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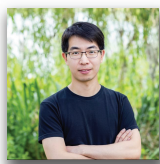
## Editorial

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# Editorial: Bio-innovation, circularity, and digital diagnostics for climate-resilient infrastructure

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The acceleration of global climate change has manifested in record-breaking temperatures, prolonged droughts, and intense precipitation events worldwide. These shifting climatic baselines exert unprecedented multi-physical stressors on civil infrastructure, threatening slope stability, accelerating coastal erosion, and compromising foundational integrity. To counteract these escalating challenges, the discipline of environmental geotechnics must pivot away from linear paradigms towards a sustainable, proactive framework. This transformation relies on three interconnected pillars: the circular valorisation of industrial and agricultural waste streams, the deployment of bio-mediated ground improvement techniques, and the integration of digital diagnostics to predict material durability and environmental risk. The ten outstanding papers compiled in this issue of *Environmental Geotechnics* collectively illustrate this evolving trajectory, bridging the gap between microstructural observations and macro-scale asset management in a rapidly changing world.

A critical prerequisite for low-carbon infrastructure is the redirection of ubiquitous waste materials away from landfills and into structural geotechnical applications. This issue features several breakthrough contributions focusing on sustainable soil stabilisation and circular materials design. The paper by Mozejko and Francisca (2026) investigates the stabilisation of loess soils using non-conventional binders, demonstrating that calcined agricultural eggshells outperform traditional lime by accelerating pozzolanic reactions and significantly enhancing unconfined compressive strength. Addressing problematic expansive clays, Alamgir and Alshameri (2026) present a sustainable alkaline-activation technique that pairs agricultural rice husk ash and industrial silica fume with low-carbon magnesium hydroxide. Their work underscores a remarkable reduction in carbon dioxide emissions compared to ordinary Portland cement, proving that mechanical swelling mitigation can be achieved with minimal ecological

footprints. Extending this circular philosophy to marine infrastructure, Ratananikom and Yimsiri (2026) evaluate the feasibility of recycling high-plasticity dredged soil from deep-sea port maintenance into controlled low-strength materials (CLSM). By establishing cement-to-water and water-to-solid weight ratios, they provide a reliable, on-site design tool that transforms a problematic environmental waste stream into a valuable backfill asset. Microbially induced calcite precipitation (MICP) has emerged as a premier bio-mediated technique, yet translating this concept to the field requires a comprehensive understanding of treatment kinetics. Khalid *et al.* (2026) clarify these time-dependent mechanics by identifying a critical 2-week cementation threshold in MICP-treated loose riverbank sands, proving that a calcite content above 17% marks the structural transition from superficial grain-surface roughening to effective cohesive bridging. To overcome the persistent challenge of uneven precipitate distribution in varied sand matrices, Song *et al.* (2026) pioneered the introduction of biochar as a microstructural scaffold. Their multi-scale analysis reveals that the biochar acts as a porous nucleation site, drastically improving bacterial retention and mechanical uniformity across diverse particle gradations. On an engineered barrier level, Zhao *et al.* (2026) investigate the micro-mechanisms governing the performance of bentonite-polymer geosynthetic clay liners. Through detailed relative humidity and subsoil hydration path tracking, they demonstrate how linear and cross-linked polymers alter trimodal pore structures, enhancing moisture uptake capacity and providing crucial guidelines for barrier design under real-world field settings.

As global infrastructure is subjected to more volatile environments, engineered soils need to maintain structural durability against climate-induced geochemical shifts. Ye *et al.* (2026) offer a critical cautionary study on cement-stabilised silts in tropical coastal zones, exposing a severe degradation mechanism driven

by the synergy of high ambient temperatures and pore-water salinity. Their findings reveal that these combined factors trigger the rapid growth of expansive ettringite clusters, causing microcracking and structural disintegration on water immersion. Concurrently, geo-environmental technologies are expanding to support large-scale carbon dioxide capture and energy transitions. Pei *et al.* (2026) deliver a cutting-edge numerical simulation of compressed flue gas energy storage in saline aquifers. Their transient thermo-hydraulic models demonstrate how cyclic injection-production operations achieve periodic stability.

The final cornerstones are advanced non-destructive diagnostics and digital intelligence, which transition traditional post-failure analysis into proactive risk mitigation. Bernardo *et al.* (2026) showcase the elegance of the continuous bender element method to monitor the evolution of small-strain shear modulus and permeability in cementitious geomaterials over time. By correlating early-stage stiffness with long-term hydraulic conductivity reductions, they present a cost-effective quality control methodology to identify on-site preparation inconsistencies before they compromise structural performance. Completing this digital toolkit, Nguyen and Doan (2026) deploy advanced machine learning algorithms, including random forest, deep neural networks, and extreme gradient boosting, to map regional landslide spatial probability. By integrating their predictive models with global SHAP and local LIME explainable artificial intelligence frameworks, they demystify the black box of statistical modelling, isolating slope gradient and the normalised difference vegetation index as the absolute primary drivers of regional slope instability.

As the UK infrastructure network faces accelerating climate hazards, ranging from severe winter flooding to historic summer heatwaves, the academic and industrial sectors are rapidly transitioning towards low-carbon resilience. This regional momentum mirrors my own research at the University of Surrey, where my team focuses on environmental and energy geotechnics for future-proof critical assets. Through the development of thermo-active geo-infrastructure for climate change adaptation, our work aims to bridge the gap between laboratory modelling and field-scale sustainability. Observing the alignment between UK strategic net-zero

goals and the pioneering global research in this issue underscores the global relevance of our collective discipline.

The papers compiled in this issue establish a forward-looking paradigm for our discipline. Our next generation of researchers, students, and practicing engineers are arriving at a critical juncture where traditional boundaries no longer suffice. The challenges of climate change demand that we embrace the complexity of multi-physics, champion the circular economy, and harness digital intelligence. Environmental Geotechnics remains committed to publishing these technological advancements, ensuring that our collective engineering solutions rise to meet the challenges of the net-zero era.

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