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摘要集

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Performance improvement of ballasted railway tracks using three-dimensional cellular geoinclusions

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Abstract: Three-dimensional (3D) cellular inclusions such as geocells and scrap rubber tyres improve the engineering properties of the infill materials by providing all-around confinement. Although the 3D geoinclusions possess immense potential in the railway industry, their application is still limited due to a lack of adequate techniques to evaluate the magnitude of improvement provided by these artificial inclusions. This article presents an innovative computational approach to evaluate the effectiveness of 3D cellular geoinclusions in improving the performance of ballasted railway tracks. The proposed method is an integrated approach that combines the additional confinement model with the geotechnical rheological model for a railway track. The methodology is applied to an open track-bridge transition, and the results revealed that the geoinclusions substantially reduce the differential settlement. However, the magnitude of improvement depends on the opening size, placement location within the track and material used to manufacture the cellular inclusions. Moreover, the magnitude of settlement reduction also depends on the axle load and subgrade soil properties. The proposed methodology can assist the railway engineers in assessing the efficacy of 3D inclusions in improving the performance of railway tracks and help select the most appropriate material, size, and location of reinforcement for deriving maximum benefits.

Keywords: Geosynthetics; Cellular geoinclusions; Railway tracks; Rheological model; Settlement; Transition zone

Pullout testing and Particle Image Velocimetry(PIV) analysis of geogrid reinforcement embedded in granular drainage layers

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Abstract: The paper investigates the feasibility of using fine-grained soil as backfill material of geosynthetic-reinforced walls and slopes, through a laboratory study on pullout behavior of geogrids in granular layers. A series of pullout tests was carried out on an HDPE uniaxial geogrid in thin sand and gravel layers that were embedded in clay specimens.

Aside from different soil arrangements, the influences of moisture content and overburden pressure on the geogrid pullout behavior is assessed and discussed. The tests were carried out at four different gravimetric water contents(GWC) on the dry and wet sides of the clay optimum moisture content(OMC), and overburden pressure values within the range σ_v = 25–100 kPa. Particle Image Velocimetry(PIV) was used to capture digital images during the tests, which were processed to help with the interpretation and improved understanding of the soilgeogrid interactions at different GWC values. Results show that embedding geogrid reinforcement in layers of sand or gravel can significantly increase the pullout resistance in an otherwise moist clay backfill, and this improved pullout efficiency is greater at higher overburden pressures. The improvement in pullout capacity was observed in clay specimens compacted at both the dry and wet sides of the OMC.

Keywords: Pullout; Geogrid; PIV; Granular layers; Drainage layers; Clay; Geosynthetic-reinforced walls and slopes

Evaluation of drainage coefficients for 2D and 3D-geocomposite embedded subbase layers

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Abstract: Drainage is one of the primary factors considered during the design of pavements. This paper presents the data from large-scale permeameter tests conducted on pavement sections to evaluate the drainage characteristic of geocomposite(GC) embedded subbase layers with and without traffic load. Two types of GCs with 2D core and 3D core were considered to enhance the drainage properties of a subbase layer. The large-scale permeameter test results indicate that the in-plane drainage capacity of the subbase layer improved by about 12 and 22 fold, respectively, for 2D-GC and 3D-GC. The GCs can drain infiltrated water at a rate of more than 300 m/day(inplane permeability), even if the thickness of the subbase layer is reduced by about 50%. Over the pavement’s design life, long-term in-plane permeability is estimated to decrease by 65–70%. It is estimated that the GC embedded subbase layers could drain off 50% of the infiltered water from a two-lane pavement system within 2h, even after reducing the layer thickness by 100 mm. A set of new drainage coefficients for geocomposite improved subbase layers(m_{3c}) were proposed based on the American Association of State Highway and Transportation Officials drainage quality guidelines.

Keywords: Geocomposite; Subbase layer; Large-scale permeameter; Drainage coefficients; Transmissivity

Improved design criteria for nonwoven geotextile filters with internally stable and unstable soils

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Abstract: In geotextile filtration, the soil fines are either accumulated near the interface, clogged, or washed out, which primarily depends on the grain size distribution(GSD) of soil and the constriction size distribution(CSD) of geotextile. Also, the movement of fines significantly affects the flow capacity of geotextile. Currently, the retention requirement is satisfied based on representative grain and opening sizes, whereas the hydraulic conductivity and clogging requirements are satisfied considering the properties of virgin geotextile. This paper presents a probabilistic retention criterion considering the grain and constriction sizes as random variables. The influence of geotextile thickness is incorporated into the criterion by considering the number of geotextile constrictions in a filtration path. A theoretical approach to predict CSD is presented if the measured data is unavailable. For hydraulic conductivity and clogging requirements, a criterion is presented considering the expected partial clogging of geotextile, which is predicted based on the semi-analytical approach. The limit states for the developed criteria are evaluated based on the wide range of experimental data from the current study and published literature. The developed design criteria are applicable to internally stable and unstable soils, which offers an improvement in design compared to the existing criteria in practice.

Keywords: Filtration; Nonwoven geotextile; Clogging; Retention; Hydraulic conductivity

Reinforcement load in geosynthetic-reinforced pile-supported model embankments

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Abstract: The stress conditions of geosynthetic reinforcements(GRs) are crucial in achieving the accurate serviceability design of geosynthetic-reinforced pile-supported(GRPS) embankments. However, the sensitivity of load distribution to the settlement process has been reported in geosynthetic-reinforced embankment overlying cavities. In this study, a three-dimensional model embankment was used to perform experiments and evaluate the load acting on the GR. A flexible pressure-mapping sensor was introduced to investigate the pressure distribution for two types of supporting conditions: partitioned displacement by multiple movable trapdoors and even trapdoor settlement underneath different subsoil materials. The results showed that the load on the GR was concentrated on the strip areas between adjacent pile heads along with the settlement. The measured load on the GR strip area was related to the settlement process and finally exhibited a U-shaped distribution after detachment from the support underneath. The soil arch height in the subgrade continuously increased with the settlement; meanwhile, the pile head load increased rapidly at first and then decreased slightly or remained stable depending on the foundation support stiffness. For both types of settlement behaviours, soil arching exhibited stress history-related characteristics that influence the load transfer in GRPS embankments.

Keywords: Geosynthetics; Embankments; Soil-geosynthetic interaction; Soil arching; Trapdoor

Research on the protection of expansive soil slopes under heavy rainfall by anchor-reinforced vegetation systems

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Abstract: An anchor-reinforced vegetation system(ARVS) is a new type of flexible slope protection system. ARVSs are composed of vegetation, anchors and high-performance turf reinforcement mats(HPTRMs) and can maintain the stability of expansive soil slopes while producing superior ecological effects. Through in situ comprehensive monitoring and comparative analyses, we systematically discuss the impact of heavy rainfall on ARVS-protected expansive soil slopes during the local wet season in Nanning. The results show that during the local wet season, the soil temperature and water content in vegetation-covered areas are lower than those in bare areas. The soil temperatures in different areas on the expansive soil slopes decrease with increasing depth. The ARVSs significantly affected the regulation of water transport and soil temperature, which limited soil deformation in different directions. The subsequent heavy rainfall would cause greater deformation of the expansive soil slope when less antecedent rainfall fell. Low-intensity and long-duration heavy rainfall events have greater negative impacts on expansive soil slopes than high-intensity and short-duration rainfall events. Under the action of severe rainfall-evaporation, expansive soil slopes protected by ARVSs can maintain stability.

Keywords: Expansive soil; Ecological protection; Heavy rainfall; Field test; Monitoring research

Numerical investigation on hydraulic and gas flow response of MSW landfill cover system comprising a geosynthetic clay liner under arid climatic conditions

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Abstract: Municipal solid waste(MSW) landfill cover systems are designed to minimize the infiltration of rainwater into waste and to mitigate the biogas emissions to the atmosphere. In the present study, the efficacy of such a landfill cover system consisting of a Geosynthetic clay liner(GCL) in mitigating the hydraulic flow and gas emissions under arid climatic conditions was investigated critically. For this purpose, the water retention curve(WRC), hydraulic conductivity function, and gas flow characteristics of the chosen GCL were studied through experimental methods in the laboratory. The unsaturated transient state seepage analysis utilizing coupled hydraulic and gas flow mechanisms was performed in the study to assess the performance of the cover system. The results obtained from the experiments were used as input parameters. The effect of drying/desiccation and the selfhealing nature of GCL due to climatic changes were also analyzed by exposing the GCL directly to the climatic boundary for one year. It was observed that the GCL present in the chosen cover system effectively functions as a hydraulic barrier in arid climatic conditions. However, during the summer and winter seasons, an increase in gas flow from 0.02 g/h/m^2 to 24.7 g/h/m^2 was observed, probably due to the drying and desiccation of GCL. Interestingly, due to the self-healing nature of the GCL, gas flow through the cover system was substantially reduced to 0.02 g/h/m^2 during the rainy season. The effect of drying was more pronounced when the GCL was exposed to the climatic condition, leading to an early gas breakthrough and an increase in gas flow from 0.02 g/h/m^2 to 957 g/h/m^2. The percolation through the cover system remains considerably low throughout the year, mostly due to the unsaturation and low hydraulic conductivity in GCL. A cumulative percolation close to 0.1 m^3 was observed at the end of one year in arid climatic conditions.

Keywords: Cover system; Geosynthetic clay liner; Hydraulic behavior; Gas flow behavior; Climatic conditions; Numerical coupled model

Permeability prediction in geotextile envelope after chemical clogging: a coupled model

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Abstract: This study develops a coupled model of chemical clogging and permeability coefficient of geotextile envelope. Based on the distribution characteristics of crystal precipitates on geotextile envelope and their influence on the permeability coefficient, a permeability coefficient model of an actual geotextile envelope that considers the overlapping effect is developed. Then, the densification effects of geosynthetic fiber hypothesis and the filter cake effect hypothesis are proposed to simulate the processes of increasing fiber diameter after crystal precipitation and the accumulation of crystal precipitates on the surface of geotextile envelope. The crystal precipitation module and permeability coefficient module are coupled, and their experimental values are used to confirm the availability of the model. Results indicate the satisfactory performance of the model. In addition, the parameter sensitivity analysis and trend prediction show that the saturation index SI and solution flow rate V are the main factors that affect the chemical clogging and permeability of geotextile envelope. When the solution conditions are not considered, the sensitivity of geotextile envelope parameter d_f increased with the amount of precipitation in crystal precipitation. When the pores of the geotextile envelope are completely clogged, the permeability coefficient of the geotextile envelope will drop sharply, then decline slowly.

Keywords: Geosynthetics; Chemical clogging; Permeability coefficient; Crystal precipitation; Coupled model

Prediction of pullout interaction coefficient of geogrids by extreme gradient boosting model

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Abstract: Geogrids embedded in fill materials are checked against pullout failure through standard pullout testing methodology. The test determines the pullout interaction coefficient which is critical in fixing the embedment length of geogrids in mechanically stabilized earth walls. This paper proposes prediction of pullout interaction coefficient using data driven machine learning regression algorithms. The study primarily focusses on using extreme gradient boosting (XGBoost) method for prediction. A data set containing 220 test results from the literature has been used for training and testing. Predicted results of XGBoost have been compared with the results of random forest (RF) ensemble learning based algorithm. The predictions of XGBoost model indicates 85% accuracy and that of RF model shows 77% accuracy, indicating significantly superior and robust prediction through XGBoost above RF model. The importance analysis indicates that normal stress is the most significant factor that influences the pullout interaction coefficients. Subsequently pullout tests have been performed on geogrid embedded in four different fill materials at three normal stresses. The proposed XGBoost model gives 90% accuracy in prediction of pullout interaction coefficient compared to laboratory test results. Finally, an open-source graphical user interface based on the XGBoost model has been created for preliminary estimation of the pullout interaction coefficient of geogrid at different test conditions.

Keywords: Geogrid; Pullout resistance; Machine learning; Extreme gradient boosting; Random forest

Pullout behavior of a bearing polymeric strap under monotonic and cyclic tensile loads

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Abstract: Soil-reinforcement interaction consists of three factors including frictional resistance, shear strength of the soil and passive resistance. In the ordinary polymeric strap (PS) reinforcement, only frictional resistance contributes to pullout resistance. In this study, in order to develop passive resistance in the soil, a number of angles as transversal elements were attached to PS reinforcement, which is called bearing polymeric strap (BPS). The postcyclic pullout behaviour of the BPS is evaluated using a large-scale pullout apparatus adopting multistage pullout (MSP) test and one-stage pullout (OSP) test procedures. The results show that a spacing-to-high ratio of angles equal to 3.33 gives the maximum pullout resistance. MSP tests were performed on the BPS with an optimum arrangement to evaluate the influence of various factors including cyclic tensile load amplitude, load frequency and number of load cycles, and also the influence of vertical effective stress on the pullout resistance and the peak apparent coefficient of friction mobilized at the soil-BPS interface. Moreover, for BPS system with a single isolated transverse member, the bearing capacity factor N_q was calculated using equations based on three failure modes and it was found that the N_q calculated in the punching shear failure mode makes the best prediction.

Keywords: Pullout; Polymeric strap; Geosynthetics; Multistage pullout test; Cyclic tensile load

A simplified method for assessing the serviceability performance of geosynthetic reinforced and pile-supported embankment

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Abstract: A simplified method for assessing the serviceability performance of geosynthetic reinforced and pile-supported embankment is presented, where the subsoil consolidation is introduced remaining compatible with the development of soil arching and the reinforcement sag. A piecewise function of the ground reaction curve is developed and used to quantify the arching efficiency. The link between the arching evolution and the subsoil consolidation is then established through the load-carrying equilibrium in the area between piles together with the tensile membrane theory. The reaction of the subsoil is described using the 1-D consolidation theory where the stress history is considered. A parametric study is performed to demonstrate the serviceability performance of a geosynthetic reinforced and pile-supported embankment. The serviceability design of the geosynthetic reinforced and pile-supported embankment is achieved with the proposed method which offers an approach to estimate the time consumed and the subsoil settlement required to achieve a service state.

Keywords: Pile-supported embankment; Reinforcement; Ground reaction curve; Consolidation of subsoil; Serviceability performance

A comparison of shear stress estimation methods for a single geobag on a rough bed

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Abstract: There are several methods for estimating bed shear stress in the literature, but comprehensive comparisons among them are limited and under specific conditions. This study compared these methods first on a bare smooth bed, and then for a single geobag on a rough bed in the interest of determining the stability of geobags used in riverbank protection structures. The geobag was filled with cement or sand and tested under different open channel flow conditions. The turbulent kinetic energy method appeared to best represent the local bed shear stress on the geobag when using the newly calibrated proportionality constants. The Reynolds stress method via extrapolation was relatively unaffected by changes to the geobags shape and measurement locations, suggesting this method inadequately represents the local bed shear stress. The Patel method and the universal law of the wall method failed to represent local bed shear stress in the rough bed cases due to instrument limitations and the breakdown of the law of the wall. This study highlights the impact of different methods on the bed shear stress estimation.

Keywords: Local bed shear stress; Geobag; Shear stress estimation; Erosion protection; Open channel flows

Analyzing the influence of facing batter on reinforcement loads of reinforced soil walls under working stress conditions

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Abstract: The level of reinforcement loads in a reinforced soil retaining wall is important to its satisfactory operation under working stress conditions since it basically determines the wall deformation. Consequently, proper estimation of the reinforcement load is a necessary step in the service limit-state design of this type of earth retaining structures. In this study, a force equilibrium approach is proposed to quantify the influence of facing batter on the reinforcement loads of reinforced soil walls under working stress conditions. The approach is then combined with a nonlinear elastic approach for GRS walls without batter to estimate the reinforcement loads neglecting toe restraint. The approximate average mobilized soil strength in the retaining wall is employed in the force equilibrium analysis. The predictions of reinforcement loads by the proposed method were compared to the experimental results from four large-scale tests. It is shown that the proposed semianalytical approach has the capacity to reproduce the reinforcement loads with acceptable accuracy. Some remaining issues are also pinpointed.

Keywords: Geosynthetics; Reinforced soil retaining wall; Facing batter; Reinforcement load; Semianalytical method