Recent Advances in Ground Engineering

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The built environment heavily relies on the performance and stability of its underpinning geotechnical structures. The ageing of existing geotechnical structures alongside with the rapidly changing climatic patterns have however imposed a risk to their performance and continue to financially strain taxpayers for their upkeep, maintenance, and in cases replacement. Emerging extreme climates is a trigger to a range of potentially problematic soil behaviours including, inter alia, fatigue, fracturing, and strain-softening; dust efflux, redeposition and formation of new airfall loose soils; evolving microstructures and emergence of uncertain structured-based mechanical behaviours; mineralisation, dissolution, reprecipitation and recrystallisation; fines migration and subsequent flow, instability and strain softening; erosion; metastability and collapsibility; structural changes leading to anisotropy, thixotropy and sensitivity; and contamination and transition of natural soils into anthroposol — man-made soils — in urban settings.

The ground in its natural form has the capacity to adapt and respond to the evolving environmental stresses, to self-heal, self-form, and self-produce, and to re-establish disrupted functions. Such capabilities can be either facilitated through the provision of the right circumstances or disrupted. These capabilities are intertwined with soils' naturally open packing, and its multiple ecosystem functional traits, including biological diversity and population regulation, carbon and nutrient regulation and cycling processes, good crop and food, good water and air, good flora and fauna, good water fluxes and resilience to climate shocks and extreme weathers. Conventional groundwork techniques, by virtue, disrupt the natural packing and are designed to transform the natural soil into a less permeable, stronger and stiffer medium through compressing or filling the voids with inert or active chemicals, as well as hydraulic alterations. That continuum then causes similar bias in implementation methods and analytical models. In recent years, biomimicry and nature-inspired solutions have been attracting interest and count as a viable, ambitious emerging alternative [1-2].

Following organising the 2nd Nature-inspired Solutions for the built Environment workshop (NiSE2) — generously sponsored by the UCCTEA Chamber of Civil Engineers, Cyprus — in September 2022, we decided to publish the contributions to the workshop and those we received afterwards in a special issue of International Journal of Geosynthetic and Ground Engineering. The articles within this special issue revolve around three themes: recent advances in (i) 3Ms: models, materials, and methods, (ii) technologies and implementation, (iii) risks, management, and governance.

Machine learning (ML) has become a vehicle for analysis of big divergent data, as well as small uncertain data. It provides new avenues for managing uncertainties and variabilities in design. Omar et al. [3] report on application of five nature-inspired ML techniques in determination of bearing capacity of reinforced soils. Among these and as an example, the 'Ensemble Tree' technique is drawn from the concept of Ensemble Learning which draws inspiration from the idea of "wisdom of the crowd" or the principle that aggregating the opinions of a group of individuals often leads to better decisions than relying on a single individual's judgment. This phenomenon is observed in various biological systems, such as the behaviour of groups of animals in nature, where collective intelligence allows them to make more accurate decisions and increase their chances of survival. Collico et al. [4] report on deployment of the Bayesian statistics to chemical stabilisation of sands with polyurethane and acrylate grouts. The statistical technique draws inspiration from Bayes' theorem—a fundamental theorem in probability theory. While the Bayesian approach itself is not directly derived from observations in nature, it is based on Bayesian probability theory, which has its roots in the work of Reverend Thomas Bayes, an 18th-century mathematician and theologian.

Thakur et al. [5] report on a programme of large-scale pile uplift test and utilisation of a Taguchi method to relax the number of experiments from an initial high due to the range of variables and their inter-relations. While the Taguchi method itself is not nature-inspired, the broader concept of using optimization techniques to improve performance and reduce variability can be related to principles found in nature. In nature, organisms often exhibit characteristics and behaviours that have been shaped by evolution to optimize their survival and reproduction under different environmental conditions.

As with materials, contributions here address upcycled, biogenic, and bio-inspired materials. Haider et al. [6] report on the use of upcycled polyethylene terephthalate alongside cement for stabilisation of silts. They touch on novel concepts including idealised void ratios and evolution of small strain stiffness. Scopes for using Waste Foundry Sand (WFS) alongside cement for stabilisation of lateritic soils is presented by Naik et al. [7]. Ilman and Balkis [8] report implications of applying glass powder and macro-silica to clays. Both materials count as upcycled industrial wastes. As for biogenic materials, Ilman and Balkis [9] review the advances made with biopolymers as binder for soil.

To mark advances with methods, select contributions in this special issue address the subject of scale (in experimentation). Bacic and Herle [10] presents the use of a pore water pressure (PWP) tester — that is a simplified cyclic shear strength test — for rapid evaluation of steady states in saturated sands. On the other side of the spectrum, semi-full-scale testing is a reasonable compromise in the light of technical and financial obstacles in front of field full-scale simulations. Desbrousses et al. [11] report on the use of a semi-full scale, 1.3x0.91x0.6 m^3 ballast box paired with a 1.8 MN load frame and 0.085 MN pneumatic actuator to apply 40,000 cycles of load at 0.8 Hz on reinforced and unreinforced ballast. Esmatkhah Irani et al. [12] present their work on semi-full scale shaking table experiments to examine the concept of 'rocking', or premeditated failure of soil to ease the seismic actions on structure. This is an interesting work, revolving around the idea of failure of a component in favour of grand system's eventual survival. Sahin et al. [13] present their findings from a programme of dynamic cone penetration (DPT) and MASW geophysical survey to examine the liquefaction mechanisms in gravely soils. The methods here are detecting a problem that otherwise is deemed unlikely in gravelly soils.

Finally, two works are truly cross-cutting. First, Tohidvand et al [14] present a peculiar testing regime to study sands mixed with flexible polypropylene fibers (the like of which one can see in sands reinforced with plant root systems). They use an automatic Direct Simple Shear (DSS) apparatus to simulate various strain paths. Second work is that of Dindar and Alevkayali [15]. This article bridges the three themes of the workshop: GIS and NASW methods are utilised to generate a data that is analysed via two nature-inspired Machine Learning models, leading to mapping of landslide risk across a Cypriot mountain system.

The Nature-inspired Solutions for the built Environment (NiSE) working party continues to be a platform for likeminded academics with interest in biomimetics in geotechnical engineering and hope to hold their 3rd workshop in September 2024.

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