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目　录

Effect of shearing rate on the behavior of geogrid-reinforced railroad ballast under direct shear conditions

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Abstract: A series of large-scale direct shear tests were conducted to investigate the behavior of unreinforced and geogrid reinforced ballast at different rates of shearing. Fresh granite ballast with an average particle size (D_{50}) of 42mm and five geogrids having different aperture shapes and sizes was used in this study. Tests were performed at different normal stresses (σ_n) ranging from 35 kPa to 140 kPa and at different rates of shearing (S_r) ranging from 2.5 to 10.0 mm/min. The laboratory test results revealed that the shear strength of ballast was significantly influenced by the rate of shearing. The internal friction angle of ballast (φ) was found to decrease from 66.5 ° to 58 ° when the shearing rate (S_r) was increased from 2.5 to 10.0 mm/min. It is further observed that the interface shear strength has improved significantly when the ballast was reinforced with geogrids. The interface efficiency factor (α), defined as the ratio of the shear strength of the interface to the internal shear strength of ballast, varies from 0.83 to 1.06. The sieve analysis of samples after the testing reveals that a significant amount of particle breakage occurs during shearing. The value of breakage, evaluated in terms of Marsal's breakage index (B_g), increases from 5.12 to 13.24% with an increase in shearing rates from 2.5 to 10.0 mm/min. Moreover, the influence of aperture shape and size of geogrid on the behavior of ballast-geogrid interfaces was also examined in this study.

Keywords: Geosynthetics; Ballast; Large-scale direct shear test; Ballast-geogrid interfaces; Rate of shearing (S_r); Friction angle (φ)

Centrifuge model tests on the use of geosynthetic layer as an internal drain in levees

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Abstract: The objective of the paper is to examine the use of a geosynthetic layer as an internal drain in a levee subjected to flooding through centrifuge model tests. Three levee sections, having an upstream slope of 1V:1H and downstream slope of 1.5V:1H, were modelled at 30 gravities in a 4.5m radius large beam centrifuge available at IIT Bombay. Out of the three levee sections modelled, one levee section was without any drainage layer (or clogged drain), while the other two had different types of horizontal drainage layers, namely, sand and nonwoven geotextile layer. The flood was induced with the help of a custom developed and calibrated in-flight flood simulator. At the onset of flood and subsequent seepage, pore water pressures within levee section, and surface settlements were measured using pore water transducers (PPTs) and linear variable differential transformer (LVDTs) respectively. Digital image analysis was employed to trace surface settlements, and downstream slope face movements at the onset of flooding during centrifuge tests. Levee section without any horizontal drain or clogged drain experienced a catastrophic failure. In comparison, the levee sections with an internal drain (sand/ geotextile) remained stable at the onset of flooding. In the case of a levee with a sand drainage layer, the phreatic surface was observed to confine within the levee section itself, whereas it was found to migrate towards toe gradually in the levee section with a nonwoven geotextile layer. It is attributed to either due to suppression of drainage capacity of nonwoven geotextile layer or due to washing of fine particles into pores of nonwoven geotextile layer. Further, seepage and stability analyses were carried out numerically and compared with centrifuge test results. In order to address blocking of pores of nonwoven geotextile layer, a concept of sandwiching nonwoven geotextile layer with sand was explored. By sandwiching nonwoven geotextile layer with sand on either side, the thickness of drainage layer can be of the order of 0.05H.

Keywords: Geosynthetics; Nonwoven geotextile; Centrifuge models; Model tests; Seepage; Levee

Uniaxial compression behavior of geotextile encased stone columns

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Abstract: The bearing capacity and failure mechanism of encased stone columns are affected by many factors such as encasement length, relative density, strength and stiffness of the encasement material. In soft soils where surrounding soil pressure is low, especially in the top section, the stone columns may be close to a uniaxial compression state, where the uniaxial compression strength controls the bearing capacity of the stone columns. A series of large-scale triaxial tests on ordinary stone columns and uniaxial tests on geotextile encased stone columns have been performed. The stone columns were 300mm in diameter and 600mm in height. Samples of four different relative densities, and five types of geotextiles were used in the tests to study the effect of initial void ratio and encasing materials on the uniaxial compression behavior of the stone columns. The results show the uniaxial compressive strength of the encased stone columns is not affected by the initial void ratio but mainly by the tensile strength of the encasing geotextiles. The stress strain curves of the encased stone columns under uniaxial loading condition are nearly liner before failure, which is similar to the tensile behavior of the geotextiles.

Keywords: Geosynthetics; Encased stone column; Uniaxial compression

Numerical analysis of geocell-reinforced retaining wall failure modes

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Abstract: Numerical analyses on the failure mode of geocell-reinforced retaining walls by the finite element strength reduction technique are reported. The effectiveness of the numerical model was validated by the centrifuge model test results. Parametric studies were conducted using the calibrated finite element procedure to investigate the effects of the apparent cohesion of geocell-reinforced soil, the friction between the wall base and the footing, the weak interlayer in the wall, and the layout of the two-tiered geocell-reinforced retaining wall on the failure surface and the factor of safety. The study results indicated that when the apparent cohesion was very large, or the friction between the wall and the footing was small, or there existed a weak interlayer in the wall, sliding failure was found to occur in geocell-reinforced retaining walls, similar to the failure mode of rigid retaining walls. Coulomb's wedge theory was suitable for the stability analysis of geocell-reinforced retaining wall in these conditions. However, in other conditions, which are more relevant in engineering applications, the failure mode of geocell-reinforced retaining walls was similar to that of slopes and the strength reduction technique for the stability analysis of slope may be suitable to analyze the stability of geocell-reinforced retaining Walls.

Keywords: Geosynthetics; Geocell-reinforced retaining wall; Failure mode; Numerical analysis; Strength reduction technique; Parametric study

Full-scale mechanically stabilized earth (MSE) walls under strip footing load

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Abstract: This study analyses two full-scale model tests on mechanically stabilized earth (MSE) walls. One test was conducted with a rigid and one with a flexible wall face. Other parameters were the same in these two tests, like the number and type of geogrid layers, the vertical distance between the layers and the soil type. The loads and strains on the reinforcement are measured as function of the horizontal and vertical earth pressure and compared with analytical models. Specifics regarding the behavior of the geogrids under the compaction load during the construction of the model and under strip footing load are included in the study. Results are compared with AASHTO and the empirical K-stiffness method. In this study, an analytical method is developed for the MSE walls taking into account the facing panel rigidity both after backfill construction and after strip footing load. There is good agreement between the proposed analytical method and the experimental results considering the facing panel rigidity. The results indicate that the tensile force on reinforcement layers for rigid facing is less than the flexible facing. The maximum strains in the reinforcement layers occurred in the upper layers right below the strip footing load. The maximum wall deflection for the flexible facing is more than for the rigid facing. The maximum deflection was at the top of the wall for the rigid facing and occurred at z/H=0.81 from top of the wall for the flexible facing.

Keywords: Geosynthetics; Full-scale model tests; MSE wall; Strip footing load; Analytical analysis; Facing panel rigidity

Bearing capacity of horizontally layered geosynthetic reinforced stone columns

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Abstract: In very soft soils, the bearing capacity of stone columns may not improve significantly due to very low confinement of the surrounding soil. Therefore, they may be reinforced with geosynthetics by using vertical encasement or horizontal layers. Very limited studies exist on horizontally reinforced stone columns (HRSCs). In this research, some large body laboratory tests have been performed on horizontally reinforced stone columns with diameters of 60, 80, and 100mm and groups of stone columns with 60mm diameter. Results show that the bearing capacity of stone columns increases by using horizontally reinforcing layers. Also, they reduce lateral bulging of stone columns by their frictional and interlocking effects with stone column aggregates. Finally, numerical analyses were carried out to study main affecting parameters on the bearing capacity of HRSCs. Numerical analysis results show that the bearing capacity increases considerably with increasing the number of horizontal layers and decreasing space between layers.

Keywords: Geothyntetics; Stone column; Horizontal reinforcing layers; Load ratio

Load-settlement characteristics of large-scale square footing on sand reinforced with opening geocell reinforcement

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Abstract: This paper describes load-carrying characteristics of a series of large-scale steel square footing tests performed on sand reinforced with two types of reinforcement methods. These are full geocell reinforcement (FGR) and geocell with an opening reinforcement (GOR). A thick steel square plate with 500mm by 500mm dimensions and 30mm thickness was used as foundation. The parameters varying in the tests include the depth of geocell mattress (u), width of opening in geocell in the GOR type (w), relative density of sand (D_r) and number of geocell layers (N). The results revealed that the use of GOR and FGR methods enhances significantly the footing load carrying capacity, decreases the footing settlement and decreases the surface heave. It has been found that the use of GOR with an opening width of w/B < 0.92, has the same improvement effect on the footing load-carrying response as the FGR has (B=footing width). Furthermore, with increasing the number of geocell layers from 1 to 2 in both GOR and FGR methods, the footing bearing pressure increases and footing settlement, surface heave and difference of performance between FGR and GOR mattress decrease.

Keywords: Geosynthetics; Geocell with an opening; Large scale model test; Reinforced sand; Square footing; Surface deformation; Improvement factor

Optimal placement of reinforcement in piggyback landfill liners

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Abstract: The optimal placement of geogrid reinforcement in clay liners subject to differential settlement was investigated both numerically and with centrifuge modelling. Two unreinforced liners, a liner reinforced at the top-quarter depth, a liner reinforced at the bottom-quarter depth and a double reinforced liner were modelled in the centrifuge. Differential settlement was induced on the model liners by lowering a trapdoor overlain with sand. By considering: 1) the magnitude of differential settlement required to induce micro-cracks in the liners, 2) the strain fields across the liners during differential settlement and 3) the distribution of these strain fields, it was found that dividing the available reinforcement equally between the top-quarter and bottom-quarter of the liner, i.e. double reinforcement, represents the optimal reinforcement strategy.

Keywords: Geosynthetics; Geogrid reinforcement; Landfill liners; Centrifuge modelling; Differential settlement

Shear strength of interfaces between unsaturated soils and composite geotextile with polyester yarn reinforcement

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Abstract: Composite geotextiles with polyester yarn reinforcement have been commonly used in combination with unsaturated soils. Both unsaturated and saturated shear strength of the interfaces were investigated between a composite geotextile and three major types of materials: silty sand (SM), low-plasticity silt (ML) and high plasticity clay (CH) in a direct shear box. The interfaces were formed using two methods (A and B) to reflect the wide range of possible contact conditions in practice. Method A involved statically compacting the soil directly on top of the composite geotextile, while for Method B, the soil was statically compacted in a separate mold and later brought into contact with the composite geotextile. Type B interfaces required a larger displacement to mobilize the shear strength than Type A interfaces. The ultimate failure envelopes of SM and ML soils were similar to those of their interface shearing. Notably, the failure envelopes for the clay-geotextile interface of both types were higher than that of clay alone. The unsaturated soil-only shearing had a higher peak strength and tended to dilate more than saturated soil-only shearing, while unsaturated soil-interface shearing appeared to be more contractant than saturated interface shearing. The strength variations with suction for all tested soils and interface shearing were clearly non-linear. A new model that takes account of the condition of soil-geotextile contact intimacy is proposed for predicting the variation of interface strength with suction, based on the variation of the soil's apparent cohesion with suction and the geotextile-water retention curve.

Keywords: Geosynthetics; Composite geotextile; Interface strength; Direct shear; Geotextile-water retention curve; Unsaturated soils

Numerical simulation of compaction-induced stress for the analysis of RS walls under working conditions

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Abstract: This paper aimed to verify numerical modelling of compaction-induced stress (CIS) for the analysis of geosynthetic- reinforced soil (GRS) walls under working stress conditions. Data from a full-scale well-instrumented GRS wall was used for a numerical analysis. The results from the wall used in this study have already been used for validation in several other numerical modelling studies. Nevertheless, in none of these studies was the real value of CIS specified for the vibrating plate compactor used in the wall employed. In the present study, the real value of CIS is employed. The CIS is modelled using a new procedure presented in this paper in addition to two other procedures found in the literature. The results indicate that when the real value of CIS was simulated using a strip load applied to the top of each backfill layer, the numerical model accurately represented the measurements. The accuracy of the results, however, depends on the width of the strip load used to model the CIS. Nevertheless, as this type of compaction modelling procedure is time consuming, modelling of CIS by applying a distribution load at the top and bottom of each soil layer is suggested as an alternative procedure.

Keywords: Geosynthetics; Compaction-induced stress; Numerical modelling; Reinforced soil walls