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目　录

3D effects of turning corner on stability of geosynthetic-reinforced soil structures

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Abstract: Current design procedures of Geosynthetic-Reinforced Soil Structures (GRSS's) are for walls/slopes with long straight alignments. When two GRSS segments intersect, an abrupt change in the alignment forms a turning corner. Experience indicate potential instability problems occurring at corners. The purpose of this study is to explore the effects of turning corner on the stability of reinforced slopes. Three-dimensional (3D) slope stability analysis, based on limit equilibrium, resulted in the maximum tensile force of reinforcement. Parametric studies required numerous computations considering various geometrical parameters and material properties. The computed results produced efficient practical format of stability charts. For long-term stability of reinforced slopes with turning corner, the influences of pore water pressure and seismic loading are also considered. Turning corner can improve the stability of reinforced slopes by virtue of inclusion of end effects. However, localized increase of pore water pressure or directional seismic amplification may decrease locally thus stability requiring strength of reinforcement larger than in two-dimensional (2D) plane-strain. While using 2D analysis for non-localized conditions may require stronger reinforcement, it also requires shorter reinforcement than in 3D analysis; i.e., 2D analysis may be unconservative in terms of reinforcement length.

Keywords: Geosynthetics; Reinforced soil; Corner; Slope stability; Three dimension; Limit equilibrium

Reduction of subgrade fines migration into subbase of flexible pavement using geotextile

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Abstract: Pumping in pavement is defined as traffic-induced migration of saturated subgrade fines into overlying granular layers or onto the surface of the pavement, negatively impacting the performance and service life of the pavement. The objective of this study was to assess the capability of geotextile as a separation and filtration layer in reducing subgrade fines migration. A one-third scale Model Mobile Load Simulator, an accelerated pavement testing device, was used to simulate the cyclic traffic loading on a scaled model of a flexible pavement. The results from three scaled pavement tests were compared to evaluate the effectiveness of geotextile separation and filtration in reducing subgrade fines migration. The three tests had identical configurations, except that a geotextile layer was placed at the interface of subgrade and subbase in one of the tests. The lab testing revealed that, under cyclic traffic conditions, the migration of subgrade fines into subbase was significant. However, using a geotextile at the subgrade-subbase interface significantly reduced the subgrade pumping. At the end of the test, the fines that migrated to the subbase, based on % mass of subbase, were 6.39% in the tests without geotextile and 1.81% in the test with geotextile. An approximately 30% reduction was observed in the amount of pavement rutting when using geotextile at the top of the subgrade. The subgrade soil migration in mass percentage increased with the traffic loading cycles, and more migration occurred in the bottom half than in the top half of the subbase. The study concludes that geotextile can be used as an effective means to reduce pumping of subgrade fines in pavement by providing both separation and filtration.

Keywords: Geosynthetics; Cyclic traffic loading; Flexible pavement; Geotextile; MMLS3; Pumping; Subgrade fines migration

Interfacial properties of geocell-reinforced granular soils

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Abstract: To provide an accurate response of Geocells under pull-out conditions such as what happened in retained backfills, interfacial characteristics of Geocell-backfill are required. A series of direct shear tests was carried out to investigate influence of soil physical properties on interfacial properties of Geocell-reinforced granular soils. Variable parameters encompass poorly graded coarse-grained soils with different medium particles sizes (3, 6 and 12 mm), different normal stresses (100, 200 and 300 kPa) and different relative densities (50 and 70%). To compare the developed strength of the shear plane, in unreinforced and Geocell-reinforced statuses, shear characteristics mobilized at the shear plane including friction angle, dilation angle and apparent cohesion have been evaluated. The results indicated improvement of the interface's shear strength characteristics due to the presence of Geocell. The shear strength in the Geocell-soil interface was increased by increasing the medium grain size and relative density of the soil. From the obtained results, for coarse aggregates (cell aspect ratio-ratio of Geocell's cells diameter (b) to the medium grains size (D50)- smaller than 8.5), Geocell reinforcement was two times, at least, more successful than compaction effort, in improving shear characteristics of the unreinforced medium dense fill materials. It has been recommended using Geocells in environments with low normal stress and coarse aggregates. Furthermore, the results clarify that Geocell with cell aspect ratio equal to 4, has the best performance in improvement of interface's shear strength.

Keywords: Geosynthetics; Geocell; Granular materials; Interface; Direct shear test; Soil grains size

Centrifuge model studies on the stability of fibre-reinforced cemented paste backfill stopes

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Abstract: Cemented paste backfill (CPB) is used extensively in Australia for providing ground support during underground mining operations. This paper considered the use of polypropylene fibres to reinforce the partial or whole body of CPB models in laboratory centrifuge tests. Specimens were cast as non-reinforced (tailings, cement and water), quarter-height, half-height and full height fibre-reinforced CPB model stopes. The stability of CPB models with vertically exposed faces was investigated by a series of centrifuge tests. The modelling data showed that the prototype height of fibre reinforced CPB stopes could be much higher than that of unreinforced stopes depending on the extent of reinforcing. The vertical displacement and failure mass ratio of CPB models were also compared and discussed. The distinct failure modes showed that fibre reinforcement was effective in preventing the CPB failing into the strong box. Furthermore, virtually no fragments were spalled from the exposed faces of reinforced sections of the stopes. It indicated that the application of fibre reinforcement would potentially reduce ore dilution and recovery costs, because the risks of failure would be lowered and prototype stope sizes be Enlarged.
Keywords: Geosynthetics; Cemented paste backfill; Fibre reinforcement; Centrifuge;

Back-analysis of geotechnical parameters on PVD-improved ground in the Mekong Delta

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Abstract: This study presents a back-analysis of geotechnical parameters on prefabricated vertical drain improved ground at a site in the Mekong Delta. Various time−settlement behaviors that reflected different clay thicknesses and loading patterns were observed. The total surface settlement behavior at several monitoring locations was simulated using an updated exponential method that considered staged construction. The analyzed results were validated by substituting the values into a theoretical solution for radial consolidation. The estimated theoretical behaviors were comparable with the monitored behaviors. The geotechnical parameters were back-analyzed by applying the previously analyzed results to various theoretical and empirical formulas. However, the use of extensometer data that were installed at large intervals produced different values of the geotechnical properties. Furthermore, finite element analysis supported the back-analyzed total settlement behaviors and nearly disregarded the application of the geotechnical properties that were obtained using either surface or subsurface settlement data. However, settlements and excess pore pressures in the sublayers were not successfully predicted even when the geotechnical properties were adjusted. Thus, subsurface instruments that can be installed closely in thick clay deposits are required to reliably reevaluate the variations in geotechnical properties along a certain Depth.
Keywords: Geosynthetics; Clay; Field monitoring; Back analysis; FEA

Comparative flexural performance of compacted cement-fiber-sand

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Abstract: This research investigates the influence of seven different fiber types on the flexural performance of compacted cement-fiber-sand (CCFS) with four fiber fractions (0.5, 1, 1.5 and 2% by volume). The seven types of fibers are 12mm polypropylene, 19mm polypropylene, 40mm polypropylene, 55mm polypropylene, 33mm steel, 50mm steel and 58mm polyolefin fibers. The overall CCFS performance was divided into seven sub design performance indicators: (1) peak strength; (2) peak strength ratio; (3) residual strength ratio; (4) ductility index; (5) toughness; (6) equivalent flexural strength ratio; and (7) maximum crack width. The interaction mechanism of the fiber/cement-sand interface was investigated by scanning electron microscopy. Finally, the effectiveness of each fiber type was compared and rated in terms of the overall performance. The results show that the 50mm steel fiber provided the best overall sub performance, resulting in an excellent overall flexural performance; in comparison, the 12mm polypropylene fiber exhibited very poor performance. However, the 19mm polypropylene and 33mm steel fiber specimens provided very good and good overall performances, respectively. The nature of the fiber surface and the fiber length affects the overall performance of CCFS. The surface of the steel fibers, compared to the other synthetic fiber types, is more hydrophilic and is more compacted in a cemented sand matrix without separation of the interfacial zone, providing the best overall flexural performance.

Keywords: Fiber-reinforced soil; Flexural performance; Geosynthetics; Pavement materials; Soil stabilization; Toughness

Radiation dose and antioxidant depletion in a HDPE geomembrane

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Abstract: The impact of α and β radiation on antioxidant depletion in smooth high-density polyethylene (HDPE) geomembranes (GMs) is described. Smooth HDPE GMs having different thickness (0.04-mm, 0.1-mm, 0.2-mm) were created by mechanically pulverizing sections of 2-mm-thick smooth HDPE GM and extruding the polymer at different thicknesses using a film blowing machine. The 2-mm-thick smooth HDPE GM was also used in the experiments. HDPE GM specimens were exposed to sealed sources of 241Am and 99Tc for 1–50 h to simulate the impact of α and β radiation from U and 99Tc in low-level radioactive waste (LLW) leachate. Standard oxidative induction time (OIT) tests were conducted to determine antioxidant depletion. No change in OIT occurred in the 2-mm-thick HDPE GM after exposure to sealed sources of 241Am and 99Tc for 50 h. In much thinner GMs (e.g., 0.04 mm), however, significant antioxidant depletion occurred after exposure most likely due to penetration of αand β particles. Penetration depth of α and β particles and dose deposition in HDPE GMs were estimated with the GEometry ANd Tracking (GEANT4) program. Predictions from GEANT4 show that maximum dose deposition occurs at the surface of the HDPE GM and decreases with depth. A multilayer model is used to estimate antioxidant depletion in HDPE GMs for depth-dependent doses. These estimates suggest that radiation from LLW leachate has an insignificant effect on antioxidant depletion in HDPE GMs due to the low dose deposition (e.g., 2.42 Gy) expected over a 1000-yr service life, even if the level of activity in LLW leachate increases 10x to 100x the level typical of today.
Keywords: HDPE geomembrane; Antioxidant depletion; Low-level radioactive waste; Radiation; Dose deposition; Service life

Liquid limit based assessment of geosynthetic clay liners subject to hydration and hydraulic conductivity testings

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Abstract: This study investigates and discusses the hydration and hydraulic conductivity of low performance (LP), medium performance (MP) and high performance (HP) GCL s. The performance description is made in terms of liquid limit rather than cation exchange capacity or smectite content. The liquid limits of LP, MP and HP GCL s were 108, 320, and 1163%, respectively. GCL s were initially hydrated over compacted silty sand subsoils for 7–90 days. After hydration, water contents of GCL s were determined. Regardless of GCL type, the water contents remarkably increased in the first 7 days of hydration and reached equilibrium after 30 days of hydration for LP and HP GCL s. The water content of MP-GCL continued increasing even at the end of 90 days of hydration. The final water contents were 69, 84, and 120% for LP, MP and HP GCL s, respectively. In other words, increase in the liquid limit of bentonite corresponds to increasing the final water contents of GCL s. The findings of this study are in agreement with literature findings. However, there was no such kind of a trend when smectite content or cation exchange capacity was the dependent variable. The hydraulic conductivity behaviors were totally dependent on GCL performance. Hydrated LP and MP GCLs were not able to reduce their hydraulic conductivity at the beginning of the test. The pore volumes of flow (PVF) required to reducing the hydraulic conductivity to around $3.0\times10-11$ m/s were 270 for LP-GCL and 77–109 for MP-GCL. The hydraulic conductivity of some specimens of LP and MP GCL s were more than$>1.0\times10-7$ m/s even at the end of test duration. Observations showed that particle erosion took place during permeation. In contrast, the hydraulic conductivity of HP-GCL s decreased below $3.0\times10-11$ m/s within a few PVF. This is due to polymer-treated bentonite used in HP-GCL. Post-test measurements on GCLs showed that the water contents kept increasing during hydraulic conductivity. Although water contents increased, the height of LP-GCL did not increase even after hydration and hydraulic conductivity testing, indicating lateral swelling only. MP and HP GCLs, however, had swollen laterally and vertically, resulting in greater heights for HP-GCL than that for MP-GCL.

Keywords: Geosynthetics; Geosynthetic clay liner; Hydration; Hydraulic conductivity; Subsoil; Water content

Experimental study on settlement and scour characteristics of artificial reef with different reinforcement type and soil type

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Abstract: An artificial reef has been actively installed to restore marine ecosystems and increase fish catching. The artificial reef which installed on soft ground loses its function due to the settlement and scour of seabed. This study performed a series of laboratory tests to investigate settlement and scour characteristics of seabed according to different reinforcement type, reinforced area and soil type. Two reinforcement types with different reinforced area were applied to reduce settlement and scour of ground: geogrid and geogrid-bamboo mat. Soil types of ground are clay, silt and sand deposits. A series of laboratory tests includes California bearing ratio test, large size settlement test, and two-dimensional wave channel test. The test results indicated that the reinforced artificial reef had less settlement and scour depth than the unreinforced artificial reef. Especially, the artificial reef reinforced with geogrid-bamboo mat had more improved stability than that with geogrid due to high bending stiffness of bamboo mat.

Keywords: Geosynthetics; Artificial reef; Settlement; Scour; Geogrid-bamboo mat

Assessment of consolidation-induced VOC transport for a GML/GCL/CCL composite liner system

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Abstract: In municipal solid waste landfills, a triple-layer composite liner consisting of a geomembrane liner (GML), a geosynthetic clay liner (GCL) and a compacted clay liner (CCL) is commonly used at the landfill bottom to isolate the leachates from surrounding environment. This paper presents a numerical investigation of the effect of liner consolidation on the transport of a volatile organic compound (VOC), trichloroethylene (TCE), through the GML/GCL/CCL composite liner system. The numerical simulations were performed using the model CST3, which is a piecewise linear numerical model for coupled consolidation and solute transport in multi-layered soil media and has been extensively validated using analytical solutions, numerical solutions and experimental results. The performed numerical simulations considered coupled consolidation and contaminant transport with representative geometry, material properties, and applied stress conditions for a GML/GCL/CCL liner system. The simulation results indicate that, depending on conditions, consolidation of the GCL and CCL can have significant impact on the transport results of TCE (i.e., TCE mass flux, cumulative TCE mass outflow, and distribution of TCE concentration within the GCL and CCL), both during the consolidation process and long after the completion of consolidation. The traditional approach for the assessment of liner performance neglects consolidation of the GCL and CCL and fails to consider the consolidation-induced transient advection and concurrent changes in material properties and, therefore, can lead to significantly different results. These differences for with and without the consolidation effects can range over several orders of magnitude. The process of consolidation induced contaminant transport is complex and involves many variables, and therefore case-specific analysis is necessary to assess the significance of liner consolidation on VOC transport through a GML/GCL/CCL composite liner system.

Keywords: Geosynthetics; Consolidation; Contaminant transport; Compacted clay liner; Geosynthetic clay liner; Numerical modeling

A performance-based approach to design reinforced-earth retaining walls

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Abstract: This paper describes a pseudo-static approach developed for geosynthetic-reinforced earth (GRE) retaining walls, calibrated against given levels of wall performance defined by specified values of earthquake-induced displacements. The GRE walls generally show a good performance under severe seismic loading due to the capability of reinforcements to redistribute the deformations induced by the seismic actions within the reinforced zone. This can be achieved by promoting the activation of internal plastic mechanisms involving the reinforcements strength, providing that they are characterised by adequate extensional ductility. In the proposed procedure, the seismic coefficient k to be used in a pseudo-static calculation is assumed equal to the internal seismic resistance of the wall k_c^{int}, related, through the kinematic theorem of limit analysis, to the maximum strength demand of geosynthetic reinforcements. The seismic coefficient is then calibrated against given levels of seismic wall performance, defined by threshold values of earthquake-induced displacements that result by the temporary activation of plastic mechanisms during severe seismic loading. Permanent displacements induced by earthquake loadings are evaluated through empirical relationships based on a parametric integration of a large number of Italian seismic records and are expressed as a function of the critical and the maximum horizontal accelerations. A procedure is finally proposed to conceive a reinforced-earth retaining wall with an internal seismic resistance lower than the external one, so that a prescribed level of seismic performance and the activation of internal mechanisms are ensured during severe seismic shaking.

Keywords: Geosynthetics; Retaining walls; Reinforced soils; Performance-based design; Earthquakes; Pseudo-static analysis

Earth pressure coefficients for reinforcement loads of vertical geosynthetics reinforced soil retaining walls under working stress conditions

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Abstract: Based on the nonlinear elastic theory and stress-dilatancy theory, two earth pressure coefficients were proposed to analyze the reinforcement loads at the potential failure surface of vertical geosynthetic-reinforced soil retaining walls under working stress conditions. The earth pressure coefficients take into account the force equilibrium and compatible deformations between soil and reinforcement, and can be obtained by solving two implicit functions by an iterative or graphic method. The effects of backfill compaction and facing restriction are taken into account in the earth pressure coefficients by two additional stress factors, which have been derived analytically using straightforward approaches. To validate the effectiveness of the proposed methods, comparisons were made with the results from large scale tests and numerical simulations. It was demonstrated that the reinforcement loads predicted by the proposed methods were in good agreement with the experimental or numerical results

Keywords: Geosynthetics; GRS retaining walls; Reinforcement load; Analytical methods; Earth pressure coefficient

Energy efficiency of fibre reinforced soil formation at small element scale: Laboratory and numerical investigation

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Abstract: This paper explores the aspects related to the energy consumption for the compaction of unreinforced and fibre reinforced samples fabricated in the laboratory. It is well known that, for a fixed soil density, the addition of fibres invariably results in an increased resistance to compaction. However, similar peak strength properties of a dense unreinforced sample can be obtained using looser granular soil matrices mixed with small quantities of fibres. Based on both experimental and discrete element modelling (DEM) procedures, this paper demonstrates that less compaction energy is required for building loose fibre reinforced sand samples than for denser unreinforced sand samples while both samples show similar peak strength properties. Beyond corroborating the macro-scale experimental observations, the result of the DEM analyses provides an insight into the local microscale mechanisms governing the fibre-grain interaction. These assessments focus on the evolution of the void ratio distribution, re-arrangement of soil particles, mobilisation of stresses in the fibres, and the evolution of the fibre orientation distribution during the stages of compaction.

Keywords: Geosynthetics; Soil reinforcement; Granular soil; Fibre; Compaction; Laboratory; Discrete element modelling

Influence of geotextile arrangement on seismic performance of mid-rise buildings subjected to MCE shaking

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Abstract: Geotextile layers make it possible to construct mid-rise buildings sitting on shallow foundations in unfavourable soil conditions; this study investigates how the arrangement of geotextiles affects the seismic performance of mid-rise buildings under Maximum Considered Earthquake (MCE) shaking. The geotextile arrangement considered here includes the stiffness (5000 kN/m–12000 kN/m), the length with respect to width of the foundation (B) (1B–4B), the number of geotextile layers (1–7 layers), and their spacing (250mm–1000 mm). FLAC3D is used for the numerical simulation and to carry out nonlinear dynamic analysis in the time domain, and an inelastic constitutive model is used to simulate the behaviour of the structure and the geotextile layers under seismic loads. Variations in the shear modulus of soil and the corresponding damping ratio with cyclic shear strain are considered using a hysteretic damping algorithm to model the reasonable dissipation of energy in the soil. The interface between the foundation and ground surface, including the material and geometrical nonlinearities, are used to capture any possible slide and uplift in the foundations. The results are presented with regard to the geotextile arrangement considered, and include the tensile force mobilised in the geotextile layers, the response spectra at the bedrock and ground surface, the shear force developed in the structure, the maximum rocking angle of the foundation, permanent foundation settlement, maximum lateral displacement and the maximum and residual inter-storey drifts. The results show that the geotextile layers close to the edges of the foundation sustained most of the stress induced by foundation rocking, and the geotextile arrangement has a significant influence on the seismic response of mid-rise buildings. Thus, to satisfy the seismic performance of buildings and to optimise the design of foundations reinforced with geotextiles, the stiffness, length, number and spacing of the geotextile layers should be designed with great care.

Keywords: Geosynthetics; Geotextile arrangement; Foundation rocking; Mid-rise buildings; Seismic performance

Barrier permeation properties of EVOH thin-film membranes under aqueous and non-aqueous conditions ☆

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Abstract: Ethylene vinyl alcohol (EVOH) copolymers can provide a superior barrier to hydrocarbons and are increasingly being used in co-extruded geomembranes for geoenvironmental applications. These thin-films behave differently under different humidity conditions. This study investigated the permeation properties of toluene through two EVOH thin-films (32 mol% ethylene and 44 mol% ethylene) for both non-aqueous and aqueous solutions. The results of this study are used to gain a better understanding of the behaviour of the EVOH layer used in coextruded geomembranes. The thin-film results are compared with published values for co-extruded linear low density polyethylene (LLDPE) and high density polyethylene (HDPE) geomembranes with an EVOH core. Permeation coefficients are presented over a range of contaminant concentrations from 25 ppm to 99% toluene based on almost five years of continuous testing and the effect of moisture is discussed. A number of EVOH thin films were affected by humidity (i.e., where moisture diffused into the film) prior to diffusion testing under nonaqueous conditions. This observation led to an investigation of the effect of moisture uptake on the permeation of toluene under non-aqueous testing. In these cases, the 44 mol% thin-film had lower toluene permeation coefficient values than the 32 mol% thin-film. These values were similar to toluene permeation coefficient values from tests with aqueous solutions. When relative humidity was less than 60%, the 32 mol% had slightly lower permeability values than 44 mol% thin-film. However, even when affected by humidity, the permeability of both thin-films were considerably (two to three orders of magnitude) lower than previously observed in a water saturated solution. Permeation of toluene from a 1/1 toluene/hexane solution was also examined for the 32 mol % EVOH thin-film at temperatures of 23–50 ℃ and results fit well with a conventional Arrhenius relationship of increasing P_g values with increasing temperature.

Keywords: Ethylene vinyl alcohol; Geomembranes; Vapour barriers; Diffusion; Relative humidity; Organic contaminants; Temperature