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# Editorial: Exploring corrosion resistance mechanisms in weathering steel

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## Editorial on the Research Topic

### Exploring corrosion resistance mechanisms in weathering steel

Weathering steels are extensively utilized in the construction of bridges, buildings, and various industrial infrastructures, largely due to their unique ability to develop a stable, adherent rust layer, commonly referred to as a patina. This natural protective barrier significantly reduces maintenance requirements and contributes to an extended service life, making weathering steel an economically and environmentally attractive material choice. Over the past several decades, considerable strides have been made in understanding the corrosion behavior of weathering steels under a range of environmental exposures. These studies have offered valuable insights into patina formation, microstructural influences, and the role of environmental parameters such as humidity, temperature, and pollutants.

However, despite these advancements, reliably predicting the long-term durability and structural integrity of weathering steel in complex service environments remains a persistent and multifaceted challenge. In particular, environments where atmospheric corrosion interacts with chemical solution exposure, such as those encountered in coastal, industrial, or deicing salt-laden settings, present a high degree of variability and unpredictability. The synergistic effects between different corrosion mechanisms under such conditions are not yet fully understood. While laboratory-based experiments have provided controlled settings to isolate specific variables, there remains a critical disconnect between these controlled studies and the real-world performance of weathering steel structures. Systematic investigations into the combined effects of atmospheric and solution-based corrosion are still relatively limited, and this gap in knowledge constrains our ability to develop robust predictive models and optimized design strategies.

This Research Topic aims to advance the understanding of corrosion resistance in weathering steels, with a special focus on marine and industrial atmospheres. It brings together contributions that investigate anti-corrosion mechanisms, compare the performance of different materials, clarify the role of rust layers, and propose strategies for performance enhancement. Collectively, these studies highlight state-of-the-art developments spanning constitutive modeling, coating degradation, localized corrosion initiation, and the microstructural and mechanical characterization of corrosion products.

In a significant contribution, [Nie et al.](#) developed a simplified model for the uniaxial tensile stress-strain response of SPA-H weathering steel. Their study established degradation expressions for critical mechanical properties, namely, elastic modulus, yield strength, ultimate tensile strength, and fracture strength, along with their corresponding strains—under both single- and double-sided corrosion. Using mass loss rate and average corrosion depth as damage variables, the authors formulated two constitutive models, which were validated against experimental results, published literature, and finite element simulations. Notably, the model predicated on average corrosion depth exhibited superior predictive accuracy. A subsequent reliability analysis confirmed that both models are applicable for designs where the partial safety factor is greater than or equal to 1.0. Furthermore, the research introduced a novel finite element methodology in ABAQUS that integrates the uniform corrosion model with the equivalent material property method to successfully reproduce the tensile behavior of corroded specimens. This work provides a robust and practical modeling framework with significant potential for engineering applications.

A study by [Zuo et al.](#) provides valuable insights into the corrosion challenges affecting cooling water heat exchangers, which are critical components in chemical production systems. Focusing on the widespread use of protective coatings, their research investigated the deterioration of coated carbon steel during prolonged immersion in circulating cooling water. To simulate realistic service conditions, the authors created large-cathode/small-anode configurations by coupling intact coated surfaces with areas where the coating was intentionally damaged. The results demonstrated that the corrosion rate of these small anodes is inversely proportional to their exposed area, leading to severe localized attack. Concurrently, prolonged immersion was found to weaken the coating's adhesion to the substrate, creating voids that facilitate underfilm corrosion. Crucially, the study identified a dual failure mechanism linked to delamination size: small delaminations promote localized substrate corrosion, whereas large-scale delamination accelerates underfilm attack, culminating in complete coating detachment. These findings offer practical guidance for optimizing the design and maintenance strategies for coatings in industrial cooling water systems.

A study by [Ge et al.](#) elucidates the influence of crevice geometry on corrosion initiation in 201 stainless steel (201-SS) exposed to a 1 M NaCl solution (pH 4.0). By integrating conventional electrochemical methods with scanning electrochemical microscopy (SECM), the authors monitored the evolving crevice microenvironment in real time. The research confirmed that acidification and chloride ion enrichment within the crevice are the primary triggers for corrosion, with narrower crevices fostering more aggressive conditions. For instance, after 48 h of immersion, the pH at the crevice mouth decreased to 1.64, 2.26, 2.73, and 2.88 for crevice gaps of 100, 250, 400, and 550  $\mu\text{m}$ , respectively. These results demonstrate that crevice size governs the rate of ion accumulation and the time to pit initiation through its effects on volume and diffusion. The synergistic impact of reduced pH and elevated chloride concentration was identified as the main driver for the negative shift in both the Open Circuit Potential and the corrosion potential. This work provides critical mechanistic clarity on the initiation processes of crevice corrosion in stainless steels.

Finally, a study by [Tang et al.](#) investigated the microstructure and mechanical properties of steel corrosion products from marine environments, providing essential parameters for predictive models of deterioration in reinforced concrete. The authors collected corrosion products from steel plates, concrete specimens with varying cover depths (10 mm and 20 mm), and cracked beams from a marine site. Through comprehensive characterization using XRD, TG, SEM, and EDS, they elucidated the structural and compositional features of the rust. Additionally, nanoindentation and consolidation experiments were employed to quantify key mechanical properties, including elastic modulus and hardness. These findings yield a critical dataset for developing advanced corrosion-induced damage models, thereby enabling more reliable durability assessments for reinforced concrete structures in marine environments.

Taken together, the contributions featured in this Research Topic underscore the multifaceted nature of corrosion in weathering steels and related structural systems. By integrating research on constitutive modeling, coating degradation, localized corrosion dynamics, and the micro-characterization of rust, this Research Topic advances both the fundamental understanding and the practical assessment of material durability in challenging engineering environments.

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