System reliability accounting for corrosion-induced degradation over time

Simone Celati, Agnese Natali, Walter Salvatore

University of Pisa, Pisa, IT.

Sebastian Thöns

Lund University, Lund, SE.

Contact: simone.celati@phd.unipi.it

Abstract

The remaining lifetime of concrete structures subjected to chloride-induced corrosion has been studied in many papers. However, few studies so far consider explicitly experiences from case studies, jointly several corrosion mechanisms and a system perspective. This paper introduces a methodology to evaluate the time-dependent system reliability for concrete bridges subjected to reinforcement corrosion. Here, both chloride and carbonation induced corrosion is jointly considered building upon the thermodynamic conditions for corrosion. The corrosion propagation is modelled with a structural system reliability analysis where different structural system models for repair and replacement consequences are developed. The developed approaches and models are applied to a bridge case study and the service life extension is quantified.

Keywords: Reinforced concrete bridges; over-time reliability; chloride-induced corrosion; system modelling.

1 Introduction

Concrete bridges are essential components of transportation networks, providing fundamental links for the movement of people and goods. The consequences of their collapse are always high and include both direct costs, related to structural rebuilding and human lives lost, as well as indirect costs such as disruptions in the transportation of essential raw materials and inconveniences for the general population. Despite their relevance, a significant proportion of bridge structures in Italy, as well as in numerous other countries worldwide, exhibit varying degrees of deterioration, primarily attributed to their age together with the lack of consistent maintenance over time and are close to the end of their designated lifetime [1,2]. However, efforts should be devoted in prolonging their service life for sustainability and economic efficiency. In this approach, level 1 verifications, involving the partial factor method, are proved to be inadequate due to the inherent limitations of such a generalized assessment approach, but given their easy-to-be-applied procedure, they can be adopted as an initial step aided at the identification of the less secure elements within a structure. Instead, Level 3 methods, encompassing full probabilistic calculations, appear to be more adequate to achieve a more accurate structural safety evaluation. This approach leads to the computation of the reliability index and, generally, allows the incorporation of supplementary information such as inspection outcomes, material tests, monitoring data, and more. Furthermore, it accommodates the integration of degradation models and the explicit consideration of the time variable. Many authors [3–5] have explored the reliability assessment of reinforced concrete structures facing corrosion degradation. Typically, these studies separately focus on degradation due to chlorides or carbonation. In the case of chloride-induced corrosion, they examine the diffusion process of chlorides as the sole trigger for corrosion, determining the time it takes for corrosion to initiate. This information is then used to predict the development of corrosion and the

https://doi.org/10.2749/manchester.2024.0655
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