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Editorial

New Frontiers in Sustainable Geotechnics

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Citation: Jastrzębska, M.; Kazimierowicz-Frankowska, K.; Chiaro, G.; Rybak, J. New Frontiers in Sustainable Geotechnics. *Appl. Sci.* **2023**, *13*, 562. https://doi.org/10.3390/app13010562

Received: 21 November 2022
Accepted: 9 December 2022
Published: 31 December 2022

1. Introduction

With increasing ecological awareness, the idea of balanced development has become more popular. Meeting the socio-economic needs of humans in the context of maintaining the ecological balance is incredibly important. Geotechnical engineers are also faced with this difficult task. Currently, their work is focused on three wide areas: sustainable ground improvement, sustainable foundation engineering, and sustainable geotechnical design. All these areas create a raising demand for a precise evaluation of geotechnical parameters in field and laboratory testing, together with a cautious quality control of the geotechnical works. A social awareness should also be considered as one of the crucial factors in the planning of future research.

"What are the hottest topics in Geotechnical Engineering right now and in the next 10 years?" [1] This question asked in 2018 on ResearchGate by Mousa Bani Baker from Al-Zaytoonah University of Jordan still seems to be more relevant and is worth considering. Surprisingly, the most recommended answer to this question in ResearchGate was not focused to very sophisticated models and methods that are the domain of scientific world at the universities but rather to "the current situation in the developing countries, where there is a big need for *infrastructure*, *food* and *energy* for the growing populations".

Geotechnical Engineering can significantly influence the sustainability of infrastructure development because of its early position in the construction process [2]. A key focus should be the use of sustainable geotechnical materials, technologies, and applications, which are those that have very little negative impact on the environment, are easily available and affordable, are environmentally friendly and do not constitute any health hazard, and finally meet the design specifications in terms of durability and maintainability [3]. In this context, the reuse and recycling of industrial by-products, commercial wastes, and construction and demolition materials in geotechnical engineering applications, as well as development of new construction techniques and ground improvement methods, are progressively sought as they provide important benefits in terms of increased sustainability and reduced environmental impacts [4].

A collection of articles gathered under the title "New Frontiers in Sustainable Geotechnics" was intended to share various experiences in the following fields: (1) the use of alternate environmentally friendly materials in geotechnical constructions (such as embankments, slopes, and dams) and the reuse of waste materials (such as rubber waste, fly ash, natural, or artificial fibers) for soil improvement and stabilization; (2) innovative and energy-efficient ground improvement techniques; (3) bio-slope engineering; (4) the efficient use of geosynthetics; (5) the retrofitting and reuse of foundations, and foundations for energy extraction (e.g., termopile); (6) the use of underground space for the storage of energy; (7) the mining of shallow and deep geothermal energy; (8) making geo-structures reliable and resilient in the case of natural or man-made hazards; (9) design and modeling on the basis of geotechnical parameters derived; and (10) experiences with solving geotechnical challenges in marine engineering (such as predicting seabed liquefaction, designing marine foundations, and using anchors). Finally, in total, 18 contributions from various countries and diverse areas of research expertise were gathered to form the basis for comments listed in proceeding sections. Every listed contribution is supplemented with information taken directly from the articles' abstracts.

2. Laboratory Testing for Geotechnical Design

It must be underlined that the majority of contributions related to laboratory testing refer to "material science" applied in geotechnical engineering as opposed to the testing of geotechnical construction models. In the Editors' opinion, this is due to the higher universality of obtained results compared to the time and high costs of laboratory models of geotechnical structures (related to a singular case study). Nonetheless, all contributions listed below have a significant scientific and educational value.

2.1. Laboratory Testing and Theoretical Modeling of Deformations of Reinforced Soil Wall [5]

From a scientific point of view, an important element of this work was analyzing the effect of friction between the backfill and the side walls of the test box on the measured displacements. For the investigated case, it was shown that the impact of this element caused a reduction in the value of external loading of more than 60%. The final results may be particularly useful in the design process of structures used in transportation engineering (bridge abutments), where deformation limit values cannot be exceeded [5].

2.2. Influence of Laboratory Compaction Method on the Compaction and Strength Characteristics of Unbound and Cement-Bound Mixtures [6]

For mixtures with a higher cement content, the optimal moisture content difference depending on the laboratory compaction method used can be significant, so the laboratory compaction method should be chosen carefully, particularly for moisture-susceptible materials. This paper also reveals that by increasing the proportion of rubber in the mixture, the compaction and strength characteristics differ significantly when the compaction method is used. Therefore, when using alternative and insufficiently researched materials, the compaction method should also be chosen carefully [6].

2.3. Effect of Chitosan Solution on Low-Cohesivity Soil's Shear Modulus G Determined through Resonant Column and Torsional Shearing Tests [7]

In this study, the effect of using a biopolymer soil stabilizer on soil stiffness characteristics was investigated. It was shown that chitosan solution added to medium-grained materials substantially improves their shear modulus G (up to 3 times), even for solutions with relatively low chitosan concentrations (1.5 g of chitosan per 1 kg of dry silica sand). The results obtained in this study and the known chitosan properties suggest that chitosan solutions can be a very effective and eco-friendly short-term stabilizer for temporary geotechnical structures, e.g., working platforms [7].

2.4. The Effect of MICP on Physical and Mechanical Properties of Silt with Different Fine Particle Contents and Pore Ratios [8]

Microbial-induced calcium carbonate precipitation (MICP) is a new soil remediation technology which can improve the physical and mechanical properties of soil by transporting bacterial solution and cementation solution to loose soil and precipitating calcium carbonate precipitation between soil particles through microbial mineralization. Based on this technique, the effects of different fine particle contents and pore ratios on the physical and chemical properties of silt after reinforcement were studied. The content of calcium carbonate, the ability of silt to fixed bacteria, unconfined compressive strength (UCS), permeability coefficient, and microstructure of samples were determined. The results showed that the permeability coefficient of cured silt can be reduced by 1 to 4 orders of magnitude compared with that of untreated silt. In particular, the permeability of MICP-treated silt A is almost impermeable [8].

2.5. The Effects of Hydroxypropyl Methylcellulose (HPMC) on the Reinforcement of Sand by Microbial-Induced Calcium Carbonate Precipitation (MICP) [9]

Existing MICP treatment technology seems to be more suitable for deeper soils due to its high permeability. In this study, HPMC, a cohesive material combined with Sporosarcina pasteurii-induced calcium carbonate precipitation, was used to improve the surface layer of the soil. The addition of HPMC effectively improved the ammonia absorption rate and reduced the release of ammonia in the process of MICP technology, which is of great significance for environmental protection. The microstructure showed that the addition of HPMC and the increase in the number of treatments using MICP technology can make the surface structure of the specimens more compact, and the calcium carbonate can more effectively fill the pores and cement the soil particles, while the addition of HPMC may not change the calcium carbonate crystal type [9].

2.6. Geotechnical Evaluation of Diesel-Contaminated Clayey Soil [10]

Soil contamination by different hydrocarbons has rapidly expanded worldwide, surpassing the self-purification capacity of soils and increasing the number of contaminated sites. Although considerable effort has been devoted to studying the effects of diesel contamination on the geotechnical properties of soil, there is still limited available information about it. Presented results showed that the soil could only retain 12.6% of the added diesel and the excess was expulsed. At such a diesel concentration, the saturation rate of the soil was lower than 80%. Diesel contamination increased the plasticity and the internal friction angle of the soil, while its cohesion was considerably decreased. It should be noted that the matric suction of contaminated soil was lower than the one obtained for natural soil. However, its osmotic suction was considerably higher. This indicates that osmotic suction must be considered to evaluate the shear strength of contaminated soils [10].

2.7. Evaluating Biosedimentation for Strength Improvements in Acidic Soil [11]

Marine clay soils are problematic soils in the construction industry when they are subjected to construction loads. In order to stabilize the marine soil, new methods for soil improvement were built with biogrouting, and physical, biological, and chemical treatments were incorporated into the soil. To address issues with marine clay soil, this study aimed to minimize the high cost of a special foundation system and the use of non-environmentally friendly materials such as calcium-based binders, aside from the reduction of deformations caused by loading. The findings of this study can be used for acidic soils and to improve the soil's geotechnical behavior in general [11].

2.8. Strength and Compressibility of Ammonia–Soda Residue from the Solvay Sodium Plant [12]

This work discussed the results of an experimental study conducted to characterize the mechanical behavior of ammonia–soda residue (ASR). According to the physical state of ASR and the depth of sampling, two different evolutions of the critical state in the stress–strain space were observed. In light of the assessed stress–strain–strength behaviors, key design engineering parameters of ASR were calculated [12].

2.9. Modelling of Static Liquefaction of Partially Saturated Non-Cohesive Soils [13]

This study applied a semi-empirical model to predict the response of partially saturated soils under undrained conditions. The model proposed is based on an incremental equation describing the pre-failure undrained response of partially saturated non-cohesive soils during monotonic shearing in a standard triaxial test. Model predictions were confronted with the results of triaxial tests for two types of non-cohesive soils (quartz medium sand and copper ore post-flotation industrial tailings). Good agreement between experimental data and theoretical predictions was achieved [13].

3. Execution of Geotechnical Works and Quality Control Procedures

Contributions presented in this section provide a concise and precise description of the experimental results derived from field (real-life) experiments or different interpretations, as well as conclusions that can be drawn from the experimental testing of geomaterials.

3.1. Measurement-While-Drilling-Based Estimation of Dynamic Penetrometer Values Using Decision Trees and Random Forests [14]

Machine learning is a branch of artificial intelligence (AI) that involves the application of various algorithms to obtain information from large data sets. The objective of this study was to correlate the drilling parameters of deep foundation machinery (measurement-while-drilling, MWD) with a number of blows in the dynamic penetrometer test. Therefore, the drilling logs could be equated with said tests, providing information that can be easily interpreted by a geotechnical engineer and that can help to validate the design hypotheses. Decision trees and random forest algorithms have been used for this purpose. The ability of these algorithms to replicate the complex relationships between drilling parameters and terrain characteristics has allowed the penetrometric profile of the traversed soil to be a reliably reproduced [14].

3.2. An Experimental Study of Nailed Soil Slope Models: Effects of Building Foundation and Soil Characteristics [15]

A soil nailing system is a proven effective and economic method used to stabilize earth slopes from the external (factors increasing the shear stress) and internal (factors decreasing material strength) failure causes. It is found that the increase in soil density reduces both slopes facing displacement and building foundation settlements. The slope face displacement and footing settlement will increase with an increase in the width of the foundation and foundation position near the crest of the slope [15].

3.3. Behaviour of the Steel Welded Grid during a Simplified Pullout Test in Fine Sand [16]

This study considered the possibility of using steel gabion baskets made of welded mesh for a soil-strengthening function. It was unequivocally stated that as the stiffness of the steel grid itself increases, its strength increases during the pullout test, which is not so obvious in the case of popular steel woven meshes. In addition, it has been shown that steel-welded meshes with wire diameters less than 6 mm are suitable for soil reinforcement in structures with gabion facing, and the determined apparent friction coefficient (μ_k = 0.39–1.47) takes values similar to the friction coefficient given in references for welded meshes with larger diameters. This is a positive premise for starting further research on the use of wires of smaller diameters for welded mesh production used as soil reinforcement [16].

3.4. Recycling of End-of-Life Tires (ELTs) for Sustainable Geotechnical Applications: A New Zealand Perspective [17]

In this study, gravel and recycled granulated rubber were mixed to explore the possibility of obtaining synthetic granular geomaterials (with adequate geotechnical and environmental characteristics) that are suitable to act as structural fills for geotechnical applications including foundation systems for low-rise light-weight residential buildings. Moreover, an original framework with a set of geo-environmental criteria is proposed to demonstrate the use of gravel–rubber mixtures (GRMs) as structural fills [17].

3.5. The Influences of Local Glacitectonic Disturbance on Overconsolidated Clays for Upland Slope Stability Conditions: A Case Study [18]

This study used numerous calculation model analyses of the optional clay position in the context of slope stability conditions. A wide range of variable soil properties was taken into account, resulting from both lithogenesis and subsequent processes which disintegrate the original soil structure. Regarding the geological conditions of the slip surface, the use of classical computational methods and numerical modelling (FEM) was considered for comparative purposes. The results indicated that local changes in equilibrium conditions were affected by the different morphologies of the clay roof surface of the slope and alterations in strength characteristics on the slip surfaces. The findings of the study contribute to the sustainable spatial planning of near-slope regions [18].

3.6. Improving Mudstone Materials in Badland in Southwestern Taiwan by Increasing Density and Low-Cement Amount [19]

This study aimed to offer a new solution with the use of compaction techniques and also the addition of a small amount of cement used as soil amendment. The feasibility of this concept was examined by performing a series of tests, including the basic physical property test, the compaction test, the unconfined compression test, the static triaxial CU and UU tests, the consolidation test, the California bearing ratio (CBR) test, and the triaxial permeability test. The results of consolidation and the CBR test showed that improvement is possible by using low amounts of cement. Overall, the present method not only adheres to low-carbon and environmental protection requirements, but also verifies the feasibility of using compacted mudstone as an engineering material [19].

3.7. Probabilistic Analysis as a Method for Ground Freezing Depth Estimation [20]

This paper presented a probabilistic method to assess the depth of soil freezing. The obtained results are not the same as those given in the older Polish Standard which was based on simplified and limited data. The results confirm the impact of climate change on ground freezing depth [20].

3.8. Numerical Analysis of Pressure Profiles and Energy Dissipation across Stepped Spillways with Curved Risers [21]

Stepped spillway models with curved risers based on the increasing suspension angles were tested to check for improvements in energy dissipation and pressure distributions. It was estimated that curving the risers increases the energy dissipation up to three percent for lower flow rates, whereas this has no significant impact on energy dissipation for higher flow rates. It was found that in simply stepped spillways, lower steps dissipate more energy as compared to stepped spillways with curved risers where energy dissipation is shifted to higher steps. It was also observed that a higher energy dissipating step as experienced more negative pressures as compared to the lower energy dissipating step [21].

3.9. Monitoring the Impact of the Large Building Investments on the Neighborhood [22]

This article proposed the concept of monitoring buildings and infrastructure elements located near large construction investments The monitoring results allow corrections to be made in the technology of works (e.g., reductions in vibration amplitudes, the application of additional protections at excavations, etc.) or allow additional safety measures to be used. Currently, there are also monitoring systems used during the operation of completed facilities [22].

4. Summary

A brief overview of the articles submitted for this Special Issue "New Frontiers in Sustainable Geotechnics" allows us to draw the following general conclusions.

– By bearing in mind the geographical spread of the research presented in this Special Issue, it is clear that the topic of sustainable geotechnics is highly relevant for geotechnical engineers and researchers working in many different places and conditions.
– The ways in which individual issues and problems are presented by the authors indicate that, currently, in order to operate effectively in the field of geotechnics, knowledge from various fields should be combined. For example, performing laboratory tests, carrying out geotechnical works, and frequently overseeing quality control procedures require knowledge of the principles of modelling and a sound grasp of theory. Examples of such a comprehensive approach can be seen in papers

such as [5,13,20,21]. It should also be noted that various mathematical tools are used to solve complex geotechnical problems. In this Special Issue, the reader can find examples of the use of analytical and numerical methods for theoretical modelling. The reader also has an opportunity to become acquainted with the use of such tools to verify the accuracy of predicting experimental data.

– The sustainability in geotechnical engineering covers different aspects, allowing researchers to contribute in a wide variety of ways suitable for their particular interests. The reader can find different examples of the use of pro-ecological solutions and materials in geotechnics [5,15,17] and a description of an effective monitoring system for the analysis of large building investments' impact on the neighbourhood [22].

We would like to thank all the authors for their contributions and encourage all colleagues (both researchers and practical engineers) who are interested in the subject of sustainable development in geotechnics to read the articles presented in this Special Issue. Given the variety of topics, we hope that everyone finds items that interest them. We encourage everyone to join the growing community that is dedicated to sustainability in geotechnical engineering.

Author Contributions: Conceptualization, J.R.; writing—original draft preparation, J.R., K.K.-F. and G.C.; writing—review and editing, M.J.; visualization, M.J.; supervision, M.J.; project administration, M.J. All authors have read and agreed to the published version of the manuscript.

Acknowledgments: The authors would like to express their gratitude to Tracy Yu who was our Contact Editor and who helped us a lot with their competence and devotion in the editorial process.

Conflicts of Interest: The authors declare no conflict of interest.

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