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Editorial

Instability and Failure of Subsea Structures

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Subsea engineering structures are an evolutive system with high diversity, e.g., submarine pipelines, foundations for offshore platforms or wind turbines, deep-sea submersibles, and underwater tunnels. Such subsea engineering structures are generally designed to have a reasonably long and safe operational life. Nevertheless, they are vulnerable to extreme marine environmental conditions, such as breaking waves, submarine landslides, and operational loads. As such, the safety and resilience of the subsea infrastructural developments are extremely dependent on the stability, deformability, ductility and strength of subsea structures or materials. The complicated interactions between the environmental fluids, subsea structures and the seabed could bring numerous geohazards, foundation instabilities, structural or material failures.

The Special Issue *Instability and Failure of Subsea Structures* includes eighteen contributions [1–18] focusing on fundamental and applied studies that may contribute to an understanding of and improvement in subsea structures (e.g., pile or monopile foundations [1–4]; spubcan foundations [5], suction caissons [6], subsea mattress [7], deep-water anchors [8], submarine pipelines [9–11], underwater tunnel linings [12], and subsea shuttle tanker [13,14]), and seabed soils or materials for deep-sea submersibles (e.g., marine sands [15], soft soils [16], gas hydrate-bearing sediments [17], and Ti-6Al-4V ELI alloys [18]). A brief overview of all the contributions is given as follows, emphasizing the main topics and the findings of their analyses.

(1) **Pile or Monopile Foundations**

To reveal the process of a solitary wave interacting with a pile installed on a sloping seabed, a numerical model was developed on the basis of volume-averaged Reynolds averaged Navier–Stokes equations [1]. The maximum breaking wave forces on the pile were found to occur not only when waves break just in front of the pile, but also when a secondary wave wall slams against the pile after wave-breaking.

To simulate the interaction between submarine landslides and a monopile, a three-dimensional water-slurry biphasic model was developed in [2]. The numerical results indicated that the debris flow height on the interaction force is significant at low-velocity stages, while the peak force representing a hazard level for the monopile is non-negligible under high-flow-velocity and low-flow-height conditions.

By using the finite-element method, incorporating a state-dependent constitutive model of sand, the influence of pile diameter and aspect ratio on the lateral response of monopiles was numerically investigated [3]. It was revealed that the rotation failure mechanism of a rigid pile is independent of pile diameter and aspect ratio.

To evaluate the service life and lateral bearing behavior of reinforced concrete piles subjected to marine environmental loads and varying temperatures, both deterministic and probabilistic models were proposed [4]. It was indicated that a rise in temperature can decrease the service life of piles, and the lifespans predicted by the probabilistic method are more conservative than those predicted by the deterministic one.

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(2) **Spubcan, Suction Caissons, Subsea Mattress, and Deepwater Anchors**

To estimate the peak resistance of a spudcan foundation in clay–sand–clay deposits, a predictive model was proposed in [5] by incorporating the bearing capacity depth factor and the protruded soil plug in the bottom clay layer into the formulation.

By employing an Arbitrary Lagrangian–Eulerian (ALE) large-deformation solid–fluid coupled finite element method (FEM), the changes in suction pressure and the seepage field were investigated during the suction caisson installation in sand [6]. An ALE solid–fluid coupled FEM is capable of simulating both jacked penetration and suction penetration caisson installation processes in the sand observed in centrifuge tests.

A physical model testing method was proposed for measuring the hydrodynamic force coefficients of an object, and applied to an articulated concrete mattress placed on a flat surface under steady current conditions [7]. This testing method was expected to be applicable to a wide range of structures, bed surfaces and flow conditions.

A unified model was introduced in [8] to analyze the comprehensive behaviors of deep-water anchors in both clayey and sandy seabeds, including unified concepts, mechanical models, and analytical procedures. By utilizing the least-force principle, various anchor properties, such as the ultimate pullout capacity, failure mode, movement direction, embedment loss, and kinematic trajectory, can all be determined using the combination and analysis of three behaviors, i.e., diving, pulling out, and keying.

(3) **Submarine Pipelines, Underwater Tunnel Linings, and Subsea Shuttle Tanker**

Two-dimensional numerical simulations were performed in [9] to investigate scour beneath a single pipeline and piggyback pipelines subjected to an oscillatory flow condition at a Keulegan–Carpenter (KC) number of 11 using an open-source SedFoam. The turbulence flow was resolved using the two-phase modified k-ω 2006 model, and the particle stresses due to the binary collisions and enduring contacts among the sediments were modeled using the rheology model of granular flow.

To simulate the three-dimensional scour around a pipeline of finite length, a numerical tool was established on the basis of the Ansys FLUENT flow solver [10]. A series of simulations were subsequently carried out to discover how the scour hole depends on the pipeline length.

To reveal the competition mechanism between the lateral instability and tunnel erosion of a submarine pipeline, a coupled flow-seepage-elastoplastic modeling approach was proposed [11]. The instability envelope for the flow–pipe–soil interaction was established, which could be described by three parameters, i.e., the critical flow velocity, the embedment-to-diameter ratio, and the non-dimensional submerged weight of the pipe.

To investigate the load-bearing mechanism of underwater mined-tunnel linings, some model tests were performed, employing an equivalent water loading device and a surrounding rock-pressure complex loading device [12]. The progressive failure characteristics for the waterproof and drainage types of lining structures were observed and analyzed, indicating that the waterproof lining has a higher water-pressure resistance than the drainage lining.

The Subsea Shuttle Tanker (SST) is an alternative solution to the transportation of liquid carbon dioxide (CO_2) from existing offshore/land facilities to marginal subsea fields. The resistance of the SST at an operating forward speed, when subjected to an incoming current, was computed using a delayed, detached, eddy-simulation method, which combines features of Reynolds-averaged Navier–Stokes simulation in the attached boundary layer parts at the near-wall regions, and large-eddy simulation at the unsteady, separated regions near the propeller [13]. The technical–economic feasibility analysis of SST was further performed in [14].

(4) **Properties of Seabed Soils and the Materials for Deep-Sea Submersibles**

To investigate the stiffness degradation and liquefaction characteristics of marine sand in the offshore wind-farm construction site at the East Nanao area in Guangdong Province of China, resonant column and undrained cyclic triaxial tests were conducted [15]. Based on the experimental data, a model for predicting shear modulus was established, as well as a model extended from Seed's pore pressure development model.

To reveal the influential mechanism of overlapping water in the scenario of underwater vacuum preloading with prefabricated vertical drains (PVDs), small-strain finite-element drained analyses were systematically conducted with the separated analysis, schemes considering suction-induced consolidation, seepage and their combinations [16]. Based on the numerical results, a theoretical approach was proposed to estimate the time-dependent, non-uniform settlement along the surface of improved soft soils.

To investigate the shear band initiation within gas hydrate-bearing sediments, triaxial compression tests were conducted, combined with a computer tomography (CT) scan [17]. Their observations indicated that the shear band either occurred in a single oblique line or inter-cross lines depending on the hydrate saturation, the effective confining pressure and the initial distribution of the gas hydrate.

The dwell fatigue (also termed as cold-creep fatigue) behavior of titanium alloys has drawn great attention, due to some of the components in the field of aviation and deep-sea that were subjected to dwell fatigue loadings during service. The effects of notches and defects on the dwell fatigue mechanism and fatigue life of the Ti-6Al-4V ELI alloy used in deep-sea submersibles were experimentally investigated under the load control mode [18]. It was indicated that the dwell fatigue is insensitive to the defect size (190–438 μm) compared to conventional fatigue. Notched specimens all present fatigue failure mode under dwell fatigue testing, and the dwell fatigue life is higher than that of the smooth specimen at the same local maximum stress.

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