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# 摘要集

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# 目　录


1. 标题：A new generation of soil-geosynthetic interaction experimentation
作者：A.M.Morsy, J.G.Zornberg, J.Han, D.Leshchinsky (USA) .....1

2. 标题：Experimental study of embankments with different reinforcement materials and spacing between layers
作者：Lihua Li, Feilong Cui, Pedro Ferreira, Henglin Xiao, Jie Huang (China & UK & USA) ….....2

3. 标题：Sliding stability and lateral displacement analysis of reinforced soil retaining walls
作者：Peng Xu, Kianoosh Hatami (China & USA) .....3

4. 标 题 ： Bioengineering of river earth embankment using natural fibre-based composite-structured geotextiles
作者：G. Basu, A.N. Roy, P. Sanyal, K. Mitra, L. Mishra, S.K. Ghosh (India) .....4

5. 标题：Full scale investigation of GCL damage mechanisms in small earth dam retrofit applications under earthquake loading
作者：Yutaka Sawada, Hiroshi Nakazawa, W. Andy Take, Toshinori Kawabata (Japan & Canada) .....……5

6. 标题：Bottom ash as a backfill material in reinforced soil structures
作者：Aali Pant, Manoj Datta, G.V. Ramana (India) .....6

7. 标题：Investigation of tensile strength on alkaline treated and untreated kenaf geotextile under dry and wet conditions
作者：Mohammad Gharehzadeh Shirazi, Ahmad Safuan A Rashid, Ramli Bin Nazir, Azrin Hani Abdul Rashid, Azman Kassima, Suksun Horpibulsuk (Malaysia & Thailand).....7

8. 标题：Pullout response of strengthened geosynthetic interacting with fine sand
作者：A. Mirzaalimohammadi, M. Ghazavi, M. Roustaei, S.H. Lajevardi (Iran)……...8

9. 标题：Required strength of geosynthetics in a reinforced slope with tensile strength cut-off subjected to seepage effects
作者：Z.W. Li, X.L. Yang (China).....9

10. 标题：The influence of a cyclic loading history on soil-geogrid interaction under pullout condition
作者：G. Cardile, M. Pisano, N. Moraci (Italy)…….....…10

11. 标题：Geotextile filtration opening size under tension and confinement
作者：Ennio M. Palmeira, Débora L.A. Melo, Isac P. Moraes-Filho (Brazil)……..11

12. 标题：Spectrophotometry as a tool for characterizing durability of woven Geotextiles
作者：José Luiz Ernandes Dias Filho, Paulo Cesar de Almeida Maia, Gustavo de Castro Xavier (Brazil).....12

# A new generation of soil-geosynthetic interaction experimentation

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**Abstract:** A new device was developed to comprehensively assess the interaction between soil and reinforcement as well as the interaction between neighboring reinforcement layers in a reinforced soil mass, under both working and ultimate interface shear stress conditions. An understanding of these two interactions is required to assess the mechanical behavior of a geosynthetic-reinforced soil mass considering varying vertical reinforcement spacings. Specifically, the new device allows direct visualization of the kinematic response of soil particles adjacent to the geosynthetic reinforcement layers, which facilitatese valuation of the soil displacement field via digital image analysis. Evaluation of the soil displacement field allows quantification of the extent of the shear influence zone around a tensioned reinforcement layer. Ultimately, the device facilitates investigating the load transfer mechanisms that occur not only at the soil-reinforcement interface, but also at distances farther from the interface, thereby providing additional insight into the effect of vertical reinforcement spacing on a reinforced soil mass. Finally, the device allows monitoring of dilatancy within the reinforced soil mass upon shear stress generation at the interface between soil and reinforcement. Overall, the device was found to provide the measurements needed to adequately predict the strains developing both in reinforcement layers tensioned by direct application of external loads as well as in reinforcement layers tensioned by the shear transfer induced by adjacent geosynthetic reinforcements. Ultimately, the proposed experimentation technique allows generation of data required to evaluate the load transfer mechanisms amongst soil and reinforcement layers in reinforced soil structures. The strain magnitude in the neighboring reinforcements was found to exceed a magnitude of 10% of the strain magnitude obtained in the active reinforcement. The zone of shear stress transfer from the soil-reinforcement interface was found to exceed 0.2 m on each side of the active reinforcement.

# Experimental study of embankments with different reinforcement materials and spacing between layers

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**Abstract:** Worldwide, waste tires are being discarded in landfills at a huge environmental cost, therefore, their use as a three- dimensional reinforcement material is a wise solution to reduce their environmental impact, and fire risk in the case of shredded tires. In this research a series of experimental model tests of embankments reinforced with Geocell and tires were conducted to compare the performance of these types of reinforcement. The models tested had different Geocell embedment depths, number of Geocell layers, vertical spacing between Geocell layers and density or soil stiffness. Testing consisted of applying pressure at the crest of the embankment and monitoring the pressure distribution as well as the vertical and horizontal deformations inside of the embankment. The results suggested that when compared with unreinforced embankments, reinforced embankments effectively improve the bearing capacity, thereby, reducing vertical and lateral displacements. This study also showed that an optimal embedment depth and spacing between Geocell reinforcement layers can further improve the slope performance. Comparisons between Geocell reinforced embankments and waste tire reinforced embankments, showed that waste tire reinforcement has a superior performance over the Geocell-reinforced embankments. This difference in performance between the two types of reinforcement is more apparent if the embankment backfill has lower stiffness. i.e. lower density.

**Keywords:** Geosynthetics; Soil reinforcement; Geocell; Waste tires; Bearing capacity; Stress Settlement; Model test

# Sliding stability and lateral displacement analysis of reinforced soil retaining Walls

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**Abstract:** Field observations have demonstrated that reinforced soil retaining walls generally have superior seismic performance when compared to traditional gravity retaining walls. However, current design guidelines for reinforced soil retaining walls are typically based on pseudo-static methods of analysis, which involve simplifying assumptions. For instance, the reinforced zone is usually assumed as a rigid body in external stability calculations. As a result, the influences of reinforcement arrangement and properties on the sliding stability and displacement of the wall cannot be accounted for in their design. Additionally, the soil shear strength is assumed to be constant in conventional displacement calculations using the New mark sliding block method. In this paper, an analysis method is proposed to determine the yield acceleration and lateral displacement of reinforced soil walls that includes soil shear strength mobilization and a two-part wedge planar failure mechanism. The proposed method is validated against the results of laboratory model tests, and influences of factors such as ground acceleration coefficients, and reinforcement and backfill properties on the stability of the wall are examined.

**Keywords:** Geosynthetics; Reinforced soil retaining walls; Displacement calculations; Newmark sliding block method; Two-part wedge stability analysis; Vertical seismic acceleration coefficient; Yield acceleration; Strength mobilization

# Bioengineering of river earth embankment using natural fibre-based composite-structured geotextiles

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**Abstract:** A Jut-HDPE composite structured geotextile was developed to improve the performance of earthen structure of river embankment. The optimized geotextiles (430 g/m2) containing 86% natural component (on weight) having better physical, mechanical (tensile strength, 10 kN/m (machine direction) and 18 kN/m (cross direction), index puncture (163 kN) and CBR (1.5 kN)), hydraulic (AOS 178 μ) and endurance properties than 100% HDPE geotextiles. A coconut fibre geotextile net was placed over jute-polyolefin geotextiles to resist washing-off of loose cover soil until the establishment of vegetation. Placing of continuous seamless geotextile tube (weight 196.2 kg/m) filled with moist river sand at the anchor trench-cum-toe guard assisted in safeguarding from eddies. It was observed that initially closed structure of the geotextile assisted in efficient filtration leading to soil through which grass root penetrated the geotextiles sheet and riveted both the layers of soil, the cover and the compacted back layers. The remnant synthetic part thus acts as durable reinforcing element and its increased porosity provides breathability for growth of soil flora and fauna. Bermuda grass turf provided very high nailing strength (658.8 kN/m) with the soil through intertwining of grass roots with durable synthetic network.

**Keywords:** Geosynthetics; Bioengineering; HDPE; Jute; Properties; Structure

# Full scale investigation of GCL damage mechanisms in small earth dam retrofit applications under earthquake loading

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**Abstract:** This paper reports results of full scale testing to further explore potential GCL damage mechanisms in earth dam retrofit applications in seismically active areas; in particular, to a) investigate whether shear displacements could reduce the magnitude of GCL panel overlap during earthquake shaking; b) explore the influence of gravel particles on GCL thickness at localised point of contact; and c) observe the consequences of an accidental exposure of an uncovered GCL to short duration rainfall in terms of moisture content and effects during subsequent compaction. The results of these experiments indicate that even under severe shaking no movements were detected at the GCL panel overlap. Whereas gravel particles were observed to locally reduce the thickness of the GCL to 2.2 mm, no plowing of the particle into the GCL occurred due to a lack of shear displacement at the interface, resulting in no localised internal erosion through the barrier. Furthermore, hydration of GCL panels during construction due to surface wetting was observed to result in a state of hydration less than its post-construction state. These results indicate that although each of the three GCL damage mechanisms cannot be ruled out to ever be relevant in practice, the performance of the GCL retrofitted earth dam tested was satisfactory under even severe Level 2 earthquake shaking, and suggests that the retrofitting of small earth dams with GCLs is a promising strategy to improve their static and seismic resistance.

**Keywords:** Geosynthetics; Earth dam; Full-scale shaking table test; Geosynthetic clay liner

# Bottom ash as a backfill material in reinforced soil structures

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**Abstract:** The paper describes the interface behaviour of bottom ash, obtained from two thermal power plants, and geogrid for possible utilization as a reinforced fill material in reinforced soil structures. Pullout tests were conducted on polyester geogrid embedded in compacted bottom ash samples as per ASTM D6706-01. Locally available natural sand was used as a reference material. The pullout resistance offered by geogrid embedded in bottom ash was almost identical to that in sand. In order to study the influence of placement condition of the material on pullout resistance, test were conducted on uncompacted fill materials. Pullout resistance offered by geogrids embedded in uncompacted specimen reduced by 30--60% than that at the compacted condition.

**Keywords:** Geosynthetics; Bottom ash; Pullout resistance; Reinforced soil structures

# Investigation of tensile strength on alkaline treated and untreated kenaf geotextile under dry and wet conditions

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**Abstract:** Geosynthetics or geotextile is used for aggregate separation, soil reinforcement, filtration, drainage and moisture or liquid barriers in geotechnical applications. Because of the environmental issues, a bio-based material is introduced as a sustainable construction material. The kenaf fibre is a bio-based material available in the tropical countries. It can be potentially used as a geotextile because of its high tensile strength. This paper presents the tensile strength characteristics of kenaf geotextile, manufactured with and without sodium hydroxide (NaOH) treatment. The tensile strength of kenaf geotextile was determined by using the wide-width strip test based on the ASTM D4595- 17 standard. Because the kenaf fibre has a high water absorption capability, the effect of wet and dry conditions on tensile behaviour of kenaf textile was studied. Two patterns of woven kenaf with two different opening sizes between their yarns (0 X 0 and 2 X 2 mm)- plain and incline patterns were studied. In addition, the tensile strength of the kenaf geotextiles, buried in natural ground, was examined after a one-year period. The tensile strength of kenaf geotextiles was higher for the smaller spaces between the yarns. Furthermore, the tensile strength and elongation were lower under wet condition. The alkaline treatment (6% concentration of NaOH) significantly improved the tensile strength of the woven kenaf geotextile. The tensile strength of the treated kenaf geotextile was higher than that of the untreated one, for both short and long term conditions, showing the advantage of NaOH treatment.

**Keywords:** Geosynthetics; Geotextile; Environmental problem; Kenaf geotextile; Tensile strength; Alkaline treatment

# Pullout response of strengthened geosynthetic interacting with fine sand

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**Abstract:** This research describes results of pullout tests performed on two new systems to reinforce the fine-grained silica sand classified as SP in the Unified Soil Classification System. The first system is composed of geogrid on which transverse steel bars are tied to make a 3-D strengthened geogrid, here called Geogrid-Bar (GGB). In the second system, plastic push pins are attached to geocomposite and a strengthened geocomposite is made, here called Geocomposite-Pin (GCP). Eighteen pullout tests were conducted with the soil relative density of 80% revealed that the use of GGB and GCP systems causes the reinforcement pullout resistance to increase by about 37% and 46%, compared with normal planar geogrid and geocomposite, respectively.

**Keywords:** Geosynthetics; Fine sand; Interaction properties; Geogrid-bar; Geocomposite-pin; Pullout test

# Required strength of geosynthetics in a reinforced slope with tensile strength cut-off subjected to seepage effects

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**Abstract:** The Mohr-Coulomb (M-C) yield criterion is found to overestimate the tensile strength of cohesive soils. By introducing the concept of tensile strength cut-off, the M-C criterion is modified to reduce or eliminate the tensile strength from the criterion. In this study, a new approach is proposed to investigate the stability of geosynthetic-reinforced slopes in cohesive soils subjected to seepage effects by means of the kinematic approach of limit analysis. The distribution of pore-water pressure is obtained using the numerical modeling software package, FLAC3D. A kinematically admissible failure mechanism is discretized to incorporate the results from the numerical simulation. The strength of geosynthetics required for maintaining the slope stability is evaluated from the work-energy balance equation. An optimization routine is used to seek out the maximum value among all possible results. Design charts providing the normalized required reinforcement under different parameters are plotted for a parametric study and convenient use in engineering. The obtained results show that less reinforcement is required in the presence of soil cohesion, and that the inclusion of the effect of tensile strength cut-off leads to a more conservative solution, which is more obvious in the presence of seepage effects.

**Keywords:** Geosynthetics; Reinforced slopes; Tensile strength cut-off; Cohesive soil; Seepage effects

# The influence of a cyclic loading history on soil-geogrid interaction under pullout condition

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**Abstract:** The knowledge of soil-geosynthetic interface behaviour is a key point in the design of geosynthetic reinforced soil structures. The pullout ultimate limit state can be reproduced conveniently by means of pullout tests performed with large-size laboratory apparatuses, which allow studying the interaction mechanisms that develop in the anchorage zone. During the service life of geosynthetic- reinforced soil structures, reinforcements may be subjected to long term cyclic vehicular loads or short-term seismic loads in addition to dead loadings, such as the structure's self-weight and other sustained loads. In order to study the influence of a cyclic loading history (a sinusoidal function with fixed amplitude *A*, number of cycles *N* and frequency *f*) on the post-cyclic peak pullout resistance, the writers carried out a series of multi-stage pullout tests on a high density polyethylene extruded uniaxial geogrid embedded in a compacted granular soil for different vertical effective stress $\sigma_v$ values. Moreover, the stability of the soil-geosynthetic interface from a point of view linked to the cyclic loading application has also been investigated. Test results showed that the design pullout resistance parameters are affected by the applied cyclic loading history for specific combined conditions (*A*, *N* and $\sigma_v$ and it should be taken into account for designing geosynthetic reinforced soil structures.

**Keywords:** Geosynthetics; Geogrid; Pullout; Cyclic loading; Soil-reinforcement interface; Multi-stage test; Residual strain; Design parameters; Apparent coefficient of friction; Viscous properties

# Geotextile filtration opening size under tension and confinement

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**Abstract:** Nonwoven geotextiles have been used as filters in geotechnical and geoenvironmental works for half a century. They are easy to install and can be specified to meet the requirements for proper filter performance. There are situations where a geotextile filter may be subjected to tensile loads, which may alter relevant filter properties, such as its filtration opening size. Examples of such situations are silty fence applications, geotextile separators, geotextile tubes and geotextiles under embankments on soft soils. This paper investigates the effects of tensile strains on geotextile pore dimensions. A special equipment and testing technique allowed tests to be carried out on geotextile specimens subjected to tension and confinement. The results obtained showed that the variation in filtration opening size depends on the type of strain state the geotextile is subjected, under which the geotextile pore diameter may remain rather constant or increase significantly. However, confinement reduces the geotextile filtration opening size independent on the strain mobilised. An upper bound for the filtration opening size of strained nonwoven geotextiles is introduced and was satisfactory for the geotextile products tested.

**Keywords:** Geosynthetics; Nonwoven geotextiles; Filtration opening size; Tension; Confinement

# Spectrophotometry as a tool for characterizing durability of woven Geotextiles

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**Abstract:** Geotextiles are used in numerous applications ranging from coastal hydraulic projects to geotechnical landfill projects. Durability studies are necessary for the sizing of these structures since these projects are subject to aggressive weathering. Therefore, it is important to be able to rapidly evaluate the rate of degradation of the geotextile, without detriment to the project. For traditional tests of geosynthetics, large areas must be exhumed, therefore a test which makes use of small specimens is proposed: spectrophotometry. The procedure proposed here makes use of electromagnetic radiation to evaluate the degradation of woven geotextiles by means of analysis of ultraviolet and infrared absorption. The aim of this study is to demonstrate the analysis of geotextile materials by spectrophotometry, making comparisons between laboratory and field degradation. The analyses and correlations were demonstrated to be satisfactory for characterization of degraded geotextiles. The results, with respect to both the absorbance of ultraviolet and transmittance of infrared, yielded both qualitative and quantitative characterizations of the behavior of the studied material. Therefore, spectrophotometry may be considered viable alternative for evaluating the characterization of durability in exhumed samples.

**Keywords:** Geosynthetics; Degradation; Durability; Geotextiles; Ultraviolet; Infrared