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摘要集

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目　录

Reexamination of traditional testing techniques for determining WRCs of woven geotextiles in full suction range

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Abstract: Woven geotextiles have been widely used in soil infrastructures for the reinforcement purpose. The hydraulic properties of a woven geotextile are not major reinforcement design parameters and the water retention capability of a woven geotextile is often ignored. The traditional testing techniques were designed for soils or nonwoven geotextiles, but not for woven geotextiles. Nowadays, a new type of woven geotextile with wicking fibers was developed which could be used for both drainage and reinforcement purposes. However, there are no proper testing techniques to determine the full-range water retention curve (WRC) for a woven geotextile, let alone for the wicking geotextile.

This paper aimed at proposing a proper testing technique to determining the full-range WRC for the wicking geotextile and to compare the water retention capability of wicking and non-wicking geotextiles. Firstly, the traditional testing techniques were re-examined to check the suitability for characterizing the WRCs of woven geotextiles whose pore size distributions were anisotropic. Secondly, a proper testing technique was proposed and the WRCs of different types of woven geotextiles were determined. Thirdly, the WRCs of wicking and non-wicking geotextiles were compared to demonstrate the advantages of the wicking geotextile to hold and transport water under unsaturated conditions. Finally, the effect of wicking fiber on the water retention capability of the wicking geotextile was quantified.

Keywords: Woven geotextiles, Testing techniques, Water retention curve, Wicking geotextile, And unsaturated condition

Uncertainties in determining the responses of reinforced flexible pavements using in-situ tests

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Abstract: A 225m long full-scale testing lane was constructed at a local road in Australia to evaluate the performance of the flexible pavements over a weak soft subgrade. The pavements were reinforced with three types of geosynthetic products: High-density polyethylene (HDPE) geogrid, HDPE geocomposite and fibreglass geocomposite. The road was divided into 15 sections with different configurations such as the thickness of the base course, reinforcement types and locations, and base course materials. A series of in-situ tests were conducted on each section to compare the behaviour of the pavement structures, such as the moduli of the subgrade, base course and asphalt layer. The comparison shows that there is a large variation in the properties of the structures and great uncertainties in determining the properties even within the sections with the same configuration. When the base course is weaker, the FWD tests may be able to detect the effect of the reinforcements below the asphalt seal layer. Smaller plates are recommended when determining the modulus of thinner base course layers using FWD or LWD tests to minimize the influences from the subgrade.

Keywords: Pavement, Full-scale field trial, Geosynthetic-reinforced base course, Geosynthetic-reinforced asphalt

Degradation of HDPE, LLDPE, and blended polyethylene geomembranes in extremely low and high pH mining solutions at 85 °C

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Abstract: The durability of five 1.5-mm thick geomembranes (GMBs) is investigated in pH 0.5 and 13.5 synthetic mining solutions using immersion tests. Two high density polyethylene (HDPE), two linear low density polyethylene (LLDPE), and one blended polyethylene (BPO) GMBs are investigated at 85 °C for incubation durations of 4.5–6.5 years. It is shown that the degradation of all five GMBs in the high pH solution is faster than in the low pH solution. In the pH 0.5 solution, one of the HDPEs and the BPO GMBs exhibited polymer degradation before or at the time of the depletion of their antioxidants. In pH 13.5, four out of the five GMBs exhibited degradation and followed the conceptual three-stage degradation model until nominal failure. However, there is no correlation between the long-term performance of these GMBs and their resin type or their initial properties since one of the examined LLDPEs outperformed all the higher density/crystallinity GMBs with higher initial properties while the other LLDPE did not perform well. Thus, when selecting a GMB for a desired application, the relative performance of different candidate GMBs can be only assessed using immersion tests using the solutions expected in the field.

Keywords: Geosynthetics, Geomembranes, HDPE, LLDPE, Blended polyolefin, Degradation, Heap leach pads, Mining, Low pH, High pH, Stress crack resistance, Morphology, HALS

Rational design method for bituminous pavements reinforced by geogrid

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Abstract: Geosynthetics have been a reinforced solution for pavement structures for more than 80 years and could be effective in extending its service life. There is a lack of consolidated design methods for pavement with this reinforcement. Therefore, this work aims at proposing a new rational design approach for reinforced structures based on the French design method. In this approach, the geogrid contribution was included by improving the fatigue and rutting properties of some layers, using coefficients named k_{maj} and k_{maj_z}. Three hypotheses were considered concerning the condition of an old bituminous layer remaining from rehabilitation works. The first one considered this layer in healthy condition to simulate a new reinforced structure. The second one considered it as cracked and the third one as disintegrated to simulate the design for rehabilitation. Two placement positions and two geogrid-interface conditions (bonded and not bonded) were analyzed. The results indicated that the geogrid was most effective in a completely deteriorated structure and it should be placed in the lowest possible position in the bound layers. This method can be used for any geogrid position within the structure. Lastly, the reinforcement by geogrid allows a reduction of the thickness of the layer above it.

Keywords: Geogrid, Reinforcement, Design method, Pavement, Bituminous mixtures,
Subject classification codes

Quantification of geogrid lateral restraint using transparent sand and deep learning-based image segmentation

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Abstract: An experimental technique is presented to quantify the lateral restraint provided by a geogrid embedded in granular soil at the particle level. Repeated load triaxial tests were done on transparent sand specimens stiffened with geosynthetic inclusions simulating geogrids. Images of laser illuminated planes through the specimens were segmented into particles using a deep learning-based segmentation algorithm. The particle outlines were characterized in terms of Fourier shape descriptors and tracked across sequentially captured images. The accuracy of the particle displacement measurements was validated against Digital Image Correlation (DIC) measurements. In addition, the method's resolution and repeatability is presented. Based on the measured particle displacements and rotations, a state boundary line between probable and improbable particle motions was identified for each test. The size of the zone of probable motions was used to quantify the lateral restraint provided by the inclusions. Overall, the tests results revealed that the geosynthetic inclusions restricted both particle displacements and rotations. However, the particle displacements were found to be restrained more significantly than the rotations. Finally, a unique relationship was found between the magnitude of the permanent strains of the specimens and the area of the zone of probable motions.

Keywords: Transparent soil, Lateral restraint, Deep learning, Segmentation, Triaxial testing, Geogrid

New approach to junction efficiency analysis of hexagonal geogrid using digital image correlation method

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Abstract: Geosynthetics are commonly used in many civil engineering applications. At the same time, intensive development of these materials is being carried out. Therefore, it becomes more and more important to correctly determine the mechanical parameters of geosynthetics in laboratory tests. This is especially important for more complicated hexagonal geogrids. This article presents the results of the laboratory research carried out to evaluate the junction efficiency of hexagonal geogrid under static load by analyzing deformations of geogrid junctions and ribs. A new approach to determination the efficiency is given by the newly defined strain junction efficiency coefficient based on the true principal strains. In the laboratory tests the digital image correlation (DIC) method was used. This method allowed for the determination of displacements and strains of geogrid specimens in any direction and at any point. The results of the conducted research and analysis indicate that the proposed innovative junction effectiveness assessment method enables a better presentation of the geogrid performance at different levels of tensile load. In addition to the parameters given in the technical approval for this material, the proposed new strain junction efficiency coefficient can be an effective parameter for evaluating hexagonal geogrid performance at different strain levels.

Keywords: Hexagonal geogrid, Geosynthetic, Digital image correlation (DIC), Tensile testing, Geogrid junction efficiency

Experimental study of a 3D printed geogrid embedded with FBG sensor for reinforcement of subgrade with underlying cave

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Abstract: Road construction in karst areas is a challenging task. Combining the advantages of geosynthetics and fiber Bragg grating (FBG), this paper creatively presents a new type of FBG-3D printed geogrid, which allows reinforcement and accurate deformation monitoring. A series of model tests were carried out to investigate the mechanical and deformation characteristics of the subgrade with underlying karst cave reinforced by FBG-3D printed geogrid. The experimental results indicated that the fully coordinated deformation between FBG sensor and geogrid was successfully achieved by 3D printing technology, and the relationship between fiber wavelength and strain was obtained. The existence of cave had an adverse effect on the subgrade, but the FBG-3D printed geogrids effectively improved the bearing capacity and footing settlement, and the reinforcement effect increased with the decrease of geogrid spacing. In the cyclic loading experiments, the earth pressure inside the subgrade reinforced by geogrid changed as a half-sine wave in each cycle. The FBG sensors accurately measured the strain change inside the subgrade, and the data showed that the deformation of measuring point above the cave model was the largest. The research conclusions provide important basic data for the construction and monitoring of highway and geotechnical engineering projects.
Keywords: Fiber Bragg grating, Geogrid, Model test, Underlying cave, Cyclic loading

Hydrodynamic assessment of bentonite granule size and granule swelling on hydraulic conductivity of geosynthetic clay liners

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Abstract: Flow in an idealized geosynthetic clay liner (GCL) containing bentonite comprised of equisized and equispaced square granules was simulated using a hydrodynamic model to quantitatively evaluate the premise that the hydraulic conductivity of GCLs diminishes as the bentonite granules hydrate and swell into adjacent intergranular pores, creating smaller and tortuous intergranular flow paths. Predictions with the model indicate that hydraulic conductivity decreases as granules swell and intergranular pores become smaller, and that greater granule swelling during hydration is required to achieve low hydraulic conductivity when the bentonite is comprised of larger granules, or the bentonite density is lower (lower bentonite mass per unit area). Predictions made with the model indicate that intergranular pores become extremely small (<1 μm) as the hydraulic conductivity approaches 10^{-11} m/s. These outcomes are consistent with experimental data showing that GCLs are more permeable when hydrated and permeated with solutions that suppress swelling of the bentonite granules, and that the hydraulic conductivity of GCLs with bentonite having smaller intergranular pores (e.g., GCLs with smaller bentonite granules, more broadly graded particles, or higher bentonite density) is less sensitive to solutions that suppress swelling.

Keywords: Geosynthetic clay liner, Hydraulic conductivity, Bentonite, Granules, Swelling

Recycling dredged mud slurry using vacuum-solidification combined method with sustainable alkali-activated binder

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Abstract: Dredged sediments with high water content is difficult to be treated and beneficially reused because of their poor engineering characteristics. To treat those slurry, this paper introduces a novel mechanical-chemical combined method, i.e., vacuum-solidification (VS) combined method, and investigates its performance in dewatering and strength improvement. Corresponding model tests using vacuum-only preloading method and binder-only solidification method, respectively, were conducted. Ground granulated blast-furnace slag, an industrial by-product, activated by hydrated lime, magnesium oxide or carbide slag was used as the binder in the proposed method. The mass of discharged water due to vacuum consolidation was measured during the model test. Soil samples were taken after vacuum preloading for unconfined compression test, permeability test, X-ray diffraction, scanning electron microscopy and mercury intrusion porosimetry to analyze the strength development, hydraulic and microstructural properties of the treated soil. The results indicate that the VS combined method exhibits a remarkable enhancement in both volume reduction efficiency and the strength improvement effectiveness. The type and content of activators have an obvious influence on the performance of the combined method. This study preliminarily revealed the mechanism and effect of using the VS combined method with alkali-activated GGBS as binder to treat high water content dredged mud.
Keywords: Dredged sediments, Mechanical properties, Microstructure, Alkali-activated GGBS, Vacuum preloading, Model test

Prediction of non-woven geotextiles' reduction factors for damage caused by the drop of backfill materials

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Abstract: The need for sustainable solutions in geotechnical works has encouraged the investigation of recycled construction and demolition wastes (RCDW) as backfill material. The possible damages caused by the launching (dropping) process of this "new" backfill material (RCWD) must be quantified for its combined use with geosynthetics. This study evaluated the influence of the backfill's grain-size distribution and the geotextile's mass per unit area in the damages caused by the launch of RCDW material and aimed to provide a prediction equation of the reduction factors. Five RCDW materials were launched from 1.0-m and 2.0-m height over five non-woven polyester needle-punched geotextile and specimens were exhumed to be tested under tensile. Databases were created with the results and subjected to machine learning to obtain a prediction equation for the reduction factor's values. The results show that the damages caused by the dropping height are complex. The 1.0-m increase in the drop height and the increase in the geotextile's mass per unit area cannot be associated with an increase in the damage. The geotextiles were more affected by the backfills with uniform gradation. A reduction factor's prediction equation is presented considering the three variables investigated (geotextile, drop height and backfill material classification). The artificial neural network is a more interesting solution than multiple linear regression since it does not possess several application criteria and provides more accurate predictions.

Keywords: Geosynthetics, Damage, Drop height, Grain-size distribution, Artificial neural network, Recycled aggregates

Hydraulic design of granular and geocomposite drainage layers in pavements based on demand-capacity modeling

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Abstract: In this paper, a new approach based on the demand-capacity model is developed for hydraulic design of granular and granular-cum-geocomposite drainage layers in pavements. The demand is given by the intensity-duration curve obtained from the Intensity-Duration-Frequency curve, which is geographic location specific and corrected for climate change. The capacity curve corresponds to critical infiltration rates and critical durations for a drainage layer which is influenced by the hydraulic and geometric characteristics. The design is acceptable if the capacity curve exceeds the demand curve. The design framework is illustrated for typical geometries of highway pavements with three granular gradations and three geocomposites. Based on the developed framework, hydraulic equivalence is defined and evaluated for the drainage layers. The permissible reduction of granular layer thickness for hydraulic equivalence is evaluated if geocomposite is embedded in the subbase layer of pavements. For an optimum gradation based on hydraulic and structural characteristics, the thickness of granular layer with geocomposite could be reduced by 30% compared to the granular layer without geocomposite, which showed similar hydraulic performance. The significance of drainage layer thickness with geocomposite is shown based on the demand for storage to satisfy the drainage requirement for rainfall events of high intensities and long durations.

Keywords: Drainage, Subbase, Geosynthetics, Geocomposites, Geotextiles, IDF

Morphological insights into the liquefaction and post-liquefaction response of sands with geotextile inclusions using drained constant volume simple shear tests

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Abstract: The present study aims to explore and bring out morphological insights into the prior-liquefaction, liquefaction, and post-liquefaction response of sands with geotextile inclusions. For this, a series of multi-stage drained constant volume simple shear tests with different cyclic stress ratios (*CSR* ranging from 0.1125 to 0.225) and different frequencies (*f* of 0.2 and 1.0 Hz) were carried out on completely dry specimens constituted with granular materials of three distinct grain morphologies (rounded, subrounded, and angular) reinforced with a nonwoven geotextile. The study also consists of morphological quantifications through image analysis algorithms and direct shear tests on sand-geotextile interfaces. Test results revealed that the inclusion of geotextile increased the liquefaction resistance and post-liquefaction shear strength of all the materials, irrespective of their particle morphology. However, the beneficial effects are more in the case of specimens constituted with angular particles. The effect of loading frequency on the response is also established. The interlocking and ploughing tendency of the angular particles leads to the mobilization of the maximum tensile strength of geotextile, which enhances the additional confinement and prevents the lateral movement of particles, thereby providing the maximum benefit.
Keywords: Geotextile, Liquefaction, Particle morphology, Cyclic simple shear test, Image analysis

Experimental study on the load bearing behavior of geosynthetic reinforced soil bridge abutments on yielding foundation

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Abstract: This paper presents an experimental study of the load bearing behavior of geosynthetic reinforced soil (GRS) bridge abutments constructed on yielding clay foundation. The effects of two different ground improvement methods for the yielding clay foundation, including reinforced soil foundation and stone column foundation, were evaluated. The clay foundation was prepared using kaolin and consolidated to reach desired shear strength. The 1/5-scale GRS abutment models with a height of 0.8 m were constructed using sand backfill, geogrid reinforcement, and modular block facing. For the GRS abutments on three different yielding foundations, the reinforced soil zone had relatively uniform settlement and behaved like a composite due to the higher stiffness than the foundation layers. The wall facing moved outward with significant movements near the bottom of facing, and the foundation soil in front of facing showed obvious uplifting movements. The vertical stresses transferred from the footing load within the GRS abutment and on the foundation soil are higher for stiffer foundation. The improvement of foundation soil using geosynthetic reinforced soil and stone columns could reduce the deformations of GRS abutments on yielding foundation. Results from this study provide insights on the practical applications of GRS abutments on yielding foundation.

Keywords: Geosynthetic, Geosynthetic reinforced soil, GRS abutment, Bridge abutment, Yielding foundation, Reinforced soil foundation, Stone column foundation

Attenuation performance of geosynthetic sorption sheets against arsenic subjected to compressive stresses

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Abstract: The attenuation layer method has been considered an effective countermeasure to deal with excavated soils and rocks containing geogenic toxic elements like arsenic (As). The geosynthetic sorption sheet is a geosynthetic product that can be employed in the attenuation layer method applications as a sorption material. The sorption sheets used in the attenuation layer will be inevitably subjected to overburdened loads in the field. In this study, laboratory column experiments are conducted to evaluate the attenuation performance of the geosynthetic sorption sheets coated with hydrotalcite as sorbent against As under different overburden pressure conditions (10, 100, and 200 kPa). Experimental results showed that the cumulative sorption masses of As for 200 kPa cases are approximately 10.5–13.3 times greater than that for 10 kPa cases. Microstructure characterizations of the geosynthetic sorption sheet before and after loading were also detected. More compacted and involved fiber configuration as a result of higher loading produces a more effective contact between As solution and hydrotalcite. The presence of partial dissolution of hydrotalcite is confirmed through the chemical analysis of effluent. However, hydrotalcite would gradually become stable during continuous use.

Keywords: Attenuation layer method, Arsenic, Geosynthetics, Hydrotalcite, Sorption, Compressive stress