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摘要集

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Structural damage and shear performance degradation of fiber–lime–soil under freeze–thaw cycling

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Abstract: The freeze–thaw cycling damages the soil structure, and the shear performance of soil are degraded. A series of tests on lime–soil(L–S) and fiber–lime–soil(F–L–S), including freeze–thaw test, the triaxial compression test, nuclear magnetic resonance (NMR) test and scanning electron microscope (SEM) test, were completed. The test results showed that fiber reinforcement changed the stress–strain behavior and failure pattern of soil. The cohesion and internal friction angle of soil gradually decreased with the increase of freeze–thaw cycles (F–T cycles). The pore radius and porosity of soil increased, while the micro pore volume decreased, and the small pore volume, medium pore volume and large pore volume increased, and the large pore volume had a little variation after 10 F–T cycles. The number of pores of F–L–S was less than L–S, demonstrating that the addition of fiber helped to reduce the pore volume. The interweaved fibers limited the development and the connection of cracks. By means of the spatial restraint effect of fiber on the soil and the friction action between fiber and soil, the shear performances and freeze–thaw durability of F–L–S better were than that of L–S.

Keywords: Freeze–thaw cycling; Fiber soil; Triaxial compression test; NMR test; SEM test

Model test of clogging effects on composite foundation of geosynthetic-encased steel slag column

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Abstract: Experiments were conducted to study the performance of geosynthetic encased steel slag column with a diameter of 150 mm and a length of 900 mm in a soft clay foundation. The effect of clogging was simulated by mixing the slag with 10% and 20% fines. The measured bearing capacity of the column treated foundation is notably increased to about 10 times than that of the untreated foundation, and is seldom affected by the intrusion of fines. The vertical stress within the soil at column tip attenuates to 85% and 60% of the stress close to the ground surface for the column with no fines and 20% fines, respectively. For the cases with fines content of 10% and 20%, the maximum excess pore pressure is in average 5% and 10% greater than the case without fines, respectively, and the dissipation rate of excess pore pressure is in average 18% and 24% slower than the case without fines. The column treated foundation prevents the water ponding on the surface as that occurs for the untreated foundation. The undrained shear strength of the soil close to the column increases by 18% at the depth of 100 mm, and 6% at the depth of half column, regardless of the fines.

Keywords: Geosynthetic encased column; Clogging; Soft clay foundation; Excess pore pressure

Short- and long-term behavior of EPS geofoam in reduction of lateral earth pressure on rigid retaining wall subjected to surcharge loading

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Abstract: Retaining walls are subjected to dead loads from backfill and adjacent structures, live loads and other loads from the vicinity of the structure. Retaining walls need to withstand earth pressure generated from above mentioned loads satisfactorily throughout their service life. Lateral earth thrust on retaining walls can be minimized by placing a compressible inclusion, such as, EPS geofoam, between the backfill and retaining wall. The present study is aimed at understanding both short- and long-term influence of EPS geofoam on surcharge induced lateral earth pressures on retaining walls through 1-g model studies. Four densities of geofoam in the range of 10–25 kg/m^3 and three thicknesses of geofoam in the range of 25–75 mm were used in the present study. Lateral earth pressure at several locations along the height of the wall were monitored using earth pressure cells. Geofoam compression and backfill settlements under the surcharge load were also quantified using image analysis. From the series of model tests, it was observed that with the use of geofoam, lateral earth pressure on retaining wall was reduced under both short- and long-term loading conditions. However, higher reduction was observed under long-term loading.

Keywords: Retaining wall; EPS Geofoam; Isolation efficiency; Geofoam compression; Short-term; Long-term tests

Effects of seismic amplification on the stability design of geosynthetic-reinforced soil walls

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Abstract: Many researches of geosynthetic-reinforced soil (GRS) walls under earthquakes demonstrate seismic acceleration amplification along the wall height. Current design methods of GRS walls often neglect the amplification effect on seismic stability and could yield an unconservative result. A pseudo-static method based on limit equilibrium (LE) analyses is carried out to calculate the distribution of required tension of seismic GRS walls following a topdown procedure. The connection load between the reinforcement and facing is correspondingly determined by the front-end pullout capacity. The approach assumes that the horizontal seismic acceleration coefficient varies linearly from the bottom to the top of GRS walls. The obtained results of the required tension involving the seismic amplification are in good agreement with other LE results in previous studies. Parametric studies are conducted to investigate the effects of horizontal seismic coefficient, primary and secondary reinforcement lengths and wall batter on the seismic stability of GRS walls. The seismic amplification yields more required reinforcement tension, significantly for the lower layers of the GRS wall subjected to strong earthquakes. In this situation, lengthening the bottom 1/2 of reinforcement layers could reduce the required tension to avoid tensile breakage of the reinforcements.
Keywords: Geosynthetic-reinforced soil wall; Earthquakes; Seismic amplification; Limit equilibrium; Stability design

Full-scale model tests of load transfer in geogrid-reinforced and floating pile-supported embankments

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Abstract: Well-designed field full-scale model tests were carried out to enhance the understanding of geogrid-reinforced and floating pile-supported (GRFPS) embankments constructed on medium compressibility soil (MCS). Two comparative test sections of GRFPS embankments with and without pile caps were built over silty clay with medium compressibility for field monitoring, over 25 months. The heavily instrumented embankments produced comprehensive high-quality data. Settlement, earth pressure, and geogrid strain measurements during embankment filling stages and the post construction placement stage were conducted. The influence of pile cap installation on the differential deformation and load transfer behaviour of the GRFPS embankment was evaluated. The results demonstrate the installation of pile caps can significantly improve the evolution characteristics of the stress increment ratio on the pile, facilitating a change in load sharing of the pile top from a "softening" feature to a "hardening" feature. The state of the "arching structure" heavily depends on the relative displacement. After the maximum arching is formed, although the subgrade load continuously increases, the arching enters the damage and recovery state, and the transfer of the overburden load increment is largely conducted by the tensioned membrane effect.

Keywords: Arching; Field test; Pile efficiency; Geogrid-reinforced and pile-supported embankments; Load transfer; Medium compressibility soil

Evaluation of back-calculated elastic moduli of unreinforced and geocell-reinforced unbound granular material from full-scale field tests

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Abstract: This paper presents a field-scale experimental track over a poor subgrade with an unreinforced section and a geocell-reinforced section subjected to in-situ performance tests. Plate load tests and Benkelman beam tests were carried out distributed in several unreinforced and reinforced layers. The objective was to: (1) examine the variability of the elastic modulus of unbound granular material (UGM) due the influence of its thickness and the presence of poor subgrade in its base, (2) evaluate the modulus improvement factor (MIF) generated by the geocell reinforcement in the UGM and (3) verify the most appropriate condition to apply the MIF to transport infrastructure design. The results showed that there is a significant influence of the thickness of the UGM layer on its elastic modulus when the layer is supported directly over a soft subgrade. The MIF values obtained in field suggest that its determination is mostly related to the UGM maximum elastic modulus rather than its decreased values (by virtue of poor subgrade or reduced thicknesses), and that the analytical formulation presented for MIF calculation has good predictive capability to be applied to pavement design.
Keywords: Soil reinforcement; Pavement reinforcement; Geosynthetic; Modulus improvement factor (MIF); Plate load test; Benkelman beam test

Centrifuge tests on geosythetic-encased stone column supported embankment on seasonal frozen soil

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Abstract: Geosynthetic-encased stone columns (GESCs) have been widely applied into soft foundation. This paper aimed to evaluate the availability and efficiency of GESCs in seasonal frozen ground. Four centrifuge tests were conducted on GESCs supported embankment on seasonal frozen soil under embankment load and thawing, where the foundation was frozen before the construction of embankment. The effects of encasement stiffness and lateral reinforced cushion were investigated. Three phases could be distinguished in the tests by two timing nodes due to the complete thawing of columns and soil, and analysis were made based on the three phases. It is found that high-stiffness encasement can effectively reduce the differential settlement between soil and columns before complete thawing of soil. The GESCs appeared a deformation mode of inward bending, which is in inverse to that in common composite foundation. The reinforced cushion rearranged stress on columns and soil, and influenced the development of pore pressure. The stress concentration ratio (SCR) first decreased to less than 1 due to column thawing, and experienced a steady stage until soil was completely thawed. The SCR rapidly increased after complete thawing of soil, and decreased to a constant value due to soil consolidation.

Keywords: Centrifuge test; GESC; Freeze-thaw condition; Encasement stiffness; Reinforced cushion

CFD-DEM modeling of geotextile clogging in tunnel drainage systems

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Abstract: In this study, a coupled Computational Fluid Dynamics-Discrete Element Method (CFD-DEM) method we used to investigate the hydraulic deterioration of a geotextile due to clogging in tunnel drainage systems. Initially, a framework was developed to generate and test a numerical representation of a typical non-woven geotextile. Following model validation, we carried out parametric analysis to examine the effect of fine content, crack angle, and groundwater inflow. The results showed a general trend of pressure increase associated with increasing both the crack angle and fine content. This increase was found to decay at larger crack angles and high content of fines. Interestingly, increasing groundwater inflow was found to had minimal effect on the final deposition of the clogging particles. Finally, an approximate semi-analytical model was developed to describe the pressure increase due to clogging. The model was able to provide a good match with the data obtained from the numerical analysis.

Keywords: Geosynthetics; Tunnel drainage; CFD-DEM; Hydraulic deterioration; Geotextile clogging

Laboratory investigation of GCL hydration from Lateritic subsoils

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Abstract: A laboratory investigation on the hydration behavior of GCLs from lateritic soils was conducted under isothermal and thermal conditions (tropical climate), varying subsoil moisture contents, GCLs bentonite particle size and mineralogy. GCL hydration levels from lateritic subsoils under isothermal conditions (55%) were similar to literature findings. A slight decrease in water content of some GCLs after long periods of contact with the lateritic soils indicates that equilibrium can demand long time in these soils. GCL with granular bentonites were less efficient to hydrate from lateritic subsoils. GCLs with activated-calcium bentonites maintained hydration levels in long-term. Nonwoven geotextile facing down favored capillary effects. Thermal cycles significantly influenced GCLs hydration from subsoils. Capillary connections developed during hydration under isothermal conditions due to suction gradient reductions. Post-hydration tests under isothermal conditions showed more alterations in GCLs swelling and cation exchange properties than thermal cycles test. An increase in the saturated hydraulic conductivity of GCLs was observed in both lateritic soils, mainly for isothermal condition, although continued attending hydraulic conductivity requirements for barrier applications.

Keywords: Geosynthetic clay liner; Hydration; Lateritic soil; Barrier system; Tropical regions; Thermal effect

Linear viscoelastic behaviours of bituminous mixtures and fiberglass geogrids interfaces

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Abstract: One major research topic is to characterize the mechanical behaviour of actual reinforced pavement structures from laboratory experimentation and take it into account for the design. This investigation aims to verify the effect of fiberglass geogrid presence on interface linear viscoelastic (LVE) behaviour separately and as a system along with the bituminous mixture layers. To conduct the research, two different fiberglass geogrids, with ultimate tensile strength (UTS) of 100 and 50 kN/m, and tack coat made of straight-run bitumen and modified by polymer were combined for the fabrication of three reinforced configurations. In addition, two unreinforced configurations were also fabricated. The first was a single layer slab and the second was a double-layered slab composed of two bituminous mixtures (same type) bonded layers by a tack coat. Complex modulus tests were carried out in specimens cored in two different directions, vertically (V) and horizontally (H) cored. The experimental data were fitted using the 2 Springs, 2 Parabolic Elements and 1 Dashpot (2S2P1D) model. The test results showed that all interfaces' complex modulus obtained for V specimens were LVE. Moreover, complex viscous properties of the interfaces were obtained from the used binder. The interface containing polymer modification presented the highest stiffness.

Keywords: Fiberglass geogrid; Reinforcement; Bituminous mixtures; Complex modulus

Experimental and numerical investigation of mechanical strength characteristics of natural fiber retrofitted rammed earth walls

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Abstract: Unreinforced earthen houses offer manifold environmental and economic advantages. However, such houses are inadmissible in today's era due to their poor performance during earthquakes. Recent Jan 3, 2017 moderate Tripura earthquake (M_w = 5.7) has evidenced a sizable stock of damages to non-engineered adobe/rammed earth houses which primarily act as the motivation behind the present study. In this context, the present study is an attempt to propose a novel seismic encasing retrofitting technique by providing natural and artificial fiber with a key focus on the economy, sustainability, and utilizing locally available material. In this regard, static mechanical strength characteristics (i.e., shear, compressive and flexural strength) of unreinforced and retrofitted rammed earth wall units are investigated through model-scale experiments in the laboratory considering parametric variations as well as numerical analysis of prototype wall. Further, multiple linear regression analysis is performed to develop empirical relationships for predicting shear and compressive strength of retrofitted rammed earth walls. The study highlights the significant improvement in mechanical strength of retrofitted rammed earth walls by treated natural fiber retrofitting strips as well as artificial waste PP strips. Besides, the sanctity of proposed regression-based empirical equations is well verified through a numerical case study on a prototype rammed earth wall.

Keywords: Rammed earth; UTM; Natural fibers; Bitumen; Numerical analysis; ANOVA

Experimental study on uplift behavior of shallow anchor plates in geogrid-reinforced soil

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Abstract: Geogrid reinforcement can significantly improve the uplift bearing capacity of anchor plates. However, the failure mechanism of anchor plates in reinforced soil and the contribution of geogrids need further investigation. This paper presents an experimental study on the anchor uplift behavior in geogrid-reinforced soil using particle image velocimetry (PIV) and the high-resolution optical frequency domain reflectometry (OFDR). A series of model tests were performed to identify the relationship between the failure mechanism and various factors, such as anchor embedment ratio, number of geogrid layers, and their location. The test results indicate that soil deformation and the uplift resistance of anchor plates are substantially influenced by anchor embedment ratio and location of geogrids, whereas the number of geogrid layers has limited influence. In reinforced soil, increasing the embedment ratio greatly improves the ultimate bearing capacities of anchor plates and affects the interlock between the soil and geogrids. As the embedment depth increases, the failure surfaces gradually change from a vertical slip surface to a bulb-shaped surface that is limited within the soil. The strain monitoring data shows that the deformations of geogrids are symmetrical, and the peak strains of geogrids can characterize the reinforcing effects.
Keywords: Anchor plate; Geogrids; Failure modes; Particle image velocimetry (PIV); Fiber optic sensing; Interface behavior

Field monitoring of wicking geotextile to reduce soil moisture under a concrete pavement subjected to precipitations and temperature variations

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Abstract: Wicking geotextile can reduce water contents in pavement layers under unsaturated conditions due to capillary action through grooves of wicking fibers. Reduction of soil water content under the pavement can minimize pavement distresses. So far, there have been limited use and verification of the wicking geotextile in reducing water content of soil under concrete pavements in the field. In this field study, moisture sensors were installed in three test sections under a newly-built concrete pavement during its re-construction. The base course in one test section had a higher percentage of small particles than those in other two sections. The wicking geotextile was used between the base course and the subgrade in two test sections while a nonwoven geotextile was used in one test section. All test sections were subjected to precipitations and temperature variations. Field monitoring data showed that the wicking geotextile reduced the volumetric water content (VWC) of an aggregate base more than the nonwoven geotextile and its wicking ability decreased as the content of small particles increased. In addition, the wicking ability of the wicking geotextile decreased as the temperature decreased due to the reduction in the evaporation rate and the increase in the water retention capacity of the soil at low temperatures.

Keywords: Geosynthetics; Pavement; Wicking geotextile; Volumetric water content; Precipitation; Temperature

Finite element limit analysis of load-bearing performance of reinforced slopes using a non-associated flow rule

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Abstract: This paper presents a numerical study on the load-bearing performance of reinforced slopes under footing load using a finite element limit analysis (FELA) method where a non-associated flow rule is assumed in the analysis. The method was validated against results from full-scale model tests and a limit equilibrium (LE) analytical method. A series of parametric analyses was subsequently carried out to examine the influences that the soil dilation angle, footing location, and reinforcement design (i.e. length, tensile strength, and vertical spacing) could have on the load-bearing performance of reinforced slopes. Results indicate that dilation angle has a significant influence on the predicted magnitudes of bearing capacity, slope deformation, and mobilized reinforcement load. The predicted values of bearing capacity using the FELA are smaller than those from the Meyerhof's analytical method for unreinforced semi-infinite foundation, especially for larger friction angle values. Additionally, the ultimate bearing capacity of the slope and its corresponding horizontal deformation increase with the reinforcement tensile strength. Finally, the slip planes under the applied footing load are found to be y-shaped and primarily occur in the upper half of the slope.

Keywords: Geosynthetics; Reinforced slopes; Limit analysis; Non-associated flow rule; Footing load; Bearing capacity; Slope stability

Geogrid reinforcement of ballasted railway superstructure for stabilization of the railway track geometry – A case study

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Abstract: *Background:* This article deals with a unique topic related to railway infrastructure, civil and geotechnical engineering, and modern materials. In the past 20–30 years, more and more synthetic materials have been applied in engineering and everyday life. Geogrid and geotextile products are adequate for substituting lacking abilities of the soils, and granular materials, mainly low tensile and shear strength, etc. This paper aims to introduce the result of the author's research dealing with investigating the behavior of geogrid-reinforced railway ballast based on a long-term field test in the busiest main railway line in Hungary. The duration of the test is more than eleven years.
Methods: Five different types of geosynthetics were installed in the superstructure of the No. 1 main railway line (Kelenfold – Hegyeshalom state border) in Hungary in 2010. More than eleven years have elapsed since the installation. The experiences are formulated in this paper. Mathematical-statistical analysis was performed to compare the (sub)sections with each other and with the designated reference sections where no geogrids were applied.
Results: As a result of the examination, the author summarized the main differences in the behavior of railway track geometry, and the geometrical deterioration rates, considering the different types of reinforcement products.
Keywords: Geogrid; Railway; Geometrical stabilization; Ballast bed; Field test

Influence of asphalt thickness on performance of geosynthetic-reinforced asphalt: Full-scale field study

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Abstract: In this study, a series of controlled traffic loadings was conducted on unreinforced and geosynthetic-reinforced full-scale asphalt overlays. Unlike the common objective of using paving interlayers to mitigate the development of reflective cracks, the main purpose of adopting geosynthetics for this study was to render an increased roadway structural capacity. The project involved instrumented test sections constructed during the rehabilitation of an in-service roadway in Texas, USA. The rehabilitation involved repairing the pre-existing pavement, placing tack coat, installing a geosynthetic interlayer (except in the unreinforced section), and finally constructing a 75 mm-thick asphalt overlay. This overlay comprised a 50 mm-thick, dense-graded (TY-D) layer overlain by a 25 mm-thick, thin-overlay mixture (TOM) layer. Controlled traffic loadings were conducted, which involved driving standard and light axle loads directly above asphalt strain gauges that had been installed at middepth of the pre-existing asphalt layer. Comparison of tensile strains among the different test sections revealed significantly smaller tensile strains in the geosynthetic-reinforced sections compared to those obtained in the unreinforced section. Consequently, and even though geosynthetic interlayers have often been adopted to minimize reflective cracking in asphalt overlays, the field monitoring results generated in this study demonstrate that they also provide added roadway structural capacity.

Keywords: Geosynthetics; Asphalt overlay; Instrumentation; Field monitoring; Tensile strains; Structural capacity