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Editorial Article

Emerging Trends in Corrosion Engineering and Technology for Steel Reinforced Concrete

PROF. DR. RAJA RIZWAN HUSSAIN
Civil Engineering Department, College of Engineering, King Saud University, Riyadh-11421, Saudi Arabia.

Corrosion of steel reinforced concrete (RC) is among the major durability challenges of civil engineering infrastructure [1-3]. With the increasing service demands for aging buildings, bridges, and highways, the durability of RC structures is not a secondary design criterion or just an academic concern. Corrosion-related durability of steel reinforced concrete directly influences the safety of the public, the economy, sustainability, and environmental protection. The recent research and development in the field of corrosion engineering have seen enormous technological advancements. Corrosion engineering for steel-reinforced concrete structures is now emerging as a state-of-the-art technology, which is renewing the optimism that engineers can now predict, prevent, and control reinforced concrete corrosion in a better way for civil engineering infrastructure. The need of the hour is to transform the RC corrosion engineering technology from reactive repair to the proactive protection trend. Conventionally, the trend was to repair [4-5] the concrete structures after the corrosion damage was visible. Usual methods used for this include patching of the spalling concrete, replacing the corroded rebars, and applying the surface sealants. However, this concept of reaction repair is expensive and effective only temporarily [5]. The emerging trends are to move away from this mindset and go for proactive corrosion protection by preventing the damage before it reduces the load-carrying capacity by causing cracks in concrete and a reduction in rebar area.

The new emerging trend in corrosion engineering technology is the use of unconventional materials, integrated advanced technologies, and sustainable practices [6-8], which are designed to bear the corrosive environmental conditions successfully without failure. One of these is to use the high-performance concrete [9-11]. It has refined micro-structure, optimized mix design, and supplementary cementitious materials such as silica fume, micro-silica, natural pozzolans, and fly ash. As the name says, this concrete is designed to perform higher than ordinary concrete [11]. It reduces the ingress of harmful materials such as chloride ions [12] and carbon dioxide [13], which are the two main causes of corrosion in RC structures. Availability of sufficient moisture and oxygen [14] further aggravates the situation under hot weather environmental conditions [12].

Corrosion-resistant rebars such as galvanized rebars [15], epoxy-coated rebars [16], micro-alloyed [17], and stainless steel bars [18] are also among the trending materials for corrosion protection. They are increasingly used in corrosion-prone environments, such as exposure to high concentrations of carbon dioxide, de-icing salts, high temperature, high humidity, airborne chlorides, and coastal areas. Yet another trend in corrosion engineering is to use self-healing materials [19-20]. These materials are introduced in smart concrete, which heals the micro-cracks automatically by the use of self-healing concrete bacteria or capsules. They precipitate calcium carbonate in those micro-cracks to reduce or close the pathways adopted by the corrosion-causing agents from reaching the rebars embedded in concrete structures.

Structural health monitoring of corrosion in RC structures [21] has emerged as an even better approach than before to mitigate corrosion by the use of smart data and smart sensors. In the era of artificial intelligence [22], this technology has emerged as one of the most promising corrosion engineering techniques. On top of that, the availability of low-cost smart sensors as well as wireless communications has made it possible to achieve more sophistication in structural health monitoring for steel-reinforced concrete. The embedded sensors can measure the electric resistivity, concentration of chloride ions, corrosion rate and potential, temperature, and moisture, etc. These emerging technologies provide resources to corrosion engineers for measuring corrosion in real-time and space domains. Coupling with artificial intelligence makes it even more reliable, easier, and automated in contrast to the conventional manual periodic inspections. Machine learning, deep learning, and artificial neural networks have enhanced their capabilities to monitor the corrosion progress, making it easier to maintain the RC structures.

The electrochemical control of corrosion in RC structures [23] is a classical technique and has widespread use around the world. Now, with the emerging technological advancements in corrosion engineering, this technique has also become mainstream for corrosion control. Cathodic protection technique by applying a small current to the rebar halts the electrochemical reactions leading to corrosion protection. The new emerging designs are now more reliable, energy efficient, and easy to merge into the existing infrastructure. Other such techniques include electrochemical chloride extraction, which reverses the chloride ingress and draws them out of the concrete, moving the ions away from the rebars. Although this was an expensive technique in the past, new emerging trends in corrosion engineering technology are now improving its feasibility for large-scale civil engineering infrastructure projects.

The sustainability and life cycle thoughts are the emerging trends of climate change due to their intensification over time. Construction materials account for carbon emissions, and corrosion engineering is being linked with the sustainability principles in this context. Increasing the service life of RC structures automatically reduces the need for new construction materials as well as carbon-intensive repairs. The environmental concerns are reshaping the selection of construction materials. In this background, corrosion inhibitors are being carefully selected so that they support the low-carbon binders and recycled materials with no compromise on the corrosion-related durability of RC structures. The corrosion research and education, overall standards, and policies are being integrated. Emerging trends in technologies must be paired with the latest standards, codes, and policies. NACE, ASTM, ACI, ISO, and other such organizations are now incorporating the new emerging trends into their corrosion engineering and technology guidelines to ensure the safety of the public and the durability of RC infrastructure. The educational institutions are emphasizing corrosion science, materials science, engineering, and technology to include the emerging trends in this field so that a new generation of engineers can be evolved who are capable of tackling the above challenges in the future.

Concluding the above, it can be said that a multi-disciplinary path has to be adopted to move forward. Corrosion of steel-reinforced concrete has always been seen as something inevitable. But, with the emerging trends in corrosion engineering and technology for advanced materials, corrosion prediction, corrosion monitoring, as well as the electrochemical protection, the engineers are now in a better shape to combat corrosion. The future of corrosion engineering is in the combination of material innovations, artificial intelligence, durability, and sustainability, resulting in integrated solutions for corrosion protection of RC infrastructure in decades to come.

ABOUT THE AUTHOR

He received his Ph.D. and M.Sc. in Civil Engineering from the University of Tokyo, Japan, ranked among the Top 20 in the world, for which he was classified as outstanding and was awarded the best research thesis, prize, and medal from the University of Tokyo. He has authored more than 250 publications and has received several awards, prizes, and distinctions throughout his research and academic career. His area of research is engineering materials.

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