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Editorial

Recent Advancements in Geosynthetic Engineering for Sustainable Construction

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Sustainable construction has become increasingly crucial recently due to the massive negative impacts that construction, including various geotechnical activities, can have on the surrounding environment. In fact, the production of cement, rubber and plastics, which are commonly used in civil/geotechnical construction, accounts for around 40% of the total greenhouse gas emissions of material manufacturers worldwide [1]. The use of geosynthetics such as prefabricated vertical drains PVDs [2], geotextiles [3], geogrids [4] and geocells [5], among others, for geotechnical purposes has been practiced with immense success over the past two decades; however, the demand for more sustainable and cost-effective designs has arisen in recent years because of the pressing issues of climate change and environmental degradation. Minimizing the use of geosynthetics to reduce environmental impacts while ensuring resilient and safe infrastructures is certainly challenging and requires more research efforts and innovative approaches. Therefore, this editorial aims to summarize the Special Issue "State-of-the-Art of Geosynthetic Engineering for Sustainable Construction", which has been created to highlight recent advancements in cost-effective and sustainable geosynthetic-based solutions for geotechnical engineering.

Using PVDs combined with vacuum and surcharge preloading has been proven as an effective method to improve soft soil around the world. China is home to one of the largest sites where this method has been applied and improved extensively over the past decade. Various advancements in this technique have been reported, for example, replacing and/or removing one component such as the sand blanket, membrane, horizontal drain or air booster in the system does not significantly affect the general process of soil consolidation, but reduces the time and cost of setup. A combination of vacuum preloading and other soil improvement techniques can significantly enhance the engineering properties of soil [2]. In addition to PVDs, geosynthetic-encased stone columns (GESCs) are a great combination of geogrid-based encasement sleeves and conventional stone columns for ground improvement. An extensive investigation into the static and dynamic behaviour of GESCs was conducted using large-scale model tests [6]. The influence of different encasement layers on the ultimate bearing capacity was found to be significant, i.e., up to 47%. Dynamic loading caused more negative impacts on the resistance of GESC, for example, lower ultimate bearing capacities, reduced stress transfers and increased lateral deformation, compared to static loading.

The tensile resistance is always one of the most important features of geosynthetics. A new testing apparatus (the in-soil test) was developed to examine the tensile behaviour of different geosynthetics under varying confining pressures (0 to 150 kPa) [3]. Various types of geosynthetics, such as nonwoven, woven, glass fibre and plastic geogrids, geomembranes and geonets, were investigated. The results showed that the tensile strength increased significantly with rising confinement, while the role of soil–interface friction was found to be less important. The in-soil test better reflects the real working conditions of geosynthetics compared to the conventional in-air test, having valuable implications in practical design.

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Additionally, a series of large-scale pull-out tests were carried out on geogrids with different filler particle sizes [7]. The results indicated a larger influence of coarser particles on the interlocking effect, thus leading to a higher pull-out force.

Geosynthetic clay liners (GCLs) have been widely used in barrier systems and seepage control; however, the influence of GCL overlaps on the behaviour of vertical barriers is not well understood. A large-scale model test with finite element analysis was thus carried out to clarify this issue [8]. The results showed that the effective hydraulic conductivity of the GCL overlap decreased from 10^{-8} to 10^{-9} cm/s when the confining pressure increased from 10 to 150 kPa. Using bentonite paste with a water-to-bentonite ratio of 19:1 in between the overlap was found to contribute to 60% of this reduction compared to an overlap without bentonite paste.

Understanding the cyclic behaviour of geosynthetic-reinforced soils plays an important role in designing soil foundations and earth structures for transport infrastructure as well as in earthquake events. A dynamic model test was carried out on closely spaced footings with and without reinforcement considering the position of centre point spacing [4]. The results showed that the ultimate bearing capacity increased by 20% when sandy soil was reinforced by geosynthetics. The optimum ratio between the centre point and the footing width was suggested to be around 2.0.

The mechanical response of (wrapped face) reinforced retaining walls to strong vibrations was investigated through a series of shaking table tests [9]. A horizontal peak ground acceleration (HPGA) varying from 0.1 to 1.0 g was applied, resulting in a downward trend in the damping ratio. When the HPGA reached 1 g, both the cumulative residual displacement (2.96%H) and the maximum uneven settlement (3.57%H) exceeded the specification limits. The test results provided valuable data to evaluate the practical guidelines and design codes for the geosynthetic-reinforced retaining walls. Similarly, shaking table tests were used to examine the mechanical response of gabion-reinforced soil retaining walls [10]. The settlement, damping and pressure characteristics of the reinforced walls were analysed with comparison to past data, having significant implications in practical design. On the other hand, a numerical investigation combined with model tests was undertaken to understand the influencing factors of the stress diffusion characteristics of retaining walls reinforced by concrete block panels [11]. The results demonstrated the predominant role of the reinforcement coefficient of soil and the dynamic stress magnitude on stress diffusion.

Geocells are an effective method to reinforce soil foundations, especially transport infrastructure foundations. To improve our understanding of geocell strip behaviour, a series of tensile and trapezoidal tests were carried out [5]. Key parameters such as the shape, width and welding junction of (HDPE) geocell specimens were addressed. The results showed that the shape and width had an insignificant influence on the tensile strength, but they can significantly affect the elongation of a geocell strip. The welding junction considerably influenced the tensile strength with a strength retention rate of 76.3%; thus, proper attention must be paid to this part when designing geocell strips in practice.

On the other hand, considerable efforts have been made to develop more eco-friendly geosynthetics based on natural fibre. A comprehensive review of various potential applications of natural fibre for geotechnical purposes was presented in [12]. Three different major functions of natural fibres were identified, including (i) soil reinforcement, (ii) enhanced drainage for soil consolidation and (iii) filtration, separation and erosion controls. The mechanisms determined by key findings in the laboratory and field were presented. In addition to various valuable engineering features, biodegradation is a unique element of natural fibre geosynthetics that requires special attention. For example, the discharge capacity and tensile strength of straw drain boards were found to decrease over time, but they still met the design requirements [13]. Despite various efforts, using natural fibre has considerable shortcomings such as a poor manufacturing efficiency, a high cost and a lack of practical guidelines and policy support, in addition to the uncertainty surrounding engineering features and biodegradation that has restricted this approach from being widely applied.

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References

1. Hertwich, E.G. Increased carbon footprint of materials production driven by rise in investments. *Nat. Geosci.* **2021**, *14*, 151–155. [CrossRef]
2. Zhou, Y.; Chen, S.; Guo, W.; Ren, Y.; Xu, G. Recent Developments in the Vacuum Preloading Technique in China. *Sustainability* **2022**, *14*, 13897. [CrossRef]
3. Li, D.; Liang, Y.; Wu, D.; Luo, C.; Yang, Y.; Yi, Y.; Wu, J. Experimental Study of Improvement in Tensile Property of Geosynthetics under Confinement. *Sustainability* **2023**, *15*, 7376. [CrossRef]
4. Wang, J.; Qi, H.; Lin, Z.; Tang, Y. Analysis of Dynamic Deformation Response of Closely Spaced Square Footings on Geogrid-Reinforced Sand under Cyclic Loading. *Sustainability* **2023**, *15*, 438. [CrossRef]
5. Zuo, Z.; Hao, X.; Li, H.; Wang, W.; Yang, G.; Liu, Y. Experimental Investigations on the Tensile Mechanical Behavior of HDPE Geocell Strip. *Sustainability* **2023**, *15*, 7820. [CrossRef]
6. Kang, B.; Wang, J.; Zhou, Y.; Huang, S. Study on Bearing Capacity and Failure Mode of Multi-Layer-Encased Geosynthetic-Encased Stone Column under Dynamic and Static Loading. *Sustainability* **2023**, *15*, 5205. [CrossRef]
7. Zhao, Y.; Yang, G.; Wang, Z.; Yuan, S. Research on the Effect of Particle Size on the Interface Friction between Geogrid Reinforcement and Soil. *Sustainability* **2022**, *14*, 15443. [CrossRef]
8. Zhan, L.-T.; Cao, L.-F.; Zhao, R.; Ding, Z.-H.; Xie, S.-P.; Chen, Y.-M. Performances of the Soil– Bentonite Cutoff Wall Composited with Geosynthetic Clay Liners: Large-Scale Model Tests and Numerical Simulations. *Sustainability* **2023**, *15*, 1886.
9. Xu, H.; Cai, X.; Wang, H.; Li, S.; Huang, X.; Zhang, S. Analysis of the Working Response Mechanism of Wrapped Face Reinforced Soil Retaining Wall under Strong Vibration. *Sustainability* **2022**, *14*, 9741. [CrossRef]
10. Cai, X.; Zhang, S.; Li, S.; Xu, H.; Huang, X.; Zhu, C.; Liu, X. Dynamic Characteristics of Reinforced Soil Retaining Wall with Composite Gabion Based on Time Domain Identification Method. *Sustainability* **2022**, *14*, 16321. [CrossRef]
11. Wang, H.; Wang, N.; Yang, G.; Ma, J. Model Test and Numerical Simulation Research of Reinforced Soil Retaining Walls under Cyclic Loads. *Sustainability* **2022**, *14*, 15643. [CrossRef]
12. Nguyen, T.T.; Indraratna, B. Natural Fibre for Geotechnical Applications: Concepts, Achievements and Challenges. *Sustainability* **2023**, *15*, 8603. [CrossRef]
13. Zhu, R.; Su, Y.; Wu, C.; Yuan, W.; Deng, Y. Evaluation of the Laboratory Degradation Performance of a Straw Drainage Board. *Sustainability* **2022**, *14*, 16365. [CrossRef]