

Editorial

Advance in Marine Geotechnical Engineering

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Marine geotechnical engineering is undergoing a rapid transformation driven by the increasing global demand for offshore energy, resilient coastal infrastructure, and sustainable seabed utilization. Traditionally focused on foundation design for offshore structures, the field now encompasses a wide range of challenges, including deep-sea mineral exploration, subsea cable routing, offshore wind turbine installations, and the assessment of submarine slope stability in response to climate change-induced events.

Marine geotechnical engineering involves the application of geoscientific knowledge and innovative engineering approaches to investigate and characterize seafloor materials [Contribution 1, Contribution 10]. Despite ongoing progress, the mechanical behavior of seafloor soils—particularly in response to infrastructure development—remains insufficiently understood. Tools such as cone penetration testing with pore pressure measurement, piezocone testing, and advanced geophysical surveys have enhanced the resolution of site investigations [1,2]. Furthermore, coupled hydro-mechanical modeling techniques now allow for more accurate simulations of soil behavior under cyclic and dynamic loading, which is critical for offshore wind farms and seismic-prone marine environments [Contribution 5, Contribution 6, Contribution 13, [3–6]]. Given the increasing complexity and scale of offshore structures, such as wind farms, pipelines, and subsea foundations, addressing this knowledge gap is more critical than ever.

Emerging topics such as bio-mediated soil improvement, methane hydrate-bearing sediments, and the impact of climate-driven processes like thawing permafrost and ocean acidification on soil properties are gaining prominence [Contribution 1, [4–6]]. Additionally, the integration of machine learning and data analytics into marine geotechnics is beginning to transform design optimization and risk assessment processes.

This Special Issue brings together recent research contributions that reflect the breadth and depth of innovation in marine geotechnical engineering. The selected articles highlight experimental breakthroughs, novel field techniques, and modeling strategies aimed at addressing the pressing engineering and environmental challenges facing offshore and coastal development. Furthermore, this Special Issue highlights recent theoretical, numerical, experimental, and applied contributions that enhance our understanding of seafloor behavior and improve the design, construction, and risk mitigation strategies for offshore and coastal infrastructure [Contribution 3, Contribution 4, Contribution 8]

My hope is that this collection of papers serves as a valuable reference for researchers, engineers, and policymakers working at the forefront of marine geotechnics, and that it inspires further interdisciplinary collaboration to sustainably develop and protect our ocean-based infrastructure. This Special Issue concentrates on the aforementioned problems, obtaining some interesting conclusions [Contribution 13]. The main contributions of each article are presented below.

Contribution 1: This study experimentally investigates the dynamic shear modulus behavior of saturated coral sand under complex consolidation conditions using multi-stage strain-controlled undrained cyclic shear tests. The research evaluates the influence of key



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consolidation parameters—effective mean principal stress (p'_0), consolidation ratio (k_c), consolidation direction angle (α_0), and intermediate principal stress coefficient (b)—on the maximum shear modulus (G_0), reference shear strain (γ_r), and shear modulus reduction (G). New indices (μG_0 and $\mu \gamma_r$) are proposed to improve predictions of G_0 and γ_r , and the Davidenkov model is validated for normalized shear modulus-strain relationships. The proposed model demonstrates high accuracy with deviations within $\pm 10\%$, enhancing the understanding and prediction of coral sand behavior in marine geotechnical applications.

Contribution 2: This study used resonant-column tests to analyze how the shear modulus (G) and damping ratio (D) of Chinese marine clays vary with depth (H , via σ_m) and shear strain (γ). A novel BPNN model was developed to predict G and D accurately without fitting parameters, showing robust performance across conditions.

Contribution 3: This study contributes to the design and protection of artificial sandy beaches by introducing a novel beach profile that enhances berm stability and resists erosion. Using XBeach modeling, it identifies erosion patterns under different wave conditions and evaluates both engineering and biological methods—such as plant root systems—to reduce sediment loss, offering practical insights for sustainable coastal development.

Contribution 4: This study introduces a numerical approach using the Coupled Eulerian–Lagrangian (CEL) method to evaluate the effect of confining stress on undrained shear strength in marine sediments. It proposes a new linear strength model that accounts for confining stress and corrects for vane size effects, improving the accuracy of shear strength estimation for sensitive clays in offshore engineering.

Contribution 5: This paper investigated the monotonic and cyclic behavior of a monopile-supported offshore wind turbine in sand using centrifuge testing. Under monotonic loading, the ultimate lateral capacity and bending moment distribution were assessed at different load levels. Cyclic tests revealed that rotational stiffness decreased with higher loading levels. In Fatigue Limit State (FLS) and Service Limit State (SLS) conditions, stiffness remained stable across cycles, whereas in the Ultimate Limit State (ULS), stiffness initially increased before stabilizing. The loading rate weakened monopile–soil interaction, as evidenced by bending moment trends. These findings provide critical insights for optimizing monopile design under cyclic lateral loads.

Contribution 6: In engineering applications, the formation of soil plugs within pipe piles is an inherent phenomenon that must be accounted for to enhance the accuracy of dynamic response analyses of pile group foundations. Furthermore, natural soils are typically stratified and exhibit radial heterogeneity due to sedimentary processes. Therefore, conducting dynamic response analyses of pile groups in layered and anisotropic soil conditions is essential as it offers more realistic and practically relevant insights for geotechnical design and engineering practice.

Contribution 7: This study enhances the understanding of vacuum pressure formation and drainage efficiency in SVD systems for marine reclamation. It develops a vacuum pressure model, analyzes key influencing factors, performs global sensitivity analysis, and calculates the theoretical vacuum limit, providing a foundation for optimizing SVD design and performance.

Contribution 8: This paper provides a micro-to-macro understanding of suction anchor–sandy soil interactions under slidable mooring loads, highlighting the critical role of interface friction. Using coupled DEM–FEM simulations validated by centrifuge tests, the research establishes how interface friction influences pullout resistance, displacement, rotation, and failure patterns, offering valuable insights for the design of mooring systems in marine engineering.

Contribution 9: The study of Sun et al. enhances our understanding of monopile foundation stability in offshore wind projects by incorporating the impact of submarine landslide loads, alongside traditional environmental forces such as wind, wave, and current. A validated finite element model is used to simulate complex lateral loading scenarios,

revealing how landslide parameters and seabed strength influence monopile displacement, rotation, and bending. The research proposes an instability criterion, offering valuable guidance for safer foundation design in extreme marine environments.

Contribution 10: This paper investigates the mechanical performance of concrete incorporating river and sea pebbles as partial or full substitutes for traditional gravel in offshore and island construction. Using Digital Image Correlation (DIC), it reveals that increased substitution reduces compressive strength and alters failure modes due to interfacial slipping between pebbles and mortar. The findings offer critical insights into the compressive behavior and deformation characteristics of eco-friendly pebble-based concretes for marine engineering applications.

Contribution 11: He et al. investigate the mechanical behavior of weathered residual soil—the dominant seabed material in southeastern China’s rocky offshore wind farm zones—and its impact on monopile foundation performance. Through dynamic triaxial tests and numerical simulations, the research reveals key insights into soil stiffness degradation and cumulative strain and evaluates monopile behavior under combined wind and wave loading. The findings offer a theoretical foundation for designing offshore wind turbine foundations in rock-based seabeds, addressing a critical gap in current practice.

Contribution 12: This review studies the feasibility of using helical piles to anchor floating offshore wind platforms in deeper waters, addressing the sector’s push toward larger wind farms in complex marine environments. Through 3D numerical modeling, it identifies optimal plate positioning (Zh/Z ratios) for helical piles under varying load inclinations and shaft diameters. The results provide design guidelines for ensuring load-bearing efficiency and stability, supporting the advancement of cost-effective and resilient mooring systems in the offshore wind industry.

Contribution 13: This review highlights the urgent need for accessible geotechnical data in Greece’s rapidly developing offshore energy infrastructure, including submarine cables, pipelines, and wind parks. It synthesizes current knowledge on surficial sediment behavior in the Aegean and Ionian Seas and identifies challenges in sampling and interpreting CPTu data. Emphasizing slope instability mechanisms linked to weak layers, gas presence, and seismic loading, the study advocates for the establishment of a national geological/geotechnical database to support future marine infrastructure planning and academic research.

I am pleased to present a collection of articles that reflect the interdisciplinary nature of marine geotechnical engineering. These contributions not only advance fundamental understanding but also provide practical insights that are vital for ensuring the safety, sustainability, and performance of marine infrastructure.

I extend my sincere gratitude to all the contributing authors and reviewers who have made this Special Issue possible. I hope that the findings presented here will inspire further innovation and collaboration in the evolving field of marine geotechnics.

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Conflicts of Interest: The author declares no conflicts of interest.

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