Journal of
Marine Science and Engineering

MDPI

Editorial

Engineering Properties of Marine Soils and Offshore Foundations

Youkou Dong [1], Dengfeng Fu [2] and Xiaowei Feng [3,*]

1 College of Marine Science and Technology, China University of Geosciences, 388 Lumo Road, Wuhan 430074, China; dongyk@cug.edu.cn
2 Key Laboratory of Marine Environment and Ecology, Ministry of Education, Ocean University of China, Qingdao 266100, China; dengfeng.fu@ouc.edu.cn
3 State Key Laboratory of Costal and Offshore Engineering, Dalian University of Technology, Dalian 116024, China
* Correspondence: xfeng@dlut.edu.cn

check for updates

Citation: Dong, Y.; Fu, D.; Feng, X. Engineering Properties of Marine Soils and Offshore Foundations. *J. Mar. Sci. Eng.* **2024**, *12*, 2077. https://doi.org/10.3390/jmse12112077

Received: 5 November 2024
Accepted: 11 November 2024
Published: 18 November 2024

To reduce greenhouse gas emissions and enhance energy security, the role of renewable energy in the global energy structure is becoming increasingly significant. Within this context, marine clean energy holds an important position, encompassing tidal energy, wind energy, solar energy and combustible ice found in the ocean. To achieve the extraction and utilization of these energy sources, the development of marine engineering research has become one of the areas of growing interest.

In the field of marine engineering, it is crucial to thoroughly understand the engineering characteristics of marine soils, foundation systems and offshore structures to better guide the work during design, construction, and maintenance phases. This Special Issue includes a total of 15 relevant papers to facilitate a broader understanding of the latest advancements in this research area and to promote its development. Among these, six papers focus on foundation treatment and foundation engineering properties, five papers are related to offshore engineering foundations, two papers address the inspection and maintenance of offshore structures, and two papers pertain to the exploitation of marine resources.

In offshore engineering, subsea pipelines are particularly vulnerable to fatigue cracks due to the intricacies of their manufacturing processes and the harsh operating environments they endure under prolonged cyclic loads. A comprehensive and high-precision detection method for subsea pipeline damage can effectively mitigate the potential safety hazards. Peng et al. [1] proposed a three-dimensional ultrasonic imaging detection method modified for cylindrical coordinates, which adeptly addresses the complex three-dimensional wave fields involved in the inspection of subsea cylindrical pipelines. The study generalizes the three-dimensional staggered-grid finite-difference method from Cartesian coordinates to cylindrical ones and simulates the full wave field in the three-dimensional space of the pipeline. After processing the ultrasonic recording signals, the method utilizes reverse time migration and cross-correlation imaging conditions to achieve three-dimensional reverse time migration imaging of defects in subsea pipelines.

Accurate surveying is essential for coastal engineering. However, conventional seismic exploration methods have become inadequate due to the challenges posed by seismic waves traversing weathered zones and reaching the necessary depths. To address the limitations of existing cross-well imaging technologies, Peng et al. [2] investigated the application of three-dimensional (3D) cross-well elastic reverse time migration (RTM) imaging, utilizing multi-wave and multi-component techniques in coastal engineering surveys. They achieved precise decomposition of vector compressional waves (P-waves) and shear waves (S-waves) through two wavefield decoupling algorithms, without any amplitude or phase distortion. Furthermore, the pressure component of the compressional wave was extracted, enabling subsequent independent imaging. This method effectively leverages the elastic properties of the soil media through multi-wave and multi-component elastic wave RTM imaging technology, providing valuable insights into subsurface rock layers, interfaces, and other structural distributions for coastal engineering projects without incurring additional costs. During the construction and operation of nearshore engineering structures, numerous engineering challenges emerge that necessitate resolution. This Special Issue comprises papers addressing the pile driving in calcareous sand foundations, the influence of structures on siliceous sands, studies on the permeability of back fill materials with a high clay content, research on the improvement and reuse of marine mud and coral sand, and methods for ground improvement. Among these contributions, Gao et al. [3] employed model experiments in conjunction with pressure sensors and close-range photogrammetry techniques to investigate the mechanical response and deformation characteristics of calcareous sands during pile driving and installation. Various types of piles were analyzed, including pipe piles, square piles, and partially closed ended steel pipe piles. The experimental results revealed that during pile driving, the tip resistance of the different piles increased with penetration depth; however, significant fluctuations in tip resistance were also observed due to particle breakage and energy dissipation in the calcareous sand. The extent of particle breakage and the variations in internal stress differed among the pile types, subsequently influencing the tip resistance. Chen et al. [4] examined the particle breakage characteristics of marine siliceous sand under high-pressure conditions. A series of conventional triaxial tests were conducted on siliceous sand subjected to confining pressures ranging from 2 MPa to 8 MPa. The results demonstrated that as the particle breakage index increased, the fractal dimension exhibited an upward convex hyperbolic trend. The boundary radius at which siliceous sand particles displayed fractal characteristics was determined to be approximately 0.4 mm. These experimental findings provide reference and supplementary data for analyzing particle breakage in sandy soils. Shan et al. [5] utilized a stepwise vacuum preloading method in the laboratory to reinforce back fill materials with a high clay content derived from dredging vessels. They assessed the pore structure and permeability characteristics of the dredged fill under varying vacuum pressures. Correlation analysis indicated a strong relationship between a large pore content and the permeability coefficient, which can be employed to describe the permeability characteristics of the soil. The findings of this study offer valuable insights for enhancing reinforcement methods and evaluating the effectiveness of dredged fill in engineering practice. Han et al. [6] proposed a method that integrates flocculation solidification with high-pressure filtration for the effective disposal of marine mud, demonstrating advantages in dewatering performance, material savings, and the shear strength of the treated mud. Yao et al. [7] explored the effects of vibration flotation and impact compaction on the densification and load-carrying capacity of coral sand foundations. Field tests were conducted in four different areas, encompassing plate load tests, California Bearing Ratio (CBR) tests, density measurements, dynamic penetration tests (DPT), and settlement monitoring. The results indicated that coral sand possesses favorable characteristics for foundation construction. The seepage and self-weight consolidation following land reclamation significantly enhanced the compaction of the coral sand, thereby meeting the requirements for areas with lower load-carrying capacities. Both vibration flotation and impact compaction techniques can substantially improve the load-carrying capacity of the foundation, with minimal differences between the two methods. Due to its simplicity and rapid construction speed, the impact compaction method is regarded as the most effective approach for improving coral sands. The DPT results suggested that the reinforcement effects of both vibration flotation and impact compaction methods are less pronounced in deeper foundations compared to surface layers. This study provides valuable insights for optimizing foundation treatment in coral reef reclamation projects. Based on the life cycle assessment (LCA) method, Yu et al. [8] developed an ontological framework for the sustainable assessment of sustainable cementitious systems (SCSs) and evaluated the effects of fineness, carbonation degree, and substitution rate of steel slag on the sustainability of SCS. The results indicated that, compared to pure cement stabilized soil (S-C), using 10% and 20% finely ground steel slag carbonated for 18 h (FSS-C-18h) as a cement substitute can significantly reduce carbon emissions and costs while achieving strength performance comparable to that of S-C. This demonstrates the feasibility of utilizing steel slag as a sustainable supplementary cementitious material for stabilizing soft soils.

In offshore structures, the stability of the foundation is a critical determinant of the overall structural integrity. This Special Issue encompasses studies on anchor rod foundations and bucket foundations. Notably, Yuan et al. [9] and Li et al. [10] investigated anchor rod foundations. Yuan et al. [9] proposed a novel unified method for estimating the uplift capacity of both deep single- and multi-helix anchors, based on the investigation of failure mechanisms. This method utilizes a modified Mohr–Coulomb model that incorporates strain softening in sand, alongside Euler–Lagrange coupling techniques for finite element analysis to ascertain deep failure modes. A simplified rupture surface was introduced, and an equation for estimating uplift capacity was derived using the limit equilibrium method. Two critical factors were examined including the lateral earth pressure coefficient and the average internal friction angle. The validity of this method was confirmed through comparisons with the results of centrifuge tests. In contrast, Li et al. [10] conducted model tests on torpedo anchors to investigate the effects of the uplift angle and bearing plate radius on the load-carrying behavior of T-type, EN3-type, EN4-type, and EC-type torpedo anchors. Research by Jiang et al. [11], Wang et al. [12], and Lian et al. [13] has concentrated on bucket foundations. Jiang et al. [11] conducted centrifuge tests to investigate the response of a single bucket foundation subjected to monotonic and symmetric cyclic loads in over-consolidated clay. The results indicated that the discrepancy between the monotonic vertical bearing capacity measured from the centrifuge tests and that obtained from the finite element results was less than 6%. This study examined the effects of the cyclic load amplitude (ranging from 37% to 64% of the vertical bearing capacity) and the number of cycles on the accumulation of vertical displacement and the evolution of stiffness. Simplified methods were proposed for predicting both dimensional and non-dimensional stiffness evolution. Wang et al. [12] explored the load-carrying behavior of tripod-bucket foundations through a series of physical modelling tests and numerical simulations. They observed that the center of rotation of the foundation diminished as the aspect ratio (L/D) decreased, leading to the transition of the failure mechanism from rotation to uplift. The impact of soil pressure on the bucket was studied through finite element analysis and model testing, which elucidated the failure mechanisms of tripod-bucket foundations with varying L/D ratios. A revised method is proposed to estimate the moment bearing capacity of the tripod bucket foundation under horizontal and moment loads. This method is thought to be more convenient and applicable in practice. Lian et al. [13] investigated composite bucket foundations (CBFs) with significant transition sections, initially developing a finite element method (FEM) to characterize the rigid deformation performance of these transition components. To clarify the impact of the transition section on wind turbines equipped with CBFs, the transition section was simplified as a rigid body, and a three-DOF theoretical model was established. This model accounted for horizontal and rotational foundation stiffness to illustrate the constraint effects below the mud line. A sensitivity analysis was conducted on the parameters of the transition section, including mass, moment of inertia, and center of mass height. Furthermore, the vibration characteristics of the CBF structure under various operational load conditions were compared between the theoretical model and field data. The results indicated that the relative error between the theoretical model and finite element model ranged from 3.78% to 5.03%, meeting accuracy requirements. The parameters of the transition section significantly influenced the natural frequency, foundation stiffness, and vibration response of wind turbines with CBF. Compared to wind loads and 1P loads, the effect of 3P loads was more pronounced when the 3P frequency approached the natural frequency of the wind turbine. This Special Issue also encompasses research focused on maintaining the safety and stability of offshore structures and resource extraction. Dong et al. [14] examined submarine pipelines subjected to the impacts of giant waves generated by natural disasters, such as hurricanes and tsunamis. The influence of various factors, including insulation layer configuration, pipeline structure, and marine environment, were investigated on the protective performance of the insulation layer. Wei et al. [15], utilizing critical state theory, proposed a predictive model for the drained shear strength of hydrate-bearing fine-grained sediments. They conducted multiple consolidated undrained triaxial tests on hydrate-bearing fine samples from the Shen hu area of the South China Sea, and analyzed the influence of effective consolidation stress and hydrate saturation on the drained shear strength.

In summary, the articles published in this Special Issue encompass a wide range of research topics related to the engineering characteristics of marine soils and offshore foundations. All articles are open access, aiming to provide readers with a comprehensive understanding of the advancements in marine engineering research. Furthermore, it is hoped that this foundation will inspire readers to pursue more in-depth research and thereby advance the development of this field.

Acknowledgments: As a Guest Editor of the Special Issue "Engineering Properties of Marine Soils and Offshore Foundations", I would like to express my deep appreciation to all the authors whose valuable work was published under this Special Issue and thus contributed to the success of the edition.

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

References

1. Peng, D.; Cheng, F.; She, X.; Zheng, Y.; Tang, Y.; Fan, Z. Three-Dimensional Ultrasonic Reverse-Time Migration Imaging of Submarine Pipeline Nondestructive Testing in Cylindrical Coordinates. *J. Mar. Sci. Eng.* **2023**, *11*, 1459. [CrossRef]
2. Peng, D.; Cheng, F.; Xu, H.; Zong, Y. An Application of 3D Cross-Well Elastic Reverse Time Migration Imaging Based on the Multi-Wave and Multi-Component Technique in Coastal Engineering Exploration. *J. Mar. Sci. Eng.* **2024**, *12*, 522. [CrossRef]
3. Gao, Y.; Guo, Z.; Yuan, Q. Pile Driving and the Setup Effect and Underlying Mechanism for Different Pile Types in Calcareous Sand Foundations. *J. Mar. Sci. Eng.* **2024**, *12*, 133. [CrossRef]
4. Chen, R.; Zhao, T.; Wu, Z.; Hao, D.; Xue, N.; Yuan, C. Experimental Investigation on Particle Breakage Behavior of Marine Silica Sand under High-Stress Triaxial Shear. *J. Mar. Sci. Eng.* **2023**, *11*, 1825. [CrossRef]
5. Shan, W.; Yuan, X.; Chen, H.-e.; Li, X.; Li, J. Permeability of High Clay Content Dredger Fill Treated by Step Vacuum Preloading: Pore Distribution Analysis. *J. Mar. Sci. Eng.* **2023**, *11*, 1714. [CrossRef]
6. Han, C.; Xie, H.; Bai, B.; Zhang, R.; Gao, Y.; Zhao, Z. Experimental Study on Mechanical Properties of Marine Mud Slurry Treated by Flocculation-Solidification-High Pressure Filtration Combined Method. *J. Mar. Sci. Eng.* **2023**, *11*, 2270. [CrossRef]
7. Yao, T.; Li, W. An Evaluation of Treatment Effectiveness for Reclaimed Coral Sand Foundation in the South China Sea. *J. Mar. Sci. Eng.* **2023**, *11*, 2288. [CrossRef]
8. Yu, C.; Yuan, J.; Cui, C.; Zhao, J.; Liu, F.; Li, G. Ontology Framework for Sustainability Evaluation of Cement–Steel-Slag-Stabilized Soft Soil Based on Life Cycle Assessment Approach. *J. Mar. Sci. Eng.* **2023**, *11*, 1418. [CrossRef]
9. Yuan, C.; Hao, D.; Chen, R.; Zhang, N. Numerical Investigation of Uplift Failure Mode and Capacity Estimation for Deep Helical Anchors in Sand. *J. Mar. Sci. Eng.* **2023**, *11*, 1547. [CrossRef]
10. Li, G.; Zhang, J.; Liu, J.; Xi, Y.; Kou, H. Pullout Bearing Capacity of End-Bearing Torpedo Anchors in Cohesive Soil Seabed. *J. Mar. Sci. Eng.* **2023**, *11*, 1548. [CrossRef]
11. Jiang, J.; Wang, D.; Fu, D. Vertical Monotonic and Cyclic Responses of a Bucket in Over-Consolidated Clay. *J. Mar. Sci. Eng.* **2023**, *11*, 2044. [CrossRef]
12. Wang, X.; Zhao, X.-L.; Sui, S.-H.; Hu, Z.-B.; Deng, W.-N.; Song, Q.-M. Bearing Characteristics of Tripod Bucket Foundation under Horizontal and Moment Load in Sand. *J. Mar. Sci. Eng.* **2023**, *11*, 1631. [CrossRef]
13. Lian, J.; Zhou, H.; Dong, X. A Theoretical Methodology and Measurement of Dynamic Characteristics of Wind Turbines with Composite Bucket Foundations. *J. Mar. Sci. Eng.* **2024**, *12*, 106. [CrossRef]
14. Dong, Y.; Zhao, E.; Cui, L.; Li, Y.; Wang, Y. Dynamic Performance of Suspended Pipelines with Permeable Wrappers under Solitary Waves. *J. Mar. Sci. Eng.* **2023**, *11*, 1872. [CrossRef]
15. Wei, R.; Liu, L.; Jia, C.; Dong, X.; Bu, Q.; Zhang, Y.; Liu, C.; Wu, N. Undrained Triaxial Shear Tests on Hydrate-Bearing Fine-Grained Sediments from the Shenhu Area of South China Sea. *J. Mar. Sci. Eng.* **2023**, *11*, 1604. [CrossRef]