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Editorial

Endeavours to achieve sustainable marine infrastructures: A new “window” for the application of biomineralization in marine engineering

1. Microbially induced corrosion on marine concrete

The acceleration of urbanization has seen a change in marine engineering. Coastal cities increasingly expedite the development and utilization of oceanic resources for social-economic development. Concrete materials are widely used in the construction of offshore and marine engineering practices. However, marine environments are aggressively threatening the durability of concrete structures, due to complex corrosion conditions, including physical degradation, chemical corrosion, and microbially induced corrosion (MIC). In past decades, different approaches have been developed to inhibit the physical degradation and chemical corrosion of concrete materials. Unfortunately, the consideration of MIC was not sufficient and the recognition of protection against MIC remains limited among researchers and engineers in civil, environmental, and material fields. This is particularly concerning as MIC commonly occurs in harsh environments where corrosive microorganisms are present, leading to concrete structures being prone to cracking, spalling, and degradation (Wei et al., 2013). For example, the expected lifespan of these structures can decrease dramatically from 100 years to as little as 30–50 years, and under extreme conditions, even down to 10–20 years (Monteny et al., 2000; Grengg et al., 2018). In this scenario, the inhibition of MIC is critical to increasing the service time of concrete structures in marine environments, beneficial for promoting the sustainability of marine infrastructures.

2. Biomineralization for corrosion inhibition

However, some developed concrete corrosion inhibition strategies (e.g., biocides, quorum sensing, new concrete formulations; supplementary cementitious materials addition) have their limitations. Recently, biomineralization has garnered significant attention in the fields of geotechnical, environmental, and material engineering (Phillips et al., 2013; Martinez et al., 2022; Wang et al., 2023b), owing to its promising potential for applications such as soil stabilization (Chu et al. 2014; Terzis & Laloui, 2019; Gowthaman et al., 2020; Shi et al., 2023; Xiao et al., 2022, 2024), soil erosion control (Hamdan & Kavazanjian, 2016; Jiang & Soga, 2017; Sun et al., 2021, 2022; Wang et al., 2024), liquefaction resistance (Montoya et al., 2013), removal of heavy metals (Lin et al., 2023), water treatment (Liu et al., 2023), and self-healing concrete (De Muynck et al. 2010; De Belie et al., 2018; Al-Tabbaa et al., 2019; Qian et al., 2021) et cetera.

The biomineralization technique provides novel insights into the isolation of marine concrete and corrosion inhibition. Sun et al. (2024) innovatively applied the biomineralization technique to inhibit MIC and isolate concrete structures from corrosive bacteria for protection. The core of MIC inhibition through biomineralization lies in the depressant of microbes, significantly decreasing the total/relative abundances of dominant corrosive bacteria. Moreover, the formed biomineralization film with precipitates acts as protective layers on the concrete surface, isolating concretes away from corrosive medium and providing the first hindrance of physical degradation as well as chemical corrosion in marine environments (Sun et al., 2024). Furthermore, the biomineralization technique led to lower surface sulfate concentrations and undermined the penetration of aggressive ions into the concrete, similarly decreasing internal sulfate levels. Meanwhile, the results demonstrate that this strategy is ecologically sustainable and exerts minimal influence on native marine biofilm communities.

3. New “window” for the application of biomineralization

The study conducted by Sun et al. (2024) has demonstrated the efficacy of employing the biomineralization technique in enhancing the resistance and sustainability of offshore and marine infrastructures. Putting forward biomineralization technology to marine environments will be desirable for sustainable maritime and marine infrastructures. The study by Sun et al. (2024) inspires researchers to advocate the utilization of biomineralization techniques to enhance the resistance of concrete against corrosion in diverse corrosive environments, including marine and sewage settings, as well as water cooling utilities, where concrete degradation is instigated by corrosive microorganisms. The application of biomineralization is anticipated to find further utility in the realm of corrosion prevention for a diverse array of reinforced concrete and steel structures, such as artificial islands, cross-sea bridges, and foundations of deep-sea floating platforms. Apart from marine concrete protection, biomineralization has been also proven effective in inhibiting the corrosion of steel in marine environments (Liu et al. 2018; Shen et al., 2020; Guo et al., 2021).

The study by Sun et al. (2024) introduces a promising avenue for employing biomineralization in marine environments, particularly for combating MIC corrosion in concrete structures. Future research is anticipated to delve into the mechanisms of corrosion inhibition from an interdisciplinary standpoint, aiming to enhance the sustainability of coastal and marine infrastructures. Addressing this complex challenge will require filling significant knowledge gaps through collaborative efforts involving fields such as environmental engineering, ocean

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engineering, materials science, environmental science, and marine microbiology, alongside practical industrial applications. This integrated approach is essential for harnessing the full potential of biomineralization in complex marine settings.

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Xiaohao Sun[a], Jieling He[b], Hao Cui[b], Jinquan Shi[b,*]

[a] *Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China*

[b] *School of Civil Engineering, Chongqing University, Chongqing 400045, China*

E-mail address: jinquan.shi@cqu.edu.cn (J. Shi).

* Corresponding author.