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Microstructure characteristics of nonwoven geotextiles using SEM and CT methods

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Abstract: Two digital image methods based on scanning electron microscope (SEM) and computed tomography (CT) were proposed to study the microstructural characteristics of staple fibers and continuous filament geotextiles. Two-dimensional (2D) image analysis was developed for SEM images using a machine-learning-based segmentation algorithm. Three-dimensional (3D) image analysis of the CT images was based on 3D reconstruction and a pore network model. The fiber orientation distribution, porosity, pore size distribution (PSD), and characteristic pore size O_{95} determined from image analysis were compared with the theoretical equation and bubble point test (BBP) results. It is shown that 2D and 3D image analyses can accurately measure the fiber orientation distribution of the geotextiles. The porosity values obtained using 3D imaging were comparable to theoretical values. The PSD curves obtained in the BBP tests were in good agreement with those obtained using the 3D image method. O_{95} sizes of continuous filament geotextiles estimated by 2D image analysis compared well with O_{95} sizes obtained by BBP tests, whereas this was not the case for staple fiber geotextiles. The O_{95} pore throat sizes of the two nonwoven geotextiles determined by 3D image analysis were comparable to the BBP test-based values and 2D image analysis-based values.

Keywords: Nonwoven geotextiles, SEM imaging, CT imaging, Image analysis, Microstructure characteristics

Electro-mechanical behaviour of graphene-based geotextiles for pavement health monitoring

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Abstract: Smart geosynthetics have attracted significant interest for potential applications in geotechnical structures owing to their conductive properties. This paper presents an analysis of the electro-mechanical response of graphene-based geotextiles for application in pavements. Experimental and numerical studies were conducted on a commercially available graphene-coated geotextile to understand its response to induced strains. The material was subjected to tensile loading with the effect of transverse strains also being tested, utilizing Digital Image Correlation (DIC). Experimental results indicated a significant electro-mechanical behaviour in the geotextile, with the relative resistance change being non-linear with applied strain. Existing analytical solutions could not predict the observed behaviour; hence, a multi-physics numerical model was developed using concepts of piezoresistivity to capture the non-linear behaviour. The numerical model was calibrated using the experimental data and then validated with experimental data from tests conducted for different specimen sizes. The model could capture the non-linear electro-mechanical behaviour and the electrical response due to axial and transverse strains in the material. This study is expected to serve as a basis for using graphene-based geotextiles for structural health monitoring (SHM) purposes in geotechnical structures, such as in roads.

Keywords: Smart geosynthetics, Graphene-based geotextiles, Electro-mechanical response, Multi-physics numerical model, Piezoresistivity, Pavement health monitoring

Coupled effect of UV ageing and temperature on the diffusive transport of aqueous, vapour and gaseous phase organic contaminants through HDPE geomembrane

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Abstract: High-density polyethylene geomembranes (HDPE GMBs) are indispensable in constructing composite barriers of modern engineered landfills. GBMs would be exposed to various weathering conditions apart from the interaction of organic pollutants in landfill gas and leachate. Though many studies have investigated the contaminant's migration, the transport of volatile organic compounds (VOCs) concerning the synergistic effect of thermal and UV exposure has not been thoroughly explored. Given this, the present study investigated the diffusive transport of four VOCs (aqueous and vapour phase) at 10 ˚C, 25 ˚C, 40 ˚C, and methane diffusion through an HDPE GMB subjected to accelerated UV weathering. The results indicated that the contaminant phase (aqueous, vapour, gaseous), its properties (aqueous solubility, molar mass, polarity), temperature, and the extent of ageing significantly influenced the transport behaviour. The standard oxidative induction time decreased appreciably with ageing duration following a first-order exponential decay. The change in tensile properties and melt flow index indicated the dominance of UV degradation by cross-linking, resulting in an increased crystallinity of GMB that was identified using Fourier transforms infrared (FTIR) spectroscopy and Differential scanning calorimeter (DSC). The crystallinity increased with UV ageing and caused the sorption and diffusion coefficients to decrease.

Keywords: Volatile organic compounds, HDPE geomembranes, Methane, Diffusion coefficient, UV ageing, Temperature

Three-dimensional physical modeling of load transfer in basal reinforced embankments under differential settlement

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Abstract: This study developed a large-scale laboratory apparatus to evaluate the load transfer behavior of basal reinforced embankment fill because of soil arching and geogrid tensile force. A 3D trapdoor-like test system performed five scaled model tests using analogical soil. The instrumentation system involved multiple earth pressure cells, dial gauges, multipoint settlement gauges, and geogrid strainmeters. Comprehensive measurements were performed to investigate the evolution of soil stress and displacement at specific fill elevations with variations in the area replacement ratio and geogrid stiffness. The critical height of the soil arching was determined to be ~1.1–1.94 times the clear pile spacing based on the soil stress and displacement profiles. The distribution of the geogrid tensile strain between and above the adjacent caps demonstrated that the maximum geogrid strains occur on top of the caps, and the tensioned geogrid effect on the load transfer efficiency was evaluated. The cap size and center-to-center pile spacing affect the pile efficacy more significantly than the stiffness of the geogrid. The measured critical heights of arching, stress concentration ratios, and geogrid strain matched those calculated by several well-recognized analytical methods. This experimental program facilitates the development of arching models that account for differential settlement impact.

Keywords: Soil arching, Tensioned geogrid effect, Embankment, Model test, Differential settlement

Model tests of geosynthetic-reinforced soil walls with marginal backfill subjected to rainfall

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Abstract: A series of model tests were conducted to investigate the performance of geosynthetic-reinforced soil (GRS) walls with marginal backfill subjected to rainfall infiltration. The effectiveness of improvement measures—such as decreasing reinforcement spacing and increasing sand cushion thickness—to prevent the GRS wall failure due to heavy rainfall was evaluated. The distribution and variation of the volumetric water content, porewater pressure, wall deformation, and reinforcement tensile strain were monitored during the test. The advancement of the wetting front and the drainage function of sand cushions were visually observed using the fluorescent dyeing technique. For the baseline case, the wall began to deform as rainfall proceeded, causing the potential failure surface to gradually move backward. When the potential failure surface moved beyond the reinforced zone, the pullout of the topmost reinforcement layers occurred, resulting in the collapse of the GRS wall in a compound failure mode. Decreases in reinforcement spacing and increases in sand cushion thickness effectively reduced wall deformation and enhanced wall stability. The placing of sand cushions between the reinforcement layers can also delay water infiltration and reduce the accumulation of porewater pressure inside the wall. Suggestions for designing rain-resistant GRS walls are also proposed based on the findings.
Keywords: Geosynthetics, GRS wall, Marginal backfill, Rainfall, Sand cushion

Effect of subgrade on leakage through a defective geomembrane seam below saturated tailings

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Abstract: Experiments are conducted to quantify leakage through saturated tailings (with 30% fines) underlain by a geomembrane with either a 100-mm-length knife cut slit defect or a 110-mm-length defective extrusion seam. Various subgrades, a poorly graded gravel (GP) with or without nonwoven geotextile (450 or 1420 g/m2) above, a well-graded gravel (GW), and a poorly graded sand (SP) are evaluated. Test results show that leakage through the slit defect and defective seam increase with the subgrade coarseness and subgrade unevenness. The inferred upper and lower bounds opening width of a slit based on the measured leakage increase with the overburden pressure and are categorized for each subgrade. Indentations in the overlapped defective extrusion seam area arise from both the entrapped materials inside the overlap and the materials underlying/overlying the geomembrane, incrementally inducing a greater interface transmissivity with the increasing stress. Overlain by tailings at total overburden pressure of 510 kPa and water head of 35m, leakage through the slit defect is 1.1L/day for SP, 2.2L/day for GW, 2.6–3.3L/day for both GP and uneven GW; leakage drops to 0.8L/day with a geotextile layer directly above the GP; leakage through the defective extrusion seam is 0.4L/day for SP and 0.8L/day for GW.
Keywords: Geosynthetics, Geomembrane, Geotextile, Tailings, Leakage, Slit defect, Defective seam