords: UN SDG 9, Industry, Innovation, And infrastructure, Geosynthetics, Additive manufacturing, Interface shear, Geogrid, Aperture ratio, Aperture shape

Experimental and numerical investigations on buffer performance of geofoam subjected by the impact of falling rocks with respect to different shapes

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Abstract: Geofoam with good buffer performance and low density is proposed to replace part of the sand, forming a composite cushion to resist rockfall impact. On the other hand, falling rock is usually variable and irregular in shape. In this study, laboratory tests and numerical research are conducted to study the buffer performance of geofoam, as well as the effect of the rock shape. When the rock shape changes from the flat form to the cone form, more time is needed to undergo the impact process and the maximum impact force decreases. Thicker geofoam is advantageous for reducing the impact force. However, the decrease degree is affected by the rock shape. Both the geofoam thickness and the rock shape have an obvious effect on the maximum deformation and the vertical stress in the geofoam. Thicker geofoam can amplify the influence of the rock shape on the stress in the beam. Accordingly, in the design of an effective composite cushion in a rock-shed, the geofoam thickness necessarily requires appropriate determination to meet both the buffer performance and the cushion deformation. Furthermore, the rock shape plays a crucial role in evaluating the buffer performance of the composite cushion.

Keywords: Laboratory impact test, Numerical research, Geofoam thickness, Rockfall shape, Rockfall impact, Dynamic response

Model test study on the protection of expansive soil slope with polymer waterproof coating

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Abstract: Polymer Waterproof Coating (PWC) is proposed to protect expansive soil slopes. Three groups of slope test models are developed to compare the efficiency of PWC, and the laws of water content, pore water pressure, soil deformation, and slope surface morphology change under repeated cycles of precipitation-evaporation environment are monitored and analyzed. The mechanism and effect of PWC protection on the expansive soil slope are discussed. The test results show that cyclic precipitation-evaporation has a significant impact on the water content, deformation, and slope surface shape of shallow layer of expansive soil slope. The change of water content and pore water pressure of slope caused by rainfall infiltration has hysteresis. The PWC-protected slope has significantly less soil deformation and water change than bare slope. The PWC protective layer blocks the water exchange between inside and outside the slope, keeping the slope water in a "dynamic and stable" state and inhibiting the slope surface cracking. The PWC protective layer significantly reduces the erosion of slope surface due to rainwater and has a significant effect on improving the integrity and strength of the slope soil. The PWC protection slope continues to have great stability even after numerous simulations of extremely harsh climates.
Keywords: Expansive soil slope, Polymer waterproof coating, Precipitation-evaporation, Slope protection, Model test

Long-term Performance of Conductive-backed multilayered HDPE Geomembranes

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Abstract: The long-term performance of three multilayered textured white conductive-backed geomembranes (GMBs) is compared to the comparable textured nonconductive GMBs and their smooth edge/equivalent to investigate the effect of the conductive layer on their longevity. Oven immersion in synthetic municipal solid waste leachate is used at a range of temperatures to accelerate the ageing during an incubation period of 50 months. It is shown that the conductive layer can antagonistically or synergistically affect the antioxidant depletion of conductive-backed GMBs relative to nonconductive GMBs produced by the same GMB manufacturer and formulated using the same nominal resin and antioxidant package. However, their relative degradation at 85 ˚C does not necessarily follow their relative antioxidant depletion times implying that the manufacturing process and the interaction between the additive packages of these GMBs can affect their relative degradation beyond the antioxidant depletion stage. Arrhenius modelling predicts the antioxidant depletion stage at field temperatures ranging between 180 and 1400 years at 20 ˚C for two different conductive-backed GMBs produced by two different manufacturers. With such variation in the long-term performance of conductive-backed GMBs currently available in the market, their durability should be investigated before their use in barrier systems to ensure they can meet the required design life of the desired geoenvironmental application.

Keywords: Geosynthetics, Multilayered textured geomembranes, Conductive-backed geomembranes, White geomembranes, Municipal solid waste landfills, Degradation

Centrifuge modeling on the effect of mechanical connection on the dynamic performance of narrow geosynthetic reinforced soil wall

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Abstract: As people migrate to densely populated cities, the importance of establishing a new transportation infrastructure to meet their needs becomes increasingly critical. The limited space available for construction makes a narrow geosynthetic reinforced soil (GRS) wall a cost-effective alternative. Prior research has primarily examined the performance of narrow GRS walls under static loads, revealing that these structures are highly vulnerable to significant crest displacements. Consequently, multiple studies have recommended incorporating mechanical connections in the upper layer during the construction of narrow GRS walls. However, some places are more susceptible to earthquakes; hence, this research was conducted to investigate the dynamic response of narrow GRS walls and quantify the effect of mechanical connections on increasing the stability of narrow GRS walls. Two sets of narrow GRS wall models were constructed, with and without mechanical connections to a stable wall, and subjected to a similar series of earthquakes. The test results indicate that the mechanical connection can reduce the accumulated normalized horizontal displacement of narrow GRS walls by 30–80% after being subjected to the same dynamic input motion excitation.

Keywords: Narrow geosynthetic reinforced soil wall, Mechanical connection, Dynamic performance

Modified method for predicting lateral displacement of PVD-improved ground under combined vacuum and surcharge loading

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Abstract: A modified method is proposed to predict the lateral displacement (δ) of prefabricated vertical drains (PVDs) improved ground under combined vacuum and surcharge loads, which is derived based on a few modified triaxial tests and a series of finite element analyses of PVD unit cells. It is observed that reducing the surcharge load (p_s) and loading rate (LR) and increasing the vacuum pressure (p_v), pre-vacuum consolidation period (t_v), and initial undrained shear strength (s_{u0}) could be effective in controlling the outward δ. Variations of the effective stress ratio (K_e) that controlling the δ with p_s, p_v, LR, t_v, and s_{u0} are then presented. A synthetic relationship between the normalized horizontal strain (ε_h) by a reference one-dimensional vertical strain (ε_{v1}) and the normalized K_e by the at-rest earth pressure coefficient (K_0) is proposed for cases with and without t_v. Further, a modified index parameter (β_1) is introduced for quantitatively considering the effect of p_s, p_v, LR, t_v, s_{u0}, and consolidation properties of the soil, a relationship between K_e and β_1 is then established for evaluating the value of K_e. Combinations of the $\varepsilon_h/\varepsilon_{v1}$–$K_e/K_0$ and K_e–β_1 relationships enable modified predictions of the δ from basic preloading conditions and soil parameters.

Keywords: Geosynthetics, Prefabricated vertical drain, Ground improvement, Lateral displacement, Finite element analysis, Combined preloading

Investigation of initial hydration and rehydration of geosynthetic clay liners from sandy subgrades via X-ray computed tomography images

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Abstract: The hydraulic conductivity of geosynthetic clay liners (GCLs) widely used as barrier systems considerably depends on their hydration status after the initial hydration of virgin GCLs and the rehydration of desiccated GCLs. Free hydration tests were performed on virgin and desiccated GCLs over sandy subgrades to compare their hydration level. In addition, high-resolution micro-X-ray computed tomography (CT) images of both GCLs and sandy subgrades with different gravimetric water content (i.e. 15%, 20%, and 25%) after the initial hydration were analyzed for better insights. The results show significant influences of subgrade water content on moisture content and thickness of virgin GCLs. Water loss of sandy subgrades and the time interval necessary for reaching a steady state of desiccated GCLs during rehydration was greater and longer than virgin GCLs during initial hydration. X-ray CT images verified a dense distribution of bentonite particles, macropores, and minor desiccation cracks that existed in poorly-hydrated GCLs over unsaturated sand. On the other hand, the completely saturated sandy subgrade facilitated the hydration of GCLs, leaving a lot of macropores in the sand. The relationship between water distribution and the frequency of macropore generation observed in the upper contact zone of sandy subgrades was also indicated via these X-ray CT images.
Keywords: Initial hydration, Rehydration, Pore structures, Geosynthetic clay liners, Sandy subgrades, X-ray CT images