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目　录

1. 标题：Effect of particle shape on the response of geogrid-reinforced systems: Insights from 3D discrete element analysis
作者：Ge Gao, M.A. Meguid (Canada) 1

2. 标题：Durability studies of surface-modified coir geotextiles
作者：S. Sumi, N. Unnikrishnan, Lea Mathew (India) 2

3. 标题：Effect of water salinity on the water retention curve of geosynthetic clay liners
作者：Yi Lu, Hossam Abuel-Naga, Eng-Choon Leong, Abdelmalek Bouazza, Peter Lock (Australia & Singapore) 3

4. 标题：Dynamic friction and the seismic performance of geosynthetic interfaces
作者：P. Pavanello, P. Carrubba, N. Moraci (Italy).....4

5. 标题：Influence of wire mesh characteristics on reinforced soil model wall failure mechanisms-physical and numerical modelling
作者：Adis Skejic, Senad Medic, Samir Dolarevic (Bosnia & Herzegovina).....5

6. 标题：Micro X-ray visualisation of the interaction of geosynthetic clay liner components after partial hydration
作者：Will P. Gates, Gift Dumadah, Abdelmalek Bouazza (Australia & Ghana).....6

7. 标题：Shaking table tests on geosynthetic encased columns in soft clay
作者：C. Cengiz, E. Guler (UK & Turkey).....7

8. 标题：Using a geotextile with flocculated filter backwash water and its impact on aluminium concentrations
作者：I. Jahan, M. Wood, C.B. Lake, G.A. Gagnon (Canada).....8

9. 标题：Insufficient initial hydration of GCLs from some subgrades: Factors and causes
作者：A.S. Acikel, W.P. Gates, R.M. Singh, A. Bouazza, R.K. Rowe (Australia & UK & Canada).....9

10. 标题：A dynamic gradient ratio test apparatus
作者：M.W. Khan, A.R. Dawson, A.M. Marshall (United Kingdom).....10

11. 标题：Numerical modelling and validation of geosynthetic encased columns in soft soils with installation effect
作者：Sparsha Sinduri Nagula, Duc Michael Nguyen, Jürgen Grabe (Germany).....11

12. 标题：Experimental and numerical investigation of the uplift capacity of plate anchors in geocell-reinforced sand
作者：M. Rahimi, S.N. Moghaddas Tafreshi, B. Leshchinsky, A.R. Dawson (Iran & USA & UK)……12

13. 标题：Estimating the bearing capacity of single reinforced granular fill overlying clay
作者：Gizem Misir, Mustafa Laman (Turkey & UK)……13

14. 标题：The determination of interface friction by means of vibrating table tests
作者：P. Pavanello, P. Carrubba, N. Moraci (Italy)……14

15. 标题：Three-dimensional numerical analysis of individual geotextile-encased sand columns with surrounding loose sand
作者：Shaymaa, T. Kadhim, Robert L. Parsons, Jie Han (Iraq & USA)……15

16. 标题：Experimental and numerical investigations of the behaviour of footing on geosynthetic reinforced fill slope under cyclic loading
作者：Md. Jahid Iftekhar Alam, C.T. Gnanendran, S.R. Lo (Australia)……16

17. 标题：Required unfactored geosynthetic strength of three-dimensional reinforced soil structures comprised of cohesive backfills
作者：Yanbo Chen, Yufeng Gao, Shangchuan Yang, Fei Zhang (China)……17

18. 标题：Role of soil inherent anisotropy in peak friction and maximum dilation angles of four sand-geosynthetic interfaces
作者：Aliyeh Afzali-Nejad, Ali Lashkari, Benyamin Farhadi (Iran)……18

19. 标题：Laboratory and numerical investigation of machine foundations reinforced with geogrids and geocells
作者：Hasthi Venkateswarlu, K.N. Ujjawal, A. Hegde (India)……19

20. 标题：Laboratory evaluation of a new device for water drainage in roadside slope along railway systems
作者：Yipeng Guo, Wuming Leng, Rusong Nie, Chunyan Zhao, Xiong Zhang (China & USA)……20

21. 标题：An extended data base and recommendations regarding 320 failed geosynthetic reinforced mechanically stabilized earth (MSE) walls
作者：Robert M. Koerner, George R. Koerner (USA)……21

Effect of particle shape on the response of geogrid-reinforced systems: Insights from 3D discrete element analysis

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Abstract: Understanding soil-geogrid interaction is essential for the analysis and design of reinforced soil systems. Modeling this interaction requires proper consideration for the geogrid geometry and the particulate nature of the backfill soil. This is particularly true when angular soil particles (e.g. crushed limestone) are used as a backfill material. In this study, a three-dimensional (3D) discrete element model that is capable of capturing the response of unconfined and soil-confined geogrid material is developed and used to study the response of crushed limestone reinforced with geogrid and subjected to surface loading. The 3D shape of the crushed limestone is modeled by tracing the surface areas of a typical particle and fitting a number of bonded spheres into the generated surface. Model calibration is performed using triaxial tests to determine the microparameters that allow for the stress-strain behaviour of the backfill material to be replicated. To demonstrate the role of particle shape on the soil-geogrid interaction, the analysis is also performed using spherical particles and the calculated response is compared with that obtained using modeled surfaces. The biaxial geogrid used in this study is also modeled using the discrete element method and the unconfined response is compared with the available index test results. This study suggests that modeling the 3D geogrid geometry is important to accurately capture the geogrid response under both confined and unconfined conditions. Accounting for the particle shape in the analysis can significantly enhance the predicted response of the geogrid-soil system. The modeling approach proposed in this study can be adapted for other reinforced soil applications.

Keywords: Geosynthetics； Geogrid-reinforced foundation； Discrete element； Particle shape； Triaxial test； Bearing capacity

Durability studies of surface-modified coir geotextiles

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Abstract: Coir (Cocos nucifera) is a natural fibre known to retain its strength and resist biodegradation far better than other industrial natural fibres. However, systematic studies in this discipline are scarce. Geotextiles are usually exposed to diverse pH, salinity, moisture, and microbial association conditions. In the present work, specific surface modifications of coir geotextiles using a natural agent (cashew nut shell liquid) have been carried out to enhance their long-term performance depending on the end applications. The modified and unmodified geotextiles were subjected to acidic, alkaline, and neutral pH conditions, saline conditions, alternate wetting and drying cycles, and thermal cycles for the assessment of their durability, measured in terms of tensile strength. In situ soil burial studies in a tropical climate were conducted in specially prepared soil to follow the biodegradation behaviour of geotextiles at various depths. The surface-modified geotextiles were found to resist adverse chemical, physical, and biological conditions much better than the unmodified geotextiles. Alkaline conditions marginally accelerated the degradation rates when compared to acidic environments. The saline conditions, as well as alternate wetting and drying conditions, resulted in marginal loss of tensile strength (< 7%). The surface-modified geotextiles buried within lower depths of soil under field conditions retained 70 – 80% of their initial tensile strength after 12 months, whereas the unmodified geotextiles lost 88% strength in four months. The positive impact of surface modification on durability is confirmed by scanning electron microscopy (SEM) and X-ray diffraction (XRD) analysis. The results indicate the excellent potential of suitably surface-modified coir geotextiles for long-term use in adverse conditions.

Keywords: Geosynthetics；Natural fibres；Surface modification；Cashew nut shell liquid；Coir；Biodegradation

Effect of water salinity on the water retention curve of geosynthetic clay liners

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Abstract: The effect of water salinity on the water retention curve of geosynthetic clay liners (GCLs), under constant volume condition is examined. The results indicate that at a constant gravimetric moisture content the total suction increases as the salinity of the wetting liquid increases. Furthermore, the difference in total suction between the GCL hydrated by saline water and distilled water is greater than the difference in the osmotic potential of the wetting water. This behaviour is possibly caused by the matric suction being affected by the expected chemically induced pore size change of the bentonite component of the GCL.

Keywords: Geosynthetics；Geosynthetic clay liners；Water retention；Bentonite；Salinity

Dynamic friction and the seismic performance of geosynthetic interfaces

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Abstract: The stability of geotechnical structures which contain geosynthetic interfaces is closely linked to the shear strength between the geosynthetics themselves, both in static and dynamic conditions. Static friction is the maximum interface shear strength mobilised before displacement, whereas dynamic friction is related to the kinematics of the displacement itself. In polymer materials, dynamic friction may be widely variable, depending on the type, geometry and integrity of the surfaces in contact, as well as on the intensity and time-history of the seismic signal. This means that predicting interface shear strength is not simple. This paper focuses on the evaluation of dynamic interface shear strength between geosynthetics, using the results of both inclined plane tests and shaking table tests; this latter test also provided a means to analyse interface behaviour under the conditions of real seismic records. To this purpose, two common geosynthetic interfaces, which exhibit different behaviour under dynamic loading, were tested. One interface was a smooth HDPE geomembrane in contact with a nonwoven polypropylene geotextile, while the second was a textured HDPE geomembrane in contact with a different type of nonwoven polypropylene geotextile. The test results shows that dynamic friction mobilised during seismic events depends on the relative speed according to the same law outlined by the free sliding tests and by the shaking table tests carried out with sinusoidal base motions. Moreover, for the two different types of studied interfaces dynamic friction may be greater, lesser or equal to the static friction and the assumption of a constant value of dynamic friction does not lead to an accurate prediction of the seismic displacements under various earthquakes.

Keywords: Geosynthetics；Interface；Dynamic friction；Earthquake；Geomembrane；Geotextile

Influence of wire mesh characteristics on reinforced soil model wall failure mechanisms-physical and numerical modelling

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Abstract: This paper presents the details of experimental and numerical analysis performed on three 0.8 m-high reinforced earth model walls with strip footing surcharge near the wall facing. The study investigates how wire mesh strength and geometry affect the failure mechanism. All three walls were nominally identical, except for reinforcement strength and geometry. The displacement field of the entire cross section was captured by high resolution digital camera through transparent sidewall. The resulting images were analyzed using digital image correlation software. The results indicate that both reinforcement strength and aperture size influence the type of failure mechanism. Numerical modelling was also applied to assess the influence of sidewall friction (3D model) and reinforcement stiffness and strength (2D model) on the failure mechanism of the walls. The parameters for the numerical models were derived from independent tests and results, which were compared with the experimental observations. A good level of agreement with measurements was confirmed, even for the 2D model that excluded sidewall friction.

Keywords: Geosynthetics；Reinforced earth；Wire mesh；Failure mechanisms；Physical modelling；Numerical modelling

Micro X-ray visualisation of the interaction of geosynthetic clay liner components after partial hydration

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Abstract: High-resolution X-ray tomography was used to observe a partially hydrated geosynthetic clay liner (GCL) specimen to gain a better understanding of the interaction of its compnents (i.e., geotextiles, fibres and bentonite) on partial hydration when deployed as part of a composite liner system. Detailed in-situ studies of hydration processes in GCLs has proven difficult despite more than two decades of effort. X-ray tomographs were collected at spatial resolutions of 12 and 7 μm to identify the different components within a GCL, as well as to examine in finer detail their interaction within the GCL after initial partial hydration. Tomograph projections provided an excellent aspect of the interaction of these components and some concepts, such as the presence of shearing features within the bentonite component, may require re-consideration based on evidence from X-ray tomography.

Keywords: Geosynthetics；X-ray microscopy；Density contrast；Bentonite；Cover；Carrier；Fibre bundles；Thermal joins；Shear planes

Shaking table tests on geosynthetic encased columns in soft clay

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Abstract: This paper presents the results of an experimental research on the behavior of geosynthetic encased stone columns and ordinary stone columns embedded in soft clay under dynamic base shaking. For this purpose, a novel laminar box is designed and developed to run a total of eight sets of 1-G shaking table tests on four different model soil profiles: Soft clay bed, ordinary stone column installed clay bed, and clay beds with geosynthetic encased columns with two different reinforcement stiffnesses. The geosynthetic encased columns are heavily instrumented with strain rosettes to quantify the reinforcement strains developing under the action of dynamic loads. The responses of the columns are studied through the deformation modes of the encased columns and the magnitude and distribution of reinforcement strains under dynamic loading. The response of the granular inclusion enhanced soft subsoil and embankment soil and the identification of the dynamic soil properties of the entire soil body are also discussed in this article. Finally, to determine the effect of dynamic loading on the vertical load carrying capacity, stress-controlled column load tests are undertaken both on seismically loaded and undisturbed columns.

Keywords: Geosynthetics；Geosynthetic encased column；Ordinary stone column；Shake table test；Laminar box；Sinusoidal loading；Earthquake loading

Using a geotextile with flocculated filter backwash water and its impact on aluminium concentrations

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Abstract: The use of geotextiles (i.e. geotextile tubes) in wastewater treatment applications is ever increasing. This paper examines the potential of using a geotextile to improve upon the treatment of aluminium present in a filter backwash water that is generated from a water treatment plant in Halifax, Canada. A field investigation to ascertain the distribution of aluminium in the filter backwash water treatment process is provided and compared to regulatory guidelines at the environmental compliance point. It is shown that aluminium is undergoing incomplete treatment at various times throughout the year. To examine a potential corrective action, the results of bench scale studies are presented in which cationic additives (i.e. CaO, MgO, and Fe3O4) are combined with a polymer to remove aluminium from solution and flocculate particulate matter from the filter backwash water. A geotextile is utilized to retain particulate matter generated from this process. It is shown that the combined use of the cationic additive with polymer can successfully reduce aluminium concentrations in the filter backwash water and that filtration via a geotextile can retain the aluminium particulate in the filter backwash water to levels close to regulatory requirements. Further optimization with the flocculation process is recommended prior to pilot testing.

Keywords: Geosynthetics；Aluminium；Filter backwash water；Geotextile；Geotextile tube

Insufficient initial hydration of GCLs from some subgrades: Factors and causes

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Abstract: Water retention and hydration tests are reported for three needle punched geosynthetic clay liners (GCLs). GCLs hydration and their maximum hydration capacity were assessed against subgrade soils prepared at different initial gravimetric water contents. The subgrade soil mineralogy and particle size distribution, as well as the carrier geotextiles used in GCLs, are shown to have a significant impact on the GCLs hydration behaviour. This work highlights the need to consider the unsaturated properties of both the GCLs and the subgrade soil when assessing the hydration of the GCLs. At gravimetric water contents above the GCL water entry value (≈30%), some forms of GCL configuration may be better than others with respect to ability to hydrate from a given soil. However, the partial hydration of GCL is mostly controlled by the bentonite microstructure for gravimetric water contents below the water entry value of the GCLs.

Keywords: Geosynthetics; Geotextiles; GCL; Mineralogy; Hydration; Water retention curve; Microstructure

A dynamic gradient ratio test apparatus

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Abstract: The soil-geotextile filtration mechanism is a complex process which depends on physical compatibility between the geotextile and the soil to be retained. Several methods have been proposed by researchers for assessing the filtration behaviour of soil-geotextile composite systems under steady state conditions. The Gradient Ratio (GR) test is the most commonly used method for measuring filtration compatibility of soil-geotextile systems. This paper describes the design of a modified GR permeability test apparatus to overcome disadvantages associated with traditional GR test devices. The apparatus can perform filtration tests under static and dynamic conditions and can be used to evaluate the filtration compatibility of fine-grained soils with geotextiles. The apparatus is incorporated within a triaxial testing system, hence representative field stress conditions can be applied to test specimens. Some exemplar GR tests performed on coarse and fine-grained soils with a non-woven geotextile are presented in this paper. Unidirectional dynamic loads are applied within the filtration tests to replicate highway traffic loading. Test results show that dynamic loading affects the filtration behaviour at the soil-geotextile interface by increasing the fine particles migration towards the geotextile, but that, for the soil evaluated here, this effect was small.

Keywords: Geosynthetics；Soil/ geotextile system；Gradient ratio test；Filtration； Dynamic conditions

Numerical modelling and validation of geosynthetic encased columns in soft soils with installation effect

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Abstract: If the bearing capacity of the soil is not sufficient an improvement method has to be considered. In case of soft and cohesive soils the vibroreplacement technique can be used. This paper describes the numerical simulation of a group of encased granular columns under an embankment based on a real life project situated to the north of Hamburg, Germany. The soft soil creep model and the hardening soil model were used to model the behaviour of the soft clay and granular material respectively. The material parameters were determined based on laboratory tests conducted on test samples from the field. The installation effect of columns in numerically modelled based on the cavity expansion method in a 2D axis symmetric model. The results of the installation effect in terms of stress state changes in the soft soil after complete consolidation are then imported to the 3D model involving group of columns. The results of the numerical simulations are validated against field measurement data in form of vertical settlement of the ground at various locations with respect to time and horizontal deformations in the encased columns with depth.

Keywords: Geosynthetics；Geosynthetic encased columns (GEC)； Installation effect；Cavity expansion； PLAXIS； 3D model

Experimental and numerical investigation of the uplift capacity of plate anchors in geocell-reinforced sand

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Abstract: Plate anchors are frequently used to provide resistance against uplift forces. This paper describes the reinforcing effects of a geocell-reinforced soil layer on uplift behavior of anchor plates. The uplift tests were conducted in a test pit at near full-scale on anchor plates with widths between 150 and 300mm with embedment depths of 1.5-3 times the anchor width for both unreinforced and geocell-reinforced backfill. A single geocell layer with pocket size 110mm×110mm and height 100 mm, fabricated from non-perforated and nonwoven geotextile, was used. The results show that the peak and residual uplift capacities of anchor models were highest when the geocell layer over the anchor was used, but with increasing anchor size and embedment depth, the benefit of the geocell reinforcement deceases. Peak loads between 130% and 155% of unreinforced conditions were observed when geocell reinforcement was present. Residual loading increased from 75% to 225% that of the unreinforced scenario. The reinforced anchor system could undergo larger upward displacements before peak loading occurred. These improvements may be attributed to the geocell reinforcement distributing stress to a wider area than the unreinforced case during uplift. The breakout factor increases with embedment depth and decreased with increasing anchor width for both unreinforced and reinforced conditions, the latter yielding larger breakout factors. Calibrated numerical modelling demonstrated favorable agreement with experimental observations, providing insight into detailed behavior of the system. For example, surface heave decreased by over 80% when geocell was present because of a much more efficient stress distribution imparted by the presence of the geocell layer.

Keywords: Geosynthetics； Plate anchor；Geocell layer；Uplift load；Upward displacements；Numerical analysis

Estimating the bearing capacity of single reinforced granular fill overlying clay

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Abstract: This paper develops an empirical design approach for estimating the footing pressure and settlement behavior of a circular footing on a geogrid reinforced granular fill overlying a weak clay soil by regression analysis. A power model has been developed with a high coefficient of determination R2 with 0.959, according to the 398 training data obtained from in-situ tests. The empirical formulation has been evaluated for the validity of the regression model with 220 data which were not used in the derivation of the formulation and the mean absolute percentage error values have been demonstrated that the predictions were obtained with less than 10% error, on average. Additionally, the validity of the developed formulation has been confirmed with different plate load test results from literature, with an acceptable convergence.

Keywords: Geosynthetics；In-situ tests；Bearing capacity；Regression analysis；Shallow foundation；Design approach

The determination of interface friction by means of vibrating table tests P.

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Abstract: This paper concerns the laboratory evaluation of dynamic friction in geosynthetic interfaces subjected to sinusoidal base motions. Tests were performed with a sliding block over a vibrating table with both a horizontal plane and an inclinable plane. The horizontal configuration is widely used because it is easier to interpret, whereas the inclined plane set-up is more complicated due to the variation in time of the normal component of the acceleration. An analytical method for interpreting the vibrating table test with the inclined plane configuration is described: for the purpose of comparison two geosynthetic interfaces were chosen, which exhibit very different behaviour from each other; one interface had a constant value of dynamic friction, whereas the second exhibited a relationship between dynamic friction and the relative speed of sliding. The tests, carried out with both the horizontal and the inclined plane configuration, showed how the mobilised friction was influenced by the kinematics of the block: at the same relative speed, the mobilised interface friction during tests with the horizontal plane was greater than that resulting from tests with the inclined plane. This difference may be ascribed to the patterns of relative motion at the interface, occurring in a single direction in the case of the inclined plane, and with a cyclic reversal of direction in the case of the horizontal plane.

Keywords: Geosynthetics；Interface friction；Shaking table；Geomembrane；Geotextile

Three-dimensional numerical analysis of individual geotextile-encased sand columns with surrounding loose sand

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Abstract: Use of geotextile-encased sand columns (GESC) to improve weak soils is an emerging technology that has great promise for field applications. This paper contains the results of a numerical study with the goal of quantifying the benefits of geotextile encasement under different conditions. A three-dimensional finite difference method implemented in FLAC3D 5.01 was used to evaluate the performance of a vertically loaded individual GESC installed in loose sand. The numerical model was first verified using the results of experimental tests performed on 150-mm diameter GESC installed in loose sand. The influence of various parameters was investigated in this study, including GESC diameter and length, soil thickness, geotextile encasement length, geotextile stiffness, and friction angle and dilation angle of the infill material. The results of the numerical model showed that vertically loaded GESC of smaller diameter experienced less settlement and lateral expansion than those of larger diameter. The geotextile material with higher stiffness had a substantial influence on the performance of GESC. The maximum effective geotextile encasement length depended on the load on the column head or the compressibility of the column.

Keywords: Geosynthetics； Geotextile encasement； Vertical loading； Loose sand； Embankment； 3D finite difference analysis

Experimental and numerical investigations of the behaviour of footing on geosynthetic reinforced fill slope under cyclic loading

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Abstract: This paper investigates the cyclic loading responses of a strip footing supported by a geosynthetic reinforced fill embankment. A series of large-scale model footing tests were conducted first to investigate the accumulation of permanent footing displacement and residual vertical soil stress over large number of load cycles. The embankment fill was a heavily compacted silty sand and the reinforcement was a flexible geogrid, so that the model test configurations were representative of actual field conditions. Both permanent displacement and residual stress accumulated asymptotically with load cycles and majority of the build-up occurred over the first few hundred cycles. The potential effect of load interruptions was part of the study. Depending on how cyclic load interruption was implemented, it may or may not induce a trailing effect on subsequent cyclic loading responses. To have more in-depth understanding, these footing tests were also investigated numerically based on a soil model that can capture the unload-reload stress-strain loop over large number of load cycles. Reasonably good agreement between experimental observations and numerical predictions was also achieved.

Keywords: Geosynthetic reinforcement；Cyclic loading；Sand；Footing；Slope；Numerical modelling

Required unfactored geosynthetic strength of three-dimensional reinforced soil structures comprised of cohesive backfills

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Abstract: Conservative design of Geosynthetic-reinforced soil structures (GRSSs) is commonly limited to two-dimensional (2D) conditions, ignoring the influence of possible cohesion in backfill material. However, the actual stability of GRSSs is directly influenced by the presence of cohesion - true or apparent - in backfill as well as three-dimensional (3D) effects. In this study, a 3D rational failure mechanism based on the kinematic approach of limit analysis is adopted to assess the stability of GRSSs comprised of cohesive backfills. Within this study, the influence of 3D effects, varying pore water pressures, varying backfill cohesion, and a range of slopes on long-term stability are illustrated in a series of convenient design charts. The results of 3D stability analyses for geosynthetic reinforced walls constructed with cohesive backfills are compared with the results obtained from design guidelines. As expected, when GRSSs are well-drained and relatively narrow in width - or when increasing levels of cohesion are present in the backfill - more stable conditions are realized. For practical scenarios, however, it is critical that cohesive soils should be utilized as backfill with great caution and reliable drainage conditions. Nonetheless, the presented solutions are directly useful towards the assessment of failures of real GRSSs, as they may be constructed with marginal fills that exhibit cohesion, accumulate pore water pressure and often exhibit failure conditions that are three-dimensional in nature.

Keywords: Geosynthetics; Three-dimensional stability; Reinforced earth structures; Cohesion; Limit analysis

Role of soil inherent anisotropy in peak friction and maximum dilation angles of four sand-geosynthetic interfaces

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Abstract: Using a modified direct shear apparatus, an extensive experimental investigation is conducted into the influence of the inherent anisotropy of sand on the mobilization of the peak and critical state friction angles as well as the maximum dilation angle of the interfaces between an inherently anisotropic crushed sand and two woven geotextiles, one nonwoven geotextile, and one geomembrane. Experimental findings confirm that both peak and maximum dilation angles of sand-geosynthetic interfaces are affected from soil inherent anisotropy depending on the bedding plane inclination with respect to the shear plane. However, a unique critical state (residual) friction angle is attained for each interface type irrespective of the bedding plane inclination angle. Compiling results of a total of 141 tests, it is shown that a unique rule describes stress-dilation relationship of four different dense crushed sand-geosynthetic interfaces. The experimental data indicate that the ϕ_p vs. θ and ψ_{max} vs. θ curves are symmetrical with respect to θ=90° for the sand-woven geotextile and sand-geomembrane interfaces. Finally, it is shown that a constitutive equation by Pietruszczak and Mroz (2001) can predict the variation of ϕ_p with θ for the sand-woven geotextile and sand-geomembrane interfaces.

Keywords: Geosynthetics；Sand；Inherent anisotropy；Interface；Direct shear；Friction；Dilation

Laboratory and numerical investigation of machine foundations reinforced with geogrids and geocells

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Abstract: The manuscript describes the results of large scale field tests and numerical studies conducted on geosynthetics reinforced soil beds supporting model machine foundation. A series of vertical mode block resonance tests are conducted over a rigid concrete footing resting on different reinforced soil conditions. The tests are performed in a test pit of size 2m×2m×0.5m using a concrete footing of size 0.6m×0.6m×0.5 m. Four different conditions, namely, unreinforced, single layer geogrid reinforced, two layer geogrid reinforced and geocell reinforced conditions were considered. The tests are performed under six different dynamic force levels using a Lazen type mechanical oscillator. In total, 38 number of field tests are conducted. The dynamic response is studied in terms of reduction in resonant amplitude, peak particle velocity (PPV) and improvement in dynamic properties of the soil. Experimental results revealed that the displacement amplitude of vibration significantly reduced in the presence of geosynthetics. The maximum reduction is observed in the presence of geocell reinforcement as compared to the other conditions. In the presence of geocell reinforcement, resonant amplitude is decreased by 61% and the natural frequency of the soil system is increased by 1.38 times as compared to the unreinforced condition. In addition, the geocell reinforcement found to reduce the PPV by 48% at a distance of 0.5m from the footing face. The elastic uniform compression of the foundation bed is improved by 91% in the presence of geocell reinforcement. Further, the experimental results are validated with the numerical studies conducted by using finite difference package FLAC3D. The encouraging agreement in the dynamic behavior of reinforced soil is observed between the numerical and experimental studies. The numerical results revealed that the lateral spreading of vibrations is significantly controlled in the presence of geocell reinforcement.

Keywords: Geosynthetics；Dynamic response；Machine vibrations；Geocell；Geogrid；FLAC3D

Laboratory evaluation of a new device for water drainage in roadside slope along railway systems

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Abstract: The majority of the existing railway systems in China, from roadside slopes to retaining walls, suffered from poor drainage induced failures. Recently, a new drainage device was proposed to tackle these problems. Preliminary field implementations indicated that the new drainage device could effectively remove groundwater from the surrounding soil without any clogging effect. However, at present, most existing designs are purely based upon the engineers' personal experience and judgement; there is no well-established design method to take full advantage of the device. In this study, a series of laboratory modeling tests were conducted to investigate flow rates, and the optimum installation angle of the drainage device. After that, the long-term performance of the drainage device and conventional perforated PVC pipe under multiple wetting-drying cycles was also evaluated and compared. The results indicate that during the constant head tests, the flow rates in the new drainage device initially increased with an increase in the installation angles of the drainage device from 0 °to 15 °, and then decreased from 15 °to 60 °. An inclination angle from 5 °to 15 °is recommended for this new drainage device when installed in the exiting railway cut slope. The clogging effect was not a primary concern for the applications of this new device. The proposed drainage device provides an alternative way to tackle the poor drainage problem in the exiting railway cut slopes and retaining walls.

Keywords: Geosynthetics；Laboratory；Drainage device；Perforated PVC pipe；Installation angle；Clogging

An extended data base and recommendations regarding 320 failed geosynthetic reinforced mechanically stabilized earth (MSE) walls

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Abstract: In 2013, the authors wrote a paper which was published in the Journal of Geotextiles and Geomembranes on the failure of 171-mechanically stabilized earth (MSE) walls reinforced with geotextiles or geogrids, Koerner and Koerner (2013). The paper generated many reprint requests via both the publisher and the authors, and it won the best paper of the year award. Furthermore, it generated considerable awareness of the situation and generated additional case histories while providing details of such failures. Presently, we have 320 failures which are reported in this paper. The database includes 99 cases of excessive deformation and 221 cases of collapse of at least part of the respective walls. The main statistical findings (including the original 171 failures) are as follows:

1. 313 (98%) were private (as opposed to public) financed walls.
2. 253 (79%) were located in North America; the vast majority being in the U.S.
3. 240 (75%) were masonry block faced.
4. 226 (71%) were 4 – 12m high.
5. 301 (94%) were geogrid reinforced; the other 6% were geotextile reinforced.
6. 246 (77%) failed in less than four years after their construction (12 of which actually failed during construction).
7. 232 (73%) used silt and/or clay backfill soils in the reinforced zone.
8. 245 (76%) had poor-to-moderate compaction.
9. 317 (99%) were caused by improper design or construction (incidentally, none were caused by geosynthetic manufacturing material failures).
10. 201 (63%) were caused by internal or external water (the remaining 37% were caused by soil related issues). While the number of reported walls in this paper is almost double the number reported in 2013, the change in percentages of the above items is relatively small with the notable exceptions of walls failing in longer time intervals (by 9%) and even greater use of fine grained backfill soils (by 12%). As with the original paper, updated opinions and recommendations in several of the above listed areas are presented. Also, several new types of failures are reported, such as guard fence instability and soil erosion at the toe of the wall. However, the overall critical issues continue to occur and no lessening of failures is apparent with this new set of data. The critical issues are the following;

- fine grained silt and clay soils continue to be used for the reinforced zone backfill.
- poor placement and compaction of these same fine grained backfill soils is regularly reported.
- drainage systems and utilities continue to be located within the reinforced soil zone.
- there is little attempt at water control either behind, beneath or above the reinforced soil zone, and.

• design details appear to be inadequate or not followed by the installation contractor.

While the issues reported in 2013 did indeed prompt the initiation of an inspector's certification program (Geosynthetic Certification Institute - Inspector Certification Program) it has not been very successful and has attracted only 24-participants to date. Hopefully this updated paper will energize the parties involved and the MSE reinforced wall community at large to take appropriate action in correcting the situation described herein.

Keywords: Geosynthetics；Geogrids；Geotextiles；Walls；Slopes；Reinforcement