

Editorial

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Welcome to this edition of *Environmental Geotechnics*, which includes six papers from four continents demonstrating some of the breadth of challenges being faced by geoenvironmentalists developing new approaches to modelling and analysing emerging problems, and proposing sustainable, workable solutions to help humanity manage our impacts on the biosphere. There is much for us to do! As our societies learn their way forwards, we appreciate that the knowledge and insights of science, rationally applied, are at the heart of problem shaping and solution finding while we also recognise not all answers can be purely technical and a systemic mindset will be required. Five papers variously explore adjustments (physical, chemical, microbial) of geotechnical properties of coarse- and fine-grained soils in the context of external stresses, illustrating improvements to marginal soils, circularity and beneficial reuse of ‘wastes’. The remaining paper describes new approaches to geochemical modelling the dissolution kinetics of groundwater in the hyperalkaline chemically disturbed zone for the UK’s proposed deep repository.

Common strands link experimental work from China and Brazil, where two granular soils are exposed to stressors: respectively, freeze-thaw cycling examined for single particles compared to ageing, cyclic wetting/drying and cyclic temperature/pressure for iron ore tailings. In the first paper, Meng *et al.* (2023) subject mudstone to freeze-thaw cycles before single particle crush testing to examine size effects on the material’s strength. The single particle crush strength and survival probability for a given characteristic stress are demonstrated to decrease with increasing particle size and increasing numbers of freeze-thaw cycles, and the Weibull modulus shows a linear correlation (decreasing slightly) with the number of freeze-thaw cycles, with the Weibull distribution accurately describing the test data.

Flórez *et al.* (2023) characterise granular tailings from an iron ore mine in Brazil in both an unaltered and a processed state by physical, chemical and mineralogical testing, and then examine these materials geotechnically using a series of consolidated isotropic undrained triaxial tests. The unaltered state samples effectively form a control group. Particular attention was paid to using representative fluid sampled from the site. The objective was to investigate ageing, cyclic wetting and drying and the combined action of cyclic temperature and pressure variations as potentially

influencing post-closure and long-term stability of tailings dams. Investigations focus on these impacts and make comparisons with the unaltered tailings. Grain densities appear unaffected, chemical composition under ageing shows a slight increase in tailings alumina percentage, and the cyclic wetting-drying process produces a new fibrous crystal material, preliminarily identified as zeolite. Geotechnical strength also appears unaffected; however, the material became more contractive under ageing and cyclic wetting-drying, and more dilatant under heating.

From a personal perspective as a containment engineer designing landfills, heap leach and tailing storage facilities, I am equally interested in the geomechanical properties of the contained material within (say) a tailings lagoon or a municipal waste landfill as those of the ‘structural’ or engineered elements such as an embankment dam or lining system components. Hence, stiffer tailings, being inherently more competent compared to slurries, contribute positively to the design of their containment elements; similarly, a high-density waste body will impart greater lateral stresses on a landfill’s sidewall lining system (refer Gallagher *et al.*, 2004), but also exhibit a different settlement behaviour to that of a less dense waste body. These considerations inform the design parameters selected for the containment structures, and the papers from Brazil (above) and Canada examine changes in the geomechanical properties of two very different tailings, one coarse grained, one fine grained subject, respectively, to degradation by environmental stressors and improvement by cement stabilisation.

Wang *et al.* (2023) investigate the effects of Portland cement binders on mature fine tailings (MFT) from Canadian oil sands. The aim of stabilising these slurries is to improve undrained shear strengths from around 0.5 kPa to more than 5 kPa, achieved with 10–15% cement addition after 28 days. Stabilisation changes the initially low-plasticity clay to a high-plasticity clay/silt. Index properties also increase with cement addition, those increases becoming more significant with additional curing time. X-ray diffractograms indicate secondary mineral growth after cement addition, and that kaolinite, illite and silica are consumed by cement-silicate-hydrate (C-S-H) gel formation, pozzolanic reactions and cement hydration. Higher cement addition led to observations of aggregation of MFT particles into larger clusters, with growth of C-S-H gel products, whose morphology changed from fibrous shaped to interspersed

bundles as cement content increased; hence connections forming between cementitious particles and filling of voids to which the increase in mechanical strength of the stabilised MFT is attributed.

The work on initial stabilisation of Canadian oil-sand slurry tailings, a soft clay, to improve its strength can be contrasted with a paper from Japan which examines a different stage and perspective of cement treatment of soft clays: the addition of microbes to mitigate deterioration in highly alkaline marine environments. Ikoma *et al.* (2023) demonstrate that deterioration of cement-treated dredged marine clays exposed to seawater can be reduced by addition of urea and urease-producing bacteria to enhance microbiologically induced calcium carbonate precipitation in a highly alkaline setting, with mitigation being more marked under deep-sea rather than laboratory or shallow-sea conditions.

A very different hyperalkaline setting is examined geochemically in the fifth paper by Baqer *et al.* (2023), who utilise the recently introduced mixed kinetic-equilibrium (MKE) approach to model elements of the containment system at the UK's proposed geological waste repository deep below the biosphere. A multi-layer barrier system will contain low/intermediate level wastes within stainless steel containers encapsulated with a cementitious engineered barrier in contact with groundwater. Previous workers used thermodynamic equilibrium also non-equilibrium and kinetically controlled precipitation/dissolution reactions. MKE allows the benefits of both approaches to be combined, and results are reported for the first 15 months of a 15-year study. Limitations imposed by an initial focus on mineral evolution rather than dissolution/precipitation kinetics led to multiple unknown parameters, hence uncertainties, in simulating dissolution kinetics. Notwithstanding, results appear positive for MKE to model the evolution of multiple mineral phases. This work enhances our understanding of these complex reactions, and we look forward to emerging analysis from this significant long-term project.

Finally, an alternative non-cement geopolymer is considered for soft Bangkok clays. Ground improvement seeks to improve the mechanical properties of marginal soils such that the amended strength renders them fit for purpose. High compressibility, soft Bangkok clay, with undrained shear strengths below 15 kPa and up to 140% natural moisture content, can certainly be considered

geotechnically marginal. Voottipruex *et al.* (2023) examine non-traditional techniques to allow surplus clay arisings from underground excavations to be reused beneficially as subgrade and engineering fill. Soft Bangkok clay was treated with a geopolymer based upon bagasse ash (BA), a by-product from combustion of dry pulpy fibrous sugarcane bagasse following sugar extraction, used in combination with fly ash from burning sub-bituminous coal, and a liquid alkaline activator. An optimum geopolymer binder mixture was identified. With 5% geopolymer addition, clays achieved a 28-day unconfined compressive strength of 380 kPa, meeting Thailand's minimum strength requirement for subgrade. These alternatives to landfill disposal of BA provide an exemplar of novel, sustainable, low-carbon-emission binders derived from waste products, and further research is merited on analogous precursor materials and applications.

I hope you enjoy the range of papers in this edition. Remember that you can access many recent papers in the Ahead of Print section on the ICE Virtual Library at www.icevirtuallibrary.com/toc/jenge/0/0

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