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目　录

Long-term performance predictions in ground improvements with vacuum assisted Prefabricated Vertical Drains

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Abstract: Investigation into time dependent long-term performance of Prefabricated Vertical Drains (PVDs) combined with vacuum consolidation in thick deposits of clay has been extremely limited. Predicting both settlements and excess pore pressures in such cases has become increasingly challenging when time duration is long-term, e.g. several years. In discussing such matter, finding a suitable model to predict the long-term performance is inevitable. Elasto-plastic analysis models such as Cam-Clay cannot predict long-term time-dependent deformational behaviour in soft soils. In this technical note, a Biot type fully-coupled creep-based elastic viscoplastic (EVP) finite element (FE) numerical model has been extended for application in vacuum consolidation. The vacuum consolidation section of the embankment constructed in Ballina, New South Wales, Australia (hereafter referred as Ballina embankment), is analysed using the model through a unit cell analysis and the numerical predictions are compared with field performance monitoring data up to 1200 days (> 3 years). The proposed analysis method for PVD combined with vacuum consolidation involving an EVP model is found to be capable of predicting both short-term and long-term deformational behaviours. Predictions are improved when an exponential function is used for the secondary compression index in the EVP model. Comparison has also been carried out at another location in the embankment where the foundation clay thickness was different to check the precision of the methodology and for better understanding of ground settlement behaviour. Details of the analysis methodology and its validation against field performance data are presented in this note.

Keywords: Geosynthetics; Creep; Prefabricated vertical drains; Vacuum consolidation; Elastic viscoplastic

Failure mechanisms of geocell walls and junctions

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Abstract: Geocell panels are honeycomb-like systems used to provide earth reinforcement. Strips of perforated highdensity polyethylene sheets, also known as cell-walls, are welded together at locations known as junctions. The cell-wall and junctions are designed to support and transfer tensile and shear loads and the integrity of these is essential for the appropriate performance of geocells in practice. Nevertheless, there is no standardized test procedure to assess the strength of the cell-wall or junction, and limited research has been undertaken regarding the failure mechanisms of geocell panels when subjected to various loading scenarios. This paper aims to examine the responses of geocell junctions and cell-walls under various loading conditions. An extensive testing program was undertaken to assess the geocell junctions, which included uniaxial tensile, shear, peeling and splitting strength tests. The uniaxial tensile strength, trapezoidal tearing strength, and creep tests were carried out on the geocell walls. A ductility ratio was developed to measure the rapidness of failure under different shortterm loading scenarios for both the cell-wall and junction. This paper presents the observed failure patterns and an evaluation of the implications of the practical uses of geocells.

Keywords: Geosynthetics; Geocell; Cell-wall; Junction; Failure mechanisms

Effect of surcharge loading rate and mobilized load ratio on the performance of vacuum–surcharge preloading with PVDs

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Abstract: The results from three laboratory model tests performed under various vacuum and surcharge loads with PVDs are reported. Different SLRs were adopted to investigate the effect on the consolidation of dredged soil. To measure the lateral displacement, a refitted inclinometer was developed and tested. In the tests, the settlement, lateral displacement, and vane shear strength were measured, and the degree of consolidation (DOC), horizontal coefficient of consolidation (C_h), and bearing capacity were calculated. The results indicate that larger SLR values promote consolidation. The largest vane shear strength, settlement, and C_h values were all obtained under the highest SLR, and the bearing capacity under this SLR was more than double that under the lowest SLR. The DOC was found to increase with the growth of the SLR. However, considering the vacuum pressure was higher in Case-III, the influence of SLR on reinforcement effect may not be so significant.

Keywords: Geosynthetics; Vacuum–surcharge preloading; Dredged fill; Prefabricated vertical drain; Surcharge loading rate

Strength enhancement of geotextile-reinforced carbonate sand

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Abstract: The mechanical behavior of carbonate sand reinforced with horizontal layers of geotextile is invetigated using a series of drained compression triaxial tests on unreinforced and reinforced samples. The main factors affecting the mechanical behavior such as the number of geotextile layers, their arrangement in specimens, confining pressure, particle size distribution, geotextile type and relative density of samples were examined and discussed in this research. To make a precise comparison between the behavior of reinforced siliceous and carbonate sand, triaxial tests were performed on both types of sands. Results indicate that geotextile inclusion increases the peak strength and strain at failure, and significantly reduces the post-peak strength loss of carbonate specimens. The amount of strength enhancement rises as the number of geotextile layers increases while two other parameters including confining pressure and particle size affect adversely. The strength enhancement of reinforced carbonate sand is greater than the corresponding siliceous sample at high axial strains. Reinforced and unreinforced carbonate specimens exhibit more contractive behavior than their corresponding siliceous samples and tend to dilate at higher axial strains. By increasing the relative density of the samples, the peak strength of reinforced specimens rises due to enhanced interlocking between geotextile layers and sand particles. This process continues as long as the geotextile is not ruptured. The utilization of geotextiles with high mass per unit areas was found to be uneconomical due to slight differences between the strength augmentation of geotextiles with high and low mass per unit areas. It should be noted that geotextile layers limit the lateral expansion of specimens which leads to changing the failure pattern from a shear plane to bulging between the adjacent layers of geotextile.

Keywords: Geosynthetics; Shear behavior; Carbonate sand; Geotextile; Triaxial test; Sand reinforcement

Experimental investigation of the effect of airgaps in preventing desiccation of bentonite in geosynthetic clay liners exposed to high temperatures

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Abstract: This paper investigates whether the introduction of an airgap above a composite liner made of a geomembrane (GMB) and a Geosynthetic Clay Liner (GCL) can decrease thermal loads on the GCL, reduce the risk of bentonite desiccation and/or help maintain its low hydraulic conductivity. A composite liner, subject to 20 kPa overburden load, over a well graded sand was subjected to a thermal gradient. In addition, to the reference base case in which no airgap was present, two designs included air gaps through the placement of a 10mm and 20 mm-thick geocomposites (GC) on top of the GCL-GMB, respectively.

Temperatures on top of the GCLs were found to be significantly reduced by the presence of air gaps, relative to the reference base case. All three designs resulted in GCL desiccation cracks at the end of the tests, due to the relatively high temperature gradients and low water retention of the subsoil, even in the presence of air gaps. However, X-Ray imaging revealed that crack patterns in bentonite samples from designs with air gaps were finer and narrower. Subsequent rehydration (and permeation tests) with distilled water indicated that significant selfhealing of bentonite was in evidence in all three cases. However, while in the absence of an air gap the saturated hydraulic conductivity was found to be 2.8 times its pre-heating value, no significant increase was recorded for other two cases. X-Ray imaging of rehydrated samples confirmed that more effective healing had occurred in samples with an air gap.
Keywords: GCL; Bentonite; Desiccation; Temperature; Air gap; Healing; Hydraulic conductivity

Scale effect on the behavior of geocell-reinforced soil

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Abstract: Existing studies confirmed that the response of geocell-reinforced beds is directly affected by contributory factors, including soil's grains, geocell's characteristics, and surface loading geometries. In this paper, a series of plate load tests has been carried out for the further understanding of the behaviour of geocell-reinforced soil. Four different soil grains sizes, two different geocell's opening sizes and three different loading plate sizes were the considered variables. During the tests, the applied loading and soil surface settlements were recorded to evaluate the systems' response. As it was expected, the geocell-reinforced soil exhibited higher bearing capacity than the unreinforced status, up to 524%. The results further focused on the important role of scale effect on the response of reinforced foundations. The optimum nominal cells size of geocells was obtained about 15 times of medium grain size of soil. Also, it was found that in order to obtain the highest reinforcement benefits, the footing's width should be in the range 13–27 (20 in average) times of medium grain size of the backfill. Finally, to provide more stable and reliable geocell-reinforced backfill, it is recommended that the cells size of geocells should be selected smaller than 0.67 times of footing width.
Keywords: Geosynthetics; Geocell-reinforced soil; Scale effect; Bearing capacity; Soil surface settlement

Laboratory tests of electro-osmotic consolidation combined with vacuum preloading on kaolinite using electrokinetic geosynthetics

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Abstract: Laboratory tests were conducted on kaolinite to investigate the effectiveness of electro-osmotic consolidation combined with vacuum preloading using electrokinetic geosynthetics (EKG). The results showed that the combined method could remove more water and induce larger surface ground settlements compared with the traditional vacuum preloading or electro-osmotic consolidation. Vacuum preloading was quite effective during the first 4 h, though the electro-osmotic consolidation took a main role in dewatering process after 9h. The combined method could also hinder the development of cracks, induce higher negative pore water pressure and hence increase the efficiency of electro-osmotic consolidation. The results showed that deep electro-osmotic consolidation technique combined with vacuum preloading could result in significant water removal efficiency along with shorter electrode length. Furthermore, both electro-osmotic consolidation and the combined method could consolidate the soil efficiently with low energy consumption.
Keywords: Vacuum preloading; Electro-osmotic consolidation; Electrokinetic geosynthetics (EKG); Kaolinite

Horizontal stiffness evaluation of geogrid-stabilized aggregate using shear wave transducers

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Abstract: Lateral restraint resulting from the interlock between geogrid and aggregate is recognized as a primary mechanism governing the load-bearing behavior of a geogrid-stabilized pavement base course. However, the level of geogrid–aggregate interlock and the local stiffness enhancement due to the lateral restraint has not been adequately quantified. In this paper, a new experimental method is proposed to evaluate the stiffness enhancement provided by the interlock of the geogrid–aggregate composite system using shear wave transducers. Repeated load triaxial tests were conducted to determine the resilient modulus and deformation characteristics of both geogrid-stabilized and unstabilized base course aggregates. The stabilized test specimens were evaluated for two geogrid types with rectangular and triangular apertures. For the shear wave measurements, three pairs of bender elements fixed at each mounting base were installed diametrically on the triaxial test specimens at three different locations above the mid-height level, where the horizontal shear modulus profiles of the geogridstabilized and unstabilized specimens were determined. The experimental results indicate that the shear modulus profiles obtained as a function of confinement changed significantly based on the geogrid inclusion and type, whereas there were no considerable changes in the resilient moduli from the different specimens, as they were only influenced by the applied stress states. The shear moduli estimated in the vicinity of the geogrid were greater than those at locations farther away from the geogrid, which was installed at the mid-height of the specimen. The shear modulus profiles varied according to the confining stress, and the shear modulus ratio of the stabilized to unstabilized specimens clearly demonstrated the stiffness enhancement provided by the two different geogrids. Accordingly, the shear modulus profiles estimated from the horizontal shear wave measurements of the bender element can be effectively used to determine the mechanically stabilized layer characteristics of a geogrid, and therefore quantify the local stiffness enhancement provided by the geogrid–aggregate interlock.

Keywords: Geosynthetics; Aggregate; Base course; Shear wave; Mechanically stabilized layer

A case study on utilizing geotextile tubes for tailings dams construction in China

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Abstract: This research presents a successful case, in which geotextile tubes have been used to construct a tailings dam for fine tailings disposal since 2008. Up to the end of 2016, the tailings dam raise has reached 9m in height. The total height of the dam including the starter dike was 61 m. In order to ensure that the tailings reservoir is safe in its current condition and during future construction, the comprehensive geotechnical investigation and stability analyses of the tailings embankment are conducted in this study. The results show that the application of geotextile tubes in the construction of tailings dam is a good alternative for fine tailings disposal.

Keywords: Geosynthetics; Geotextile tube; Fine tailings disposal; Tailings dam constructing; Environmental control

On the shear failure mode of granular column embedded unit cells subjected to static and cyclic shear loads

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Abstract: Since the initial conception of geosynthetic encased columns (GECs), exhaustion of column capacity due to vertical loads in bulging and punching failure modes were readily recognized. This lead to a vast majority of the available research on GECs to be about the behavior of columns under the action of vertical loads. Recently, two other likely and perhaps more dominant failure modes for granular columns namely, shear and bending failure modes, were identified. The purpose of this paper is to study the behavior of unit cells containing ordinary stone columns (OSCs) and GECs under static and cyclic lateral loads where shear failure of the column is imminent. 1-g physical tests are conducted with a novel apparatus, designated as Unit Cell Shear Device (UCSD), to model the behavior of the unit cells located close to the toe of an embankment where OSCs and GECs experience significant lateral loading. Overall failure envelope and strength parameters for GECs with varying reinforcement stiffnesses are quantified under static and cyclic lateral loading conditions. The distribution and magnitude of reinforcement strains in horizontal (hoop) and vertical direction of the columns are also considered.
Keywords: Geosynthetics; Unit cell; Cyclic shear box; Encased column; Stone column

Uplift capacity of horizontal anchor plate in geocell reinforced sand

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Abstract: The paper investigates the uplift performance of horizontal anchor plate in geocell reinforced sand through a series of model tests. It is noted that the unreinforced anchor plate undergoes a clear failure at a displacement of about 3% of its width, whereas with the provision of geocell and a layer of geotextile right below the geocell mattress significantly increases the uplift capacity by about 4.5 times higher than that of unreinforced sand and could sustain anchor displacement of more than 60%. Results indicates that the geocell mattress by virtue of its rigidity distributes the uplift load in the lateral directions to a larger area, thereby reducing the stress in the overlying soil mass and hence increases the performance of anchor plate system. The provision of the additional geotextile layer right below the geocell mattress is found to be very effective in increasing the stiffness as well as load carrying capacity of anchor plate system. The optimum size (i.e., width and length) of geocell mattress giving adequate load carrying capacity of anchor plate is found to be 5.4 times of anchor width (5.4B). The comparison of model tests results with 3D numerical analysis shows good agreement, indicating that the proposed model is able to capture the uplift load-displacement behaviour of geocell reinforced anchor plate system.
Keywords: Geosynthetics; Horizontal anchor plate; Geocell reinforcement; Laboratory model tests; Uplift load; Numerical analysis

Performance of geosynthetic-reinforced flexible pavements in full-scale field trials

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Abstract: The paper presents the results of a series of full-scale trials carried out in Thailand examining the performance of geosynthetics as reinforcement for flexible pavements. The geosynthetics were embedded at different pavement depths and the structural response was monitored across four test sections by means of strain gauges, pressure sensors, deflection points and deflection plates. The results show that all reinforcement configurations helped reduce the vertical static stresses developed at the base of the pavement by up to 66% and by up to 72% for dynamic stresses. The performance enhancement expected to prolong the lifespan of the base layers. The reinforcement layers closer to the base experienced the highest lateral strains of up to 0.13%, providing evidence that geosynthetics can also effectively reduce lateral spreading. All reinforcement configurations helped enhance rut resistance with maximum traffic benefit ratio (TBR) of 13.70, effectiveness ratio (EF) of 12.70 and minimum rutting reduction ratio (RRR) of 0.74. The best configuration included a geotextile within the asphalt concrete layer and a geogrid under the base layer. Non-linear finite element analyses of the test sections predicted very well the strains and stresses in the pavement. The study provides a benchmark for future studies in this field and concludes that geosynthetics can help increase maintenance periods and extend the lifetime of flexible pavements.
Keywords: Geosynthetics; Field trials; Rut resistance; Flexible pavement; Geotextile; Geogrid

Comparison of the behaviour of various geotextiles used in the filtration of clayey sludge: An experimental study

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Abstract: This paper presents the results of an experimental study of various geotextiles used to filter clayey sludge. The use of geotextiles to filter clayey sludge or suspensions of fine particles in water is more complex than that for filtering suspensions of granular soils. In practice, such applications generally use flocculants to postpone the formation of a low-permeability filter cake. The objective of the present study, which does not use flocculants, is to determine how geotextile characteristics affect the capacity of the geotextile to filter clayey sludge. Three key questions are addressed: (1) What are the main differences between vertical and horizontal filtration? (2) How do geotextile characteristics (nature, opening size, permeability, etc.) affect its capacity to filter clayey sludge (3) How do clayey sludge characteristics (i.e., grain size distribution and concentration)? and the type of flow (i.e., constant head or constant flow) affect the filtering capacity of geotextiles? To evaluate the capacity of a geotextile to filter clayey sludge, we propose three relevant criteria and analyse two filtration phases induced by different cake-formation processes (controlled by the geotextile and controlled by the filter cake). To determine the main differences between vertical and horizontal filtration, the settling of fines in the testing device and its influence on the results are analysed and discussed. This study shows that, for the various clayey sludge tested, the geotextiles (needle-punched nonwoven and thermally bonded nonwoven) with the smallest opening sizes ($O_{90} \leqslant 60$ μm) give the most promising results for filtering fines without the use of flocculants. Of these geotextiles, the thermally bonded nonwoven structure seems to offer the best filtration performance for the largest range of fines concentration in the sludge.

Keywords: Geosynthetics; Geotextiles; Filtration; Clayey sludge; Fines; Suspension

Radial consolidation of PVD-Installed normally consolidated soil with discharge capacity reduction using large-strain theory

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Abstract: The radial consolidation rate of prefabricated vertical drain (PVD)-installed soft deposits is known to be closely related to the PVD discharge capacity, which usually decreases during consolidation. Conventional solutions for radial consolidation of PVD-installed deposits have been developed to consider discharge capacity reduction using small-strain theory, in which the volume compressibility coefficient and soil permeability were assumed to be constant. This paper formulates a general expression for discharge capacity reduction with time in numerical analysis based on large-strain theory. Soil disturbance effects caused by PVD installation, such as a nonlinear distribution for radial hydraulic conductivity, are captured in the proposed solution. The proposed solution was applied to field data from a test embankment at Saga Airport. The proposed solution provides a good result which is close to the measured data.
Keywords: Geosynthetics; Discharge capacity; Large-strain; PVD-Installed deposit; Radial consolidation; Soil disturbance

Water retention of geosynthetics clay liners: Dependence on void ratio and temperature

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Abstract: The dependence of the geosynthetic clay liners (GCLs) soil-water characteristic curve (SWCC) on temperature and overburden stress are characterised experimentally. It is shown that changes in void ratio and temperature alter the relationship between suction and moisture content and new forms of existing SWCC equations are developed. To cover a wide suction range, the SWCCs are measured using axis-translation and dew point methods. Based on the available experimental data, both proposed SWCCs are shown to perform well in predicting the effects of void ratio on SWCC along the drying path when compared to the experimental results. It is found that the air-entry value increases as the net vertical stress increases for the experiments under the same temperature. In addition, elevation of temperature reduces retention capacity of the GCL.
Keywords: Geosynthetics; Void ratio and temperature-dependent SWCC; GCL; Composite lining systems

Experimental investigations and constitutive modeling of cyclic interface shearing between HDPE geomembrane and sandy gravel

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Abstract: This paper presents the results of experimental investigations and constitutive modeling of cyclic interface shearing between HDPE geomembrane and cohesionless sandy gravel. A series of cyclic interface shear tests was performed using a large-scale cyclic shear apparatus with servo controlled system. Particular attention was paid to the influences of the amount of shear-displacement amplitude, number of cycles, shear rate and the normal pressure on the mechanical response. The experimental results show that the path of the shear stress against the cyclic shear displacement is strongly non-linear and forms a closed hysteresis loop, which is pressure dependent, but almost independent of the shear rate. For small shear-displacement amplitudes, the obtained damping ratio is significantly greater than zero, which is different to the behavior usually observed for cyclic soil to soil shearing. In order to describe the pressure dependency of the hysteresis loop using a single set of constitutive parameters, new approximation functions are put forward and embedded into the concept of the Masing rule. Further, a new empirical function is proposed for the damping ratios to capture the experimental data for both small and large cyclic shear-displacement amplitudes. The included model parameters are easy to calibrate and the new functions may also be useful in developing enhanced constitutive models for the simulation of the cyclic interface shear behavior between other geosynthetics and soils.

Keywords: Geosynthetics; Geomembrane; Interface; Cyclic interface shear test; Constitutive model; Damping ratio