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摘要集

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目　录

Centrifuge shaking table tests on tiered reinforced soil retaining walls subjected to the excitations of near-field ground motions

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Abstract: Tiered geosynthetic-reinforced soil (GRS) retaining walls are becoming increasingly popular in earthquake-prone areas due to their excellent earthquake resistance. Typically, near-field strong ground motion is characterized by a significant vertical component and/or a long-period velocity pulse. However, this is seldom considered in the current design of tiered GRS walls. In this study, two centrifuge shaking table tests were conducted to investigate the earthquake performance of tiered GRS walls under bidirectional and pulse-like excitations. The results revealed that under bidirectional excitation, the wall model underwent significant deformation. The confining pressures in the soil increased due to vertical motion, resulting in notable changes in the shear modulus of the backfill. Due to large differential settlement and vertical excitation, the earth pressures were significantly impacted. In the second case, pulse-like motions induced considerable shear strains in the backfill, leading to significant alterations of the shear modulus and dynamic damping of the structure. The facing exhibited distinct deformation modes, with some sliding at the toe. The peak wall displacement and reinforcement strain were both notably higher than the residual values. However, in both cases, the connections between the reinforcements and the facing endured relatively large strains, and need to be considered in seismic design.

Keywords: Geosynthetic-reinforced soil wall, Multi-tiered configuration, Centrifuge test, Shaking table, Near-field earthquake response

Effect of welding parameters on properties of HDPE geomembrane extrusion welds

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Abstract: The stress crack resistance (SCR) of high-density polyethylene (HDPE) geomembrane extrusion welds is examined for a 1.5 mm HDPE geomembrane and three different welding parameter combinations (denoted as "Cool", "Good", and "Overheated"). Results are reported for unnotched welds, unnotched sheet, and notched sheet. The average SCR for a Good extrusion weld is 23% of that of the unnotched sheet SCR. Little variation is found between the three welding parameter combinations for low geometry irregularity SCR weld specimens. There is no statistically significant difference between a good-quality fusion and extrusion weld. However, operator-dependent weld induced geometric irregularity (WIGI) greatly affects the SCR of extrusion welds. Extrusion welds with high WIGI have an average unnotched SCR of only 9% of the unnotched sheet. Extrusion welds with an overground surface can have an unnotched SCR as little as 1% of the best extrusion weld. Deleterious weld bead geometries are identified to provide a framework with which engineers can identify "high-risk" extrusion welds with respect to stress cracking.
Keywords: Geosynthetics, Extrusion welds, Fusion welds, stress cracking resistance (SCR), HDPE, Geomembranes, Quality assurance

Innovative design of self-adhesive basalt fiber mesh geotextiles for enhanced pavement crack resistance

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Abstract: This study introduces a novel design of self-adhesive basalt fiber mesh geotextile, aiming to significantly enhance the crack resistance of asphalt pavements. Reflective cracks from environmental and traffic stresses in traditional semi-rigid asphalt pavements, compounded by current geotextiles' mechanical and adhesion limitations, reduce service life. This study explores the mechanical properties, adhesion to asphalt, and resistance to simulated cracking of self-adhesive basalt fiber mesh geotextiles within pavement structures. This is accomplished through a series of mechanical tests, interfacial adhesion tests, and advanced characterization using Digital Image Correlation. The results indicate that the distinctive pore structure of basalt fiber mesh geotextiles introduces an embedded interlocking reinforcement effect, which significantly enhances the strength of the composite geotextile. The SAM-160M specimen demonstrates a maximum tensile strength of 3.599 kN, surpassing that of the plain fabric specimen by over 34%. The twisted weaving process of the mesh fabric improves adhesion to asphalt by 14.54% compared to plain fabric, thereby enhancing the performance of the pavement structure's interlayer and its resistance to cracking. The mesh fabric excels at dispersing concentrated stresses, enhancing weak interface zones, and increasing the structural capacity and longevity of pavements. These improvements support sustainable road construction with broad engineering applications.

Keywords: Basalt fiber mesh fabric, Self-adhesive composite geotextiles, Crack resistance, Interlayer properties, Interface analysis

Effect of a lateral drainage layer on leakage through a defect in a geomembrane overlain by saturated tailings

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Abstract: Experiments are conducted to investigate the effect of a drainage layer in/below saturated tailings on leakage through a hole of various shapes and sizes in a 2-mm-thick HDPE geomembrane. Three cases: no drainage (Case 1), drainage layer between two layers of tailings (Case 2), and drainage layer below tailings and above the GMB (Case 3) are examined. Analytical solutions predicting leakage through a circular GMB hole overlain by tailings with an internal drainage in (Case 2) and below (Case 3) tailings are developed, and match the experimental and numerical results well. Results show that a drainage layer separated from the GMB by a thin layer of tailings (Case 2) gives leakage slightly greater than if no drainage layer is present, but 3-5 orders of magnitude lower than when the drainage is placed directly over the GMB (Case 3). In Case 3, leakage is dependent on the hydraulic conductivity k of both the drainage and subgrade, and is not affected by the tailings. Unlike Cases 1 and 2 where the subgrade has negligible effect on leakage, a low permeability subgrade with k less than 10% of k for the drainage layer is recommended in Case 3 to minimize leakage through geomembrane defects.
Keywords: Geosynthetics, Geomembrane, Holes, Tailings, Leakage, Drainage layer

Experimental study on the effect of temperature on HDPE geomembrane/geotextile interface shear characteristics

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Abstract: Geomembranes (GMBs) and geotextiles (GTXs) are the most widely used geosynthetics in landfills and other barrier systems. While various temperature environments may be encountered in practice, the interface shear characteristics of geosynthetics under different temperatures are still not clear. Shear tests of the interface between a high-density polyethylene GMB and nonwoven GTX are performed using a temperature-controlled submerged direct shear apparatus. The testing temperatures range from 10 °C to 70 °C, which covers most of the situations commonly encountered in engineering. The shear behaviors of the textured GMB/GTX interface and smooth GMB/GTX interface are presented, and the mechanism of the temperature influence is analyzed according to the test results and phenomena. Temperature has a significant impact on the GMB/GTX interface peak strength and post-peak strength, and maximum interface shear strength could be obtained when the temperature is approximately 30–40 °C. The influencing mechanisms of temperature on the GMB/GTX interface shear strength are thoroughly discussed. The shear characteristics of the GMB/GTX interface under different temperatures are critical to the stability analysis of geosynthetic slopes in special condition, and this study can also provide a reference for the effect of temperature on the shear behavior of other geosynthetics.
Keywords: Temperature, Geomembrane, Geotextile, Interface, Shear strength

Self-healing capacity of GCLs under simulated field conditions

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Abstract: The self-healing capacities of a GCL with natural bentonite (NB) as core (NB-GCL) and a GCL with a polymerized bentonite (PB) as core (PB-GCL) were investigated under simulated field conditions, i.e. geomembrane-GCL-a clayey subsoil layer composite liner system with a damage hole on the geomembrane and the GCL. The clayey subsoils tested had initial water contents of 22.2% and 26.8%. The liquids used were deionized (DI) water and 0.3 M NaCl solution. The test results indicate that for both the PB-GCL and NB-GCL only hydrated on the subsoils for 1–3 months, a damage hole of 15 mm in diameter was almost not self-healed. For cases of applying a constant liquid head on the top of the geomembrane of 100 mm, the sizes of damage holes were self-healed in term of diameter is about half of the values reported in the literature for tests with plenty liquid supply to the damaged GCLs. Further, for the conditions tested and for the cases self-healed, DI water leaked into the subsoil was less than about 60 g, and 0.3 M NaCl solution leaked was less than 150 g.

Keywords: Geosynthetics, GCL self-healing, Composite liner, Laboratory test

Performance of eccentrically loaded strip footings on geocell-reinforced soil

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Abstract: In this pioneering study, the performance of an eccentrically loaded strip footing on geocell-reinforced sand was assessed with instrumented laboratory model tests in terms of pressure-settlement response, surface displacement profiles, failure mechanisms and ultimate bearing capacity considering load eccentricity, geocell height, geocell material stiffness and the relative density of the soil. The results indicated that strip footings on the geocell-reinforced sand outperformed those on unreinforced soils, with up to a 6.5-fold increase in the bearing capacity and significant improvements in the initial slope of the pressure-settlement curve. Furthermore, the strip footing under centric loading on the geocell-reinforced loose and dense sand exhibited either only punching or local shear failure while load eccentricity on the strip footing could lead to the shear failures including punching, local and general. In this research, both a design chart for predicting failure modes of geocell-reinforced strip footings and a new interpretation method to evaluate ultimate bearing capacity were proposed. Increasing the relative density of the soil and material stiffness enhanced the ultimate bearing capacity of geocell-reinforced strip footings under both centric and eccentric loading conditions, with stiffer materials resulting up to 25% increase. However, increased geocell height had no significant impact on bearing capacity.

Keywords: Geocell, Eccentric loading, Geosynthetics, Model test, Strip footing, Bearing capacity

Exploring the influence of size-related factors on geocell-reinforced soil response using coupled continuum-discontinuum analysis

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Abstract: Size-related factors, such as the dimensions and cell count of geocell, play a crucial role in determining the effectiveness of soil reinforcement. In this study, a 3D coupled framework that leverages the strengths of both continuum and discontinuum methods was developed to investigate the influence of pocket size and multi-cell configuration on geocell-reinforced soils. To unveil the impact of size-related factors on soil-geocell interactions, reinforced soils containing various geocell configurations (single large-sized cell, multiple small-sized cells), as well as geocell-free soils subjected to increasing levels of confining pressure were extensively examined. This thorough investigation aimed to establish correlations between macroscopic responses and underlying micromechanical mechanisms. Our findings revealed that the presence of the geocell not only enhances the densification of interparticle contacts and reduces the number of floating particles that contribute minimally to load support, but also facilitates the concentration of force chains within the geocell structure. This leads to an increase in elastic stiffness along the loading axis. These observations highlight that the geocell's confining mechanism enhances both the load-carrying capacity and the infill rigidity, thereby preventing lateral soil spreading. In essence, the geocell serves to increase the soil's ability to withstand load and maintain its structural integrity laterally.
Keywords: Geosynthetics, Geocell-reinforced soil, Size-related factors, Coupled continuum-discontinuum method, Microscopic characterization

An analytical solution for the settlement of encased stone columns beneath rigid footings

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Abstract: This paper presents a new approximate solution to study the settlement of rigid footings resting on a soft soil improved with groups of encased stone columns. The solution development is fully analytical, but finite element analyses are used to verify the validity of some assumptions, such as a simplified geometric model, load distribution with depth and boundary conditions. Groups of encased stone columns are converted to equivalent single encased columns with the same cross-sectional area and the same ratio of encasement stiffness to column diameter. In this way, the problem becomes axially symmetric. Soft soil is assumed as linear elastic but plastic strains are considered in the column using the Mohr-Coulomb yield criterion and a non-associated flow rule with a constant dilatancy angle. Soil profile is divided into independent horizontal slices and equilibrium of stresses and compatibility of deformations are imposed in the vertical and horizontal directions. The solution is presented in a closed form and may be easily implemented in a spreadsheet. Comparisons of the proposed solution with numerical analyses show a good agreement for the whole range of common values, which confirms the validity of the solution and its hypotheses.

Keywords: Geosynthetics, Geotextiles, Encased stone columns, Analytical solution, Settlement, Footings, Design

Assessment of the functionality of geotextile and granular filter systems in hydraulic engineering in case of iron ochre clogging tendency

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Abstract: In recent decades, there have been individual cases of damage to geotextile filters due to clogging by flocculated ochre products. This process is defined as ochre clogging and has been extensively explained in recent theoretical studies (Tophoff et al., 2022). Several revetments of tidally influenced German North Sea estuaries have been damaged due to a severe reduction in the permeability of geotextiles. Therefore, experimental investigations of granular and geotextile filter constructions were carried out to better understand filter clogging. The investigations reproduce a revetment section at a scale of 1:1. For this purpose, the clogging process in the fluctuating water level or clogging zone was reproduced as a purely chemical iron precipitation. Ten short-term tests (10 h) and one long-term test (50 h) were carried out in total. The tests show that the process involves internal clogging and that the iron precipitates adhere immovably to the filter structure, reducing the pore space and permeability of the filter. This process is considered less problematic for granular filters. A reduction in permeability was measured in some cases for geotextile filter designs. Different geotextile material parameters appear to influence the iron ochre clogging tendency.

Keywords: Granular and geosynthetic filter design, Iron ochre clogging, Iron precipitation, Revetment durability, Permeability tests

Behavior of geosynthetic-encased stone column reinforced foundation under freeze-thaw cycles

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Abstract: In this paper, an experiment study was carried out to identify the fundamental behavior of geosynthetic-encased stone column (GESC) reinforced foundation under freeze-thaw cycles. Three loading tests under four freeze-thaw cycles were considered. A 10-m thick reinforced foundation unit consisted of four floating GESCs with 2.5-m underlain clay layer, and the foundations were preconsolidated to three different initial degrees of consolidation (U = 1.0, 0.6 and 0.3, respectively). The results showed that soil near GESCs had a larger frozen depth due to the excellent heat transfer ability of GESCs. An extra uneven subsidence of soil also appeared around GESCs. Voids could be found between foundation soil and the loading plate after thawing, which indicated that only GESCs carried the overburden pressure. The GESCs showed outward bending under lower initial degree of consolidation, while inward bending under higher one. A bulging failure was observed on frozen part of GESCs, especially at the connection of encasement in foundation with lower initial degree of consolidation. In the first freezing process, a rapid decrease in frost heave force was noticed, inferring the fracture of frozen soil. The stress on GESC was found to almost have no change until complete freezing, when the soil was freezing and the stress on soil exceeded that on GESC. Negative pore pressure was observed in the foundation soil, and the absolute value decreased with the increasing overburden pressure. Both the peak positive and negative pore pressures were reduced as the foundation was preconsolidated to a higher degree. The freeze-thaw cycles were also found to generate excess pore pressure in soil during thawing. Moisture migration was also analyzed using Electrical Resistivity Tomography (ERT) method, and the results showed that moisture tended to go upwards and outside the reinforced unit from thawing to freezing, while downwards and inside the unit from freezing to thawing.

Keywords: GESC-reinforced foundation, Freeze-thaw cycles, Frost heave force, Negative pore pressure, Moisture migration

Seismic time-history analysis of block-faced reinforced-soil retaining wall based on pseudo-dynamic method

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Abstract: The horizontal displacement of a reinforced-soil retaining wall is a common deformation mode of seismic damage. The horizontal displacement time history and accumulative deformation after earthquakes are important parameters for evaluating the seismic performance of a reinforced-soil retaining wall, but theoretical study on this issue is scarce at the moment. In this study, an analytical method is proposed to calculate the horizontal displacement time history of a block-faced reinforced soil retaining wall. The method is based on the pseudo-dynamic method and differential kinematics equations, and this method was used to calculate the reinforcement material's tensile displacement and overall displacement in the reinforced area under earthquake motion, while simultaneously taking into account the accumulative deformation. The rationality and accuracy of this method are verified through comparison with model experiments and existing theories. Besides, parameter analysis was carried out to further confirm the applicability of this method. The study shows the method takes into account the influence of the accumulated deformation, and can effectively calculate the horizontal displacement time history of the block-faced reinforced soil retaining wall under larger magnitudes. Although the calculated values are smaller than the actual deformation, they are still relatively close.

Keywords: Reinforced soil retaining wall, Pseudo-dynamic method, accumulative deformation, Time history analysis

Full-scale accelerated testing of geogrid-reinforced inverted pavements

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Abstract: Decades of research has been dedicated to investigating inverted pavement as an alternative to traditional flexible pavement structures. While previous studies have largely focused on the stress dependency of the unbound aggregate base (UAB) layer using numerical simulations, there is limited research on the construction and use of geogrid reinforcement in inverted pavement. This study presents a comprehensive evaluation of full-scale inverted pavements, specifically assessing the impact of geogrid reinforcement on rutting performance. The results indicate that adding geogrid to the UAB layer improves rutting resistance, with optimal results achieved when the geogrid is placed in the upper third of the layer. On the other hand, when the geogrid was positioned in the bottom two-thirds of the layer, it led to inferior rutting performance compared to the inverted pavement where geogrid reinforcement was placed in the upper one-third of the UAB layer. Numerical simulations validate the field test results, demonstrating that higher tensile strains in the upper third location enhance aggregate interlocking and stiffness due to the geogrid's enhanced constraining capacity and reinforcement. Conversely, lower tensile strains in the bottom two-thirds location limit geogrid constraints, leading to increased rutting and surface deformation.

Keywords: Inverted pavement, Accelerated pavement test (APT), Geogrid, Full-scale pavement, Unbound aggregate materials

Macro-microscopic mechanical behavior of geogrid reinforced calcareous sand subjected to triaxial loads: Effects of aperture size and tensile resistance

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Abstract: Reinforcing calcareous sands with geogrids is a potentially effective method for large-scale geotechnical constructions in coastal lands. The breakable nature of polygonal calcareous sands determines the complex particle-geogrid interactions. A three-dimensional numerical model of geogrid reinforced calcareous sand (GRCS) was established to investigate the potential mechanical laws based on the discrete element method (DEM), and the reasonableness of the numerical model was verified by comparing with the indoor triaxial test. It follows that the macro-microscopic mechanical behavior of GRCS under the influence of aperture size and tensile resistance of geogrids was further investigated via effective DEM simulations. The presented results show that the decreased aperture size and increased tensile resistance are beneficial to enhance the macro-mechanical properties of GRCS, including strength, internal friction angle and pseudo cohesion. Particle crushing is mainly affected by shear strain and confining pressure. The bulging deformation of GRCS is partially suppressed due to the confining effect of geogrids. Besides, the source of strength enhancement of GRCS is revealed based on the microscopic particle-geogrid interactions, and the calculation method of horizontal and vertical additional stresses in the reinforced soil element considering the effects of tensile resistance and aperture size is further established.

Keywords: Calcareous sand, Geogrid reinforcement, Mechanical behavior, Particle crushing, Discrete element modeling

Seismic performances of the wrapped retaining wall backfilled with polypropylene fiber reinforced rubber-sand mixture

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Abstract: In this study, a fiber-reinforced rubber-sand mixture (FRRSM) was produced by adding random distribution reinforcement of polypropylene fiber recycled from waste plastic, which can strengthen the RSM. The mechanical parameters of FRRSM were tested using indoor experiments. Moreover, the seismic behavior of a wrapped reinforced earth retaining wall backfilled with FRRSM was investigated using the finite element method. First, by comparing the model test results, the accuracy of the nonlinear finite element analysis method, which simulated the earthquake response of a retaining wall well, was verified. Subsequently, the soil used in the model test was replaced with FRRSM, and the facing displacement, vertical settlement, and acceleration response of the retaining wall were analyzed. The results indicate that the seismic performance of the retaining wall was significantly enhanced with an increase in the fiber content (F_C) of the FRRSM. According to the present research, the optimal mixture ratio that can ensure the seismic performance of FRRSM-RW is 10% rubber and 1.5% fiber, that is, R_C = 10% and F_C = 1.5%.

Keywords: Fiber-reinforced rubber-sand mixture, Reinforced earth retaining wall, Seismic behavior, Numerical simulation, Indoor experiment

Mechanism of air-boosting and its effects on vacuum consolidation

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Abstract: This study aimed to address some basic issues about an air-boosting vacuum consolidation. Through theoretical analysis, it has been clarified that air-boosting pressure is not a consolidation pressure, and the efforts for developing a consolidation theory considering the effect of air-boosting pressure are unnecessary ones. Air-boosting can cause pneumatic fracturing in a soil mass, and equations for estimating the minimum air pressure required have been newly derived based on cavity expansion theories. Then, effects of air-boosting on a vacuum consolidation have been identified as: de-structuring, dewatering, and mitigating apparent clogging around drains. Then, by analyzing some published data of laboratory model tests using clay slurries, it is shown that mitigating apparent clogging contributed to about 30%–60% of the effect of air-boosting (increase settlement), and other part could be the effect of dewatering. Increase air pressure and duration of air-boosting had positive effects on both mitigating apparent clogging and dewatering, but might be more effect on dewatering.
Keywords: Vacuum consolidation, Effects of air-boosting, Pneumatic fracturing, Prefabricated vertical/horizontal drain

Enhanced drainage performance of PVF-wicking geosynthetics: Development and experimental assessment

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Abstract: An enhanced geosynthetic material, PVF-wicking geosynthetic (PWG), was developed to improve the performance of the wicking geosynthetic product family, e.g., the wicking geotextile (WG). The PWG was made by coating deep-grooved wicking yarns and reinforcement with the layered polyvinyl alcohol formaldehyde (PVF) high-absorbent materials. The drainage performance of PWG was assessed through beaker drainage tests and soil column tests. The results of the beaker drainage test and SEM images indicate that PVF does not obstruct the deep-grooved yarns. It is found that, by facilitating efficient water absorption, storage, and transfer as a transit layer between the subgrade and wicking yarns, PVF plays a crucial role in enhancing the drainage capabilities of the geosynthetic material. PWG outperforms WG in terms of drainage efficiency under both static and cyclic loading conditions. The mechanism of the drainage improvement by PWG under cyclic loading is that the excess pore pressure within the PVF layer accelerates the water transfer from the pores of the PVF into the grooves of yarns. PWG, included with reinforcement, exhibited comparable interface characteristics to WG, with the potential to meet the requirements of soil stabilization. The remarkable drainage efficiency of PWG underscores its potential for practical applications.

Keywords: Wicking geotextile, Geosynthetic, Drainage, PVF, Cyclic loading, Volumetric water content

Experimental evaluation of geosynthetic-modular block connection loads

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Abstract: The design of segmental geosynthetic mechanically stabilized walls with masonry block facing is often governed by the loads that develop at the connection between the facing and geosynthetic. Yet the current understanding of the mechanisms involved in the mobilization of such connection loads is, at best, incomplete. The testing apparatus developed as part of this study facilitates simulating the transference of stresses at the face and evaluating the facing connection loads in geosynthetic-reinforced soil walls. This study assesses the connection loads between a geogrid reinforcement connected frictionally to modular concrete blocks. A comprehensive instrumentation program was implemented to capture lateral earth pressures, geosynthetic strains and loads acting at the geogrid-block connection in a geosynthetic-reinforced unit cell subjected to incremental surcharge stages. Results indicate that conventional calculations, based on earth pressure theory, may underestimate the facing connection loads, mainly when the connection loads are triggered by the differential settlement of the backfill relative to the block facing. When this mechanism dominates the mobilization at the connection, reinforcement loads increase as the differential settlement increases, developing down-drag forces at the connection between the geogrid and modular blocks.

Keywords: Geosynthetics, Facing, Connection loads, Modular blocks, Down-drag

Electroosmosis of gold tailings under multiple electrokinetic geosynthetics electrodes

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Abstract: In dry-stack tailing ponds with high fine-grained content, a high long-term saturation line can lead to dam failure. Electroosmotic consolidation is an effective method for reducing dam saturation lines. However, traditional electrodes have low corrosion resistance and poor contact, which limits the development of electroosmotic drainage technology for tailings. In this study, an electroosmotic drainage device, an electrokinetic geosynthetic (EKG) electrode, was designed. The influence law of the electrode material, potential gradient, and number of electrodes on the water drainage, current, and resistance was analyzed. The results show that the EKG electrode has excellent corrosion resistance, with its weight loss after electroosmosis, water drainage, and equivalent allowable current being 1.67%, 122%, and ～2.3 times that of a copper electrode, respectively. Furthermore, it was found that the optimal potential gradient was 1.2 V/cm, and the water drainage cannot be improved by an exceedingly high potential gradient. The current pathway in the test box was in parallel, and the water drainage increased to 410% and the contact resistance decreased by 83% when the number of electrodes was four. These results and novel methodology provide new ideas for EKG electrode design and represent an effective method for saturation line control in gold tailing ponds.

Keywords: Electrokinetic geosynthetics, Dry-stack tailings, Electroosmotic drainage, Potential gradient, Multi-electrode

Using strain hardening to predict the stress crack resistance of unaged and aged smooth black HDPE geomembranes

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Abstract: The correlation between the single-point notched constant tensile load-stress crack resistance (SP-NCTL SCR) Test (ASTM D5397; Appendix) of smooth high density polyethylene (HDPE) geomembranes and their strain hardening modulus is investigated for both unaged and aged specimens. The strain hardening modulus was calculated based on the (force-elongation) raw data from the tensile strength test conducted at room temperature using Type IV and/or Type V specimens (as described in ASTM D638) at a test speed of 7 mm/min. Three different approaches are used to define the strain hardening modulus and to compare the representative strain hardening modulus with the SP-NCTL SCR. It is shown that the high test speed of 7 mm/min performed at room temperature provides a good correlation with the SP-NCTL SCR of different smooth black HDPE geomembranes. Additionally, the proposed method using Type V specimens predicts the SCR values during oxidative degradation close to those observed using the SP-NCTL SCR test. For the resins and conditions examined, the proposed method provides a quick assessment of the SP-NCTL SCR of unaged geomembranes when the SP-NCTL SCR takes long testing times (e.g., >1000 h) or in jurisdictions in which the use of surfactants becomes prohibited to allow conducting the SP-NCTL SCR tests.

Keywords: Geosynthetic, Smooth geomembrane, Strain hardening modulus, Stress crack resistance, Hardening stiffness

Seismic bearing capacity of strip footings placed on reinforced soil slopes using slip line method

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Abstract: This study investigates the seismic vertical bearing capacity of strip footings positioned on reinforced soil structures employing a two-phase approach and the slip line method. The investigation aims to establish a slip line field and determine the critical slip surface without any assumptions of predefined surfaces. The obtained results are compared with previous studies, demonstrating a good agreement and validating the accuracy of the proposed approach. The variation of the bearing capacity factor with the horizontal seismic coefficient, soil internal friction angle, setback distance normalized by footing width, and slope incline angle. An increase in the horizontal seismic coefficient leads to a decrease in bearing capacity factor, while an increase in the soil internal friction angle has the opposite effect. The influence of the setback distance on the bearing capacity is also examined, highlighting significant improvements with increased setback distances. Additionally, the study investigates the impact of the tensile strength ratio and setback distance on the ultimate bearing capacity factor and the bearing capacity ratio. The distribution of reinforcement forces beneath the footing is analyzed and presented through contour plots, providing valuable insights into the seismic behavior of footings on reinforced soil slopes.

Keywords: Reinforced soil slope, Seismic vertical bearing capacity, Slip line method, Two phase approach, Setback distance

Introduction to a novel geotextile tube connection construction method: A case study of test site and field application

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Abstract: One particular challenge in constructing geotextile tubes is ensuring proper alignment and leveling, especially when connecting them in a series. This study introduces a novel connection configuration to address this challenge by inserting an auxiliary tube between two main tubes. The proposed connection method offers the advantage of consolidating individual geotextile tubes into a unified structure while maintaining a consistent horizontal level. The proposed connection technique was successfully applied both at test site and on dry construction platform for bridge construction. This study is beneficial for practicing engineers as it presents a new and effective method for connecting geotextile tubes, offering valuable insights into its practical application.

Keywords: Geotextile tube, Geotextile tube connection, Land reclamation project, Shoreline protection, Embankment

Numerical modelling of reinforced fill over a void considering rate-dependent stiffness of the reinforcement

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Abstract: The problem of a reinforced fill over a void has been the subject of much research in the geosynthetics literature. Previous studies have mainly focused on finding closed-form solutions to predict the tensile loads and strains in the reinforcement layer once a void develops below the fill. In this paper, a 2D finite difference (FLAC) model that implements the hyperbolic isochronous load-strain model for the reinforcement by Bathurst and Naftchali (2021) is used to investigate the influence of the rate-dependent properties of polymeric geosynthetic reinforcement materials on reinforcement tensile strains and load, and overall system performance including vertical deformation at the reinforcement elevation and at the fill surface. The paper also investigates the influence of fill soil properties and constitutive model type, foundation condition, void geometry and fill height on system performance. The results of numerical modelling are compared to predictions made using the closed-form solution of Giroud et al. (1990) and in the BSI 8006-1 (2010) design code. The results of numerical modelling demonstrate that the choice of fill height to void width and the stiffness of the rate-dependent geosynthetic reinforcement layer are important to ensure that the maximum reinforcement strain, allowable strength and fill surface settlement criteria are not exceeded.

Keywords: Geosynthetics, Reinforced fill, Void, Rate-dependent stiffness, Arching, 2D finite difference model (FDM), FLAC, Limit states

Experimental investigation of the geometry of geocell on the performance of flexible pavement under repeated loading

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Abstract: To evaluate the benefit of geocells of different geometrical configurations for pavement application, full-scale instrumented model tests were performed on pavement sections reinforced with geocells of different geometrical configurations subjected to monotonic and repeated loading. The responses studied were stress distribution in different pavement layers, induced strains in geocell walls, and settlement characteristics. The reinforced sections exhibited a significant reduction in rut depth as well as localized stress concentration compared to the unreinforced section. The reduction in rut depth was found to be influenced by the geocell height as well as weld spacing. The geocell reinforcement was found to distribute the stresses in the subgrade and subbase layers more efficiently, thus reducing the stress concentration in these layers. The strain measurements were found to be higher at the bottom of the geocell walls indicating a higher confinement effect on a lower part of the geocell. In the field, mostly geocells of 356 mm weld spacing and 150 mm height (SW356-H150) are used. However, this study suggests that a geocell of 330 mm weld spacing and 100 mm height (SW330-H100) having approximately 30% lower cost compared to SW356-H150 is as effective in reducing the rut depth and localized vertical stress distribution.
Keywords: Rut depth, Stress distribution, Geocell, Subgrade, Pavements, Repeated load, Configuration

Evaluation of arched EPS block and geocell inclusions in trench backfill for protection of buried flexible pipes

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Abstract: This paper presents an experimental investigation examining the novel idea of employing curved expanded-Polystyrene (EPS) blocks that arch around the upper section of buried flexible pipes to reduce the pressures acting on them and hence resulting deformation/deflections. Large-scale testing was performed to examine key performance indicators for reinstated trenches with buried 250-mm diameter plastic pipe (0.75-m invert depth) when subjected to cyclic surface loading simulating vehicular traffic. The real-scale model tests investigated unreinforced and geocell-reinforced trenches with conventional rectangular and differently shaped EPS block inclusions placed above the crown or fitting snugly around the upper section of the buried pipes. Compared to conventional rectangular EPS block, the curved-arched EPS block produced greater reductions in the pressures acting on the buried pipes, resulting in substantially smaller pipe deformation/deflections. The geocell layer overlying the EPS block significantly reduced the pressures bearing on the highly compressible EPS material, thereby reducing its compression and the trench surface settlement. Optimum trench reinstatements incorporated both the geocell layer and a 75-mm thick curved-arched EPS block fitted around the top section of the pipe. Doubling the EPS block thickness produced only modest reductions in the pipe deflections, but significantly increased the trench surface settlement.

Keywords: Geosynthetics, Buried pipes, EPS geofoam, Geocell, Pipe deformation, Trench surface settlement

2D failure mechanisms and failure modes of a new type of geotextile tubes used for river dikes

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Abstract: A new type of small, dry-filled geotextile tubes is introduced, that, in a stacked formation, can be used as dike cores. Dikes made out of these tubes consist of great potential regarding more resilient flood protection. The geotextile protects the fill from erosion, enabling steeper slopes along with reduced material and less land consumption. The behavior and potential failure mechanisms of such dikes were investigated first by literature research and second by full-scale hydraulic model tests under systematic variation of tube number, number of textile layers, filling ratio, and fill material. The tubes were exposed to the loads of seepage and overflow. Most relevant failure mechanisms were seepage-induced sagging, lateral displacement, and overturning of the upper tube due to overflow. During seepage, the tube height was reduced by up to 22.8 % due to sagging. Overflow led to a lateral displacement of up to 13 cm and, at overflow heights of 23.1 cm and 26.8 cm, to overturning of the upper tube. The present results give new insights into the behavior of innovatively constructed geotextile tubes under hydraulic loads and serve as basis for the development of design rules.

Keywords: Geotextile tubes, Dikes, Seepage, Overflow, Resilience, Flood protection

Effective stiffness matrix calculation of geocell layer and reinforcement mechanism analysis of geocell reinforced embankment

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Abstract: The anisotropic effective stiffness matrix (ESM) of the unit cell (UC) of a geocell layer with different laying modes (denoted by θ), which cannot be measured directly by conventional tests but can be obtained by the mathematical homogenization method (MHM) on the UC of the geocell layer, is needed in simulation and design of geocell reinforced embankment. The components of the ESM are divided into two independent parts based on whether they depend on θ. Compared with the direct numerical simulation (DNS), the homogenized numerical simulation (HNS) of the embankment with the ESM reduced the calculation cost, and the settlement loading curves were in good agreement with the test curves. By analyzing the results of HNS, it was found that (1) the vertical stress diffusion effect is independent on θ, (2) the membrane effect is dependent on θ, and (3) two aspects of the lateral resistance effect were verified.

Keywords: Mathematical homogenization method, Anisotropic material, Engineering constants, Vertical stress diffusion effect, Membrane effect, Lateral resistance effect

New simple method for calculating large-strain consolidation settlement of layered soft soils with horizontal drains and vacuum preloading with comparison to test data

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Abstract: Prefabricated horizontal drains and vacuum preloading have advantages in the consolidation of ultra-soft dredged sludge and soils for maintenance dredging, reclamation, and ground improvement in coastal regions. While laboratory tests and field trial projects have been reported, a convenient analysis and design method is still unavailable. This study proposes a new simple method for the settlement analysis of soft soils considering horizontal drains, vacuum preloading, creep, and large-strain effects. A unified equation is constructed to account for various layouts of horizontal drains in consolidation. A new explicit method is developed to consider the large-strain deformation with the nonlinear evolution of permeability and compressibility of ultra-soft soils under vacuum preloading. The viscous compression is taken into account using a simplified Hypothesis B method. The proposed solution also facilitates convenient consideration of multiple layers of soils and drains subjected to staged loading. The proposed method is examined by a series of physical model tests with different horizontal drain dimensions. Finally, the method is applied in the analysis of two well-documented field cases in Hong Kong and Japan, which confirms its effectiveness and accuracy.
Keywords: Soft soils, Horizontal drains, Consolidation, Simple method, Large-strain

Investigation on the static performance of geogrid reinforced aeolian sand railway embankment: Field test and discrete element simulation

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Abstract: To enhance the mechanical properties and stability of desert railway embankments, the utilization of geogrids has proven to be an effective measure. The article conducted field tests and discrete element simulations to thoroughly examine the static performance of embankments reinforced with geogrids. The study systematically explored the macroscopic and microscopic characteristics of the geogrid-reinforced embankment under static loading. Various factors were investigated, including the horizontal laying arrangements and depth to the top layer of the geogrid, as well as key design parameters such as the number of geogrid layers, geogrid width, and vertical spacing between geogrid layers. The findings indicate a progressive enhancement in the ultimate bearing capacity of the embankment with an increase in both the number of geogrid layers and the geogrid width. Conversely, there is a decrease in ultimate bearing capacity as the depth to the top layer increases. In comparison to unreinforced embankments, reinforced embankments exhibit a reduced contact anisotropy, signifying that the geogrid effectively disperses static loads, resulting in a more uniform contact distribution. The geogrid restrains both displacement and rotation of the aeolian sand, and this restraining effect progressively strengthens with an increase in the number of geogrid layers or the geogrid width. The research findings can serve as a reference for the design and application of aeolian sand railway embankments.

Keywords: Aeolian sand, Desert railway, Geogrid, Discrete element method, Reinforced embankment

Experimental study on the improvement of sludge by vacuum preloading-stepped electroosmosis method with prefabricated horizontal drain

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Abstract: To improve the defects of low electroosmosis efficiency in the later stage and high energy consumption of conventional vacuum preloading combined with electroosmosis, the vacuum preloading-stepped electroosmosis method (VP-SEO) with prefabricated horizontal drain (PHD) was proposed for dredged sludge in this paper. In the test, waste concrete fine aggregate was used as the horizontal drainage cushion to alleviate the clogging of the PHD. The results showed that compared to vacuum preloading combined with electroosmosis (VP-EO), more drainage channels throughout the soil were produced after VP-SEO treatment, and VP-SEO could maintain a higher drainage efficiency in the later stage of treatment with improved final drainage and consolidation. The sludge treated by VP-SEO showed a significant increase in vane shear strength and a reduction in water content. Furthermore, the water loss and shrinkage of the soil surface after VP-SEO treatment were more uniform than that of VP-EO treatment, and the electroosmotic energy consumption and anode erosion were also lower. This study provides an effective improvement scheme for solidifying sludge with a high water content by conventional vacuum preloading combined with electroosmosis method.

Keywords: Dredged sludge, Vacuum preloading, Stepped electroosmosis, Drainage cushion, Solidification

Transport parameters for PFOA and PFOS migration through GCL's and composite liners used in landfills

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Abstract: The effect of applied stress (20, 60, and 150 kPa) on the diffusion of perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) through a geosynthetic clay liner (GCL) is examined. The diffusion coefficients deduced from GCL diffusion tests for PFOA and PFOS decrease linearly with decreasing final bulk GCL void ratio (increasing applied stresses). The different components of the same GCL are also tested for PFOA and PFOS sorption. No statistically significant sorption of PFOA is observed for any of the components of the GCL. However, some sorption of PFOS onto the cover and carrier geotextiles of the GCL is observed with in an average distribution coefficient, K_d ～2.22 ml/g for the GCL. Permeants containing different PFAS compounds are tested to assess their impact on the Geomembrane (GMB) - GCL interface transmissivity in composite liners. Results show PFAS concentrations up to 20 ppm had negligible impact on the GMB-GCL interface transmissivity. Lastly, the GCL specimens extracted from the diffusion tests are tested for hydraulic conductivity. No impact of PFAS is seen on the hydraulic conductivity of GCLs subjected to high applied loads, but a small increase is seen on the GCLs subjected to relatively low applied stresses.
Keywords: PFAS, Sorption, Diffusion, Geosynthetic clay liners, Interface transmissivity

Locating leaks in geomembrane-lined ponds using the electrical leak location method: Case histories

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Abstract: Results from seven years of electrical leak location methods applied to geomembrane-lined ponds to locate leaks are presented. Inspections were conducted on 195 projects designed with single (n = 74), double (n = 120), or triple (n = 1) liners. These projects are located in the U.S.A. (n = 159), Canada (n = 30), and Mexico (n = 11). All inspections were conducted on full ponds, which resulted in the detection and repair of 1230 leaks during the study period across an analyzed area of 322 ha. From 2015 to 2021, the average was 14 leaks/ha, with values ranging from 0 to 689 leaks/ha. The results reveal that larger inspected areas (greater than 2 ha) tend to have fewer leaks. 63% of projects had up to 5 leaks/ha. 15% of projects had more than 20 leaks/ha. The results of this study could influence landfill designers, operators, and environmental agencies in defining new practices for designing and operating geomembrane-lined ponds.
Keywords: Electrical leak location, Geomembrane, Lined pond, Leak

Optimum tack coat rate for different asphalt geosynthetic interlayers to achieve optimum shear bond strength

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Abstract: Designing geosynthetics for asphalt overlay is challenging due to the diversity of paving composites and paving geogrids available on the market. Challenges remains on the ideal product and tack coat to avoid debonding failure and to increase bonding quality. This research evaluates interface shear strength properties of geosynthetic-asphalt concrete specimens using seven geosynthetic interlayers tested under different tack coat rates based on asphalt retention of geosynthetics. Leutner shear tests were conducted on laboratory-prepared asphalt concrete specimens under different interface combinations. Index asphalt retention of paving geosynthetics depended on various parameters including geosynthetics type, geotextile backing, thickness and coating. The study suggests 100% of asphalt retention of the composite as design tack rate for paving geocomposites and paving geogrid composites with permanent porous fabric backing, while 220% asphalt retention as tack coat rate is suggested for geogrids. The optimum tack coat for reinforcement composites with light fabric backing falls between the optimum tack coat rates for composites and grids. The study also showed that the interface shear bond is a complex property and is not necessarily related to the fabric backing being permanent or temporary, the mass of the fabric backing, and the geosynthetics coating type and bitumen content individually.
Keywords: Geosynthetics, Bond strength, Pavement interlayers, Tack coat, Asphalt retention

Three-dimensional numerical analysis of large-scale horizontal square anchors in geogrid-reinforced sand

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Abstract: This paper presents a comprehensive three-dimensional numerical investigation of horizontal square anchors embedded in geogrid-reinforced sand. Prior experimental studies have demonstrated notable enhancements in anchor uplift capacity when placed below geogrid reinforcement in soil. However, these results are limited to small anchor plates tested in laboratory conditions with over-reinforced sand. In contrast, this study focuses on large field-scale anchors and explores the influence of anchor width, embedment depth, reinforcement size, stiffness, and tensile strength on uplift capacity. The findings reveal that the optimal size for geogrid reinforcement is three times the anchor width. A diminishing improvement in uplift capacity with increasing anchor width was observed. Additionally, deeper anchor embedment reduces the uplift capacity improvement in geogrid-reinforced sand. The geogrid reinforcement is found to be more efficient in the case of shallow anchors placed in loose sand. The major contribution of this paper lies in the response analysis of large anchors and providing a better understanding of the uplift mechanism in geogrid-reinforced sand.

Keywords: Geogrid, Anchors, Uplift capacity, Numerical modeling, Large anchors, Deep anchors

Long-term hydraulic conductivity of bentonite-polymer geosynthetic clay liners

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Abstract: Hydraulic conductivity tests were conducted on six bentonite-polymer (B–P) geosynthetic clay liners (GCLs) to investigate the effect of the slow cation exchange process and polymer elution on the long-term hydraulic conductivity of B–P GCLs. Tests were conducted up to 1458 days and as many as 443 pore volumes of flows (PVFs). Three B–P GCLs consist of linear polymer whereas the other three have crosslinked polymer. One sodium geosynthetic clay liner (Na–B GCL) was used as a control. Hydraulic conductivities (K_{6766}) of B–P GCLs (5.4×10^{-12} m/s to 3.7×10^{-11} m/s) per ASTM D6766 were approximately 2-3 orders of magnitude lower than that of Na–B GCL (2.3×10^{-9} m/s to 3.5×10^{-9} m/s). Tests were continued after hydraulic and chemical equilibrium to investigate the long-term hydraulic conductivity of GCLs. Hydraulic conductivities of GCLs had an increasing trend after hydraulic and chemical equilibrium. The ratio of K_L/K_{6766} for B–P GCLs was 3.5–14.7, whereas ratio of K_L/K_{6766} for Na–B GCLs was 1.0–1.7. Total organic carbon (TOC) tests results confirmed that polymer elution occurred during the entire permeation process. The higher ratio of K_L/K_{6766} for B–P GCLs was attributed to the effect of polymer elution.

Keywords: Geosynthetic clay liners (GCLs), Bentonite-polymer (B–P), Hydraulic conductivity, Polymer elution

Plastic shakedown limit of geosynthetic reinforced coarse-grained soil: Experiments and prediction model

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Abstract: This study aims to explore the accumulated behavior of reinforced coarse-grained soils through cyclic triaxial tests and to develop a prediction model for the plastic shakedown limit. Cyclic triaxial test results illustrate that the reinforced specimens, especially those incorporating geocells, demonstrate the lowest accumulated axial strain and the highest plastic shakedown limit when compared to unreinforced ones under identical cyclic loading. Additionally, the accumulated axial strain at the plastic shakedown limit for reinforced specimens is determined. This strain is then used to determine the additional confining pressure exerted by geogrid or geocell, employing a function proposed by Yang and Han. By integrating the additional confining pressure into the plastic shakedown criterion for unreinforced specimens, a prediction model for the plastic shakedown limit in reinforced specimens is ultimately established. The model's applicability and the accuracy of computed additional confining pressure values are validated using experimental data.

Keywords: Geosynthetic, Coarse-grained soil, Cyclic triaxial test, Accumulated axial strain, Plastic shakedown limit, Additional confining pressure

Influence of secondary reinforcements on the behavior of geosynthetic reinforced soil walls

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Abstract: This paper presents numerical simulations to investigate the influence of secondary reinforcements on the behavior of geosynthetic reinforced soil (GRS) walls under static loading. Simulations were conducted using a finite difference program to model an instrumented field GRS wall with secondary reinforcements. Simulated results are in good agreement with field measurements, including facing displacements, lateral soil stresses, and tensile strains of the primary and secondary reinforcement. A parametric study was then conducted to investigate the influences of secondary reinforcement length, backfill soil friction angle, and wall height on the static behavior of GRS walls with secondary reinforcements. Results indicate that the maximum facing displacement and the required reinforcement tensile force of primary reinforcements generally decrease with increasing secondary reinforcement length up to a critical value. The decreasing effect is more pronounced for GRS walls with lower soil friction angle and higher wall height. The K-stiffness method is overconservative for the calculation of required tensile force of primary reinforcements for GRS walls with secondary reinforcements, and the overestimation increases with increasing secondary reinforcement length. A design method that accounts for the influence of secondary reinforcements on the internal stability of GRS walls is provided.

Keywords: Geosynthetics, Geosynthetic reinforced soil, GRS wall, Secondary reinforcement, Required tensile strength

Predictive model for the interface bond strength of geosynthetic-reinforced asphalt layers

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Abstract: Innovation in the use of geosynthetics in roadway applications has resulted in the development of several different products, such as asphalt reinforcement geogrids and paving mats to minimize reflective cracks and limit moisture infiltration. For a proper performance of the reinforced asphalt systems, an adequate interface bond strength has proven to be crucial. However, the influence of the different paving interlayer characteristics, combined with tack coat types, and tack coat rates on the interface bond strength remains unclear. In this study, a comprehensive program of interface shear tests was conducted using Leutner shear device and laboratory-prepared reinforced asphalt specimens. The program involved eight geosynthetic types, two tack coat types, and three application rates. Results revealed that the geosynthetic type, tack coat type and rate, as well as the interactions among the parameters significantly affect interface bond strength. Multiple linear regression analysis indicated that geogrid aperture area, geosynthetic thickness, geotextile backing thickness, and the presence of bitumen coating are the most affecting parameters on bond strength. A predictive model for the bond strength based on geosynthetic parameters is presented. Based on literature results for specimens extracted from the field, the proposed predictive models were found to adequately predict interface bond strength.

Keywords: Geosynthetics, Asphalt layer Reinforced asphalt system, Interface bond strength, Geosynthetics parameters, Predictive model

Evaluation of dynamic soil stress distribution in GRS bridge abutments subjected to cyclic loading

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Abstract: Traffic-induced cyclic loading generates repetitive stresses and cumulative deformations on the GRS abutments, which affect the serviceability of GRS abutments. To evaluate the stress distribution of GRS abutments under cyclic traffic loading, this paper presents reduced-scale GRS abutment models constructed with sand backfill and geogrid reinforcements. The GRS abutment models were subjected to staged cyclic loading with different cyclic loading amplitudes to investigate the influences of cyclic loading amplitude, bridge superstructure load, and reinforcement vertical spacing on the dynamic soil stress distributions. The results indicate that the increase in residual stresses due to stress redistribution induced by cyclic loading is most pronounced at the top of the abutment, while there is little stress redistribution down to the foundation level. Increasing the static load of bridge superstructure or the amplitude of cyclic loading results in an increase in the incremental dynamic vertical soil stresses. Reinforcement vertical spacing does not significantly impact the incremental dynamic vertical soil stresses under cyclic loading, while the cyclic load has the most significant influence. Closer reinforcement vertical spacing could provide stronger lateral confinement, resulting in larger dynamic lateral soil stresses behind wall facing.

Keywords: Geosynthetic reinforced soil, Bridge abutment, Cyclic loading, Traffic loading, Soil stress