MODELLING STRUCTURAL STEEL ELEMENTS UNDER VARIOUS CORROSIVE ENVIRONMENTS

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Atmospheric corrosion can affect age-related structural degradation, leading to changes in the structural integrity of metals. European codes provide only general provisions to prevent the effects of corrosion during the lifetime of steel structures. Currently, there is only a few studies have been done considering realistic varying corrosion thickness loss models and almost all of them focus only on extreme corrosion conditions like in industrial, coastal, and urban areas. In this paper, the behaviour of axially loaded corroded steel sections under exposure to different atmospheric corrosivity conditions are investigated. First, five different critical corrosion loss models are proposed to represent actual corrosion decay scenarios including the control specimen (CM0), one uniform thickness loss model (CM1) in which corrosion occurs in the entire cross-section, and three varying thickness loss models (CM2, CM3 and CM4) in which corrosion occurs only in some parts of the cross-section. The corrosion rate model is selected based on the ISO 9224:2012 to estimate the amount of corrosion thickness loss of steel with the time of exposure. ISO 9223:2012 is used to classify atmospheric corrosivity into six different categories namely, Very Low Corrosivity (C1), Low Corrosivity (C2), Medium Corrosivity (C3), High Corrosivity (C4), Very High Corrosivity (C5), and Extreme Corrosivity (CX) considering both high and low corrosivity conditions. Next, with the help of Eurocode 3 guidelines, an analytical framework is established to calculate both the tensile and compression capacities of corroded steel I-sections subjected to axial loads. Prediction of residual cross-section capacities with the changing cross-section is achieved through a programme designed to perform repetitive calculations using MATLAB environment. Results are validated using numerical modelling results after performing both linear and non-linear analyses for different cross-sections by ABAQUS Explicit Solver. The obtained results not only help in designing steel members exposed to corrosion but also in explaining possible reasons for the variations of cross-section capacity in different scenarios. Both tensile and compression capacities get reduced with the corroded age and the residual capacity gets reduced when the severeness of the corrosivity increases from C1 to CX. It is observed that sudden changes may take place in compression capacity curves because of the changes in the cross-section class from class 3 to class 4. This change can cause a member to fail by local buckling before overall buckling or material crushing. The probability of being subjected to local buckling failures is higher in higher corrosive environments like C5 and CX. Results show that the reduction factor in compression capacity is less than 5% which is a very minimal value even after the exposure of 50 years for corrosivity categories from C1 to C4. It suggests that failures are unlikely to happen when exposed to those four corrosive environments. For corrosivity categories C5 and CX, the reduction factor is approximately 10% and 35%, respectively. Therefore, unexpected structural failures can occur during the lifetime of structures, in those two environments. Since the CM1 corrosion loss model has the highest area reduction due to corrosion, it has the highest capacity reduction factor of 0.35 while the other three models (CM2, CM3, and CM4) have a factor around 0.1-0.2. This work can be extended to investigate the behaviour of flexural members subjected to corrosion losses in various corrosive environments.

Keywords: Atmospheric Corrosion, Buckling, Axial Members, Structural Steel

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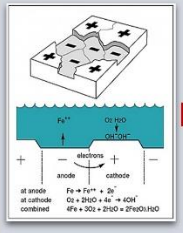
Background



Corrosion

Material Loss

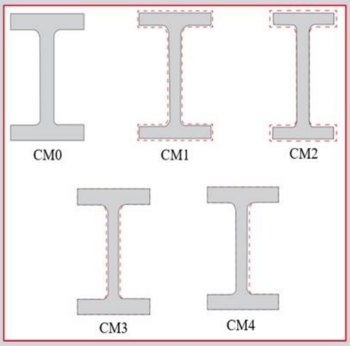
Structural Failures

"The annual global cost of corrosion is roughly 3.4% of the world's gross domestic product." - NACE

Research Methodology

1. Corrosion Loss Model

- CM0 – Control specimen
- CM1 – Uniform loss
- CM2, CM3, CM4 – Varying loss



2. Corrosion Rate Model

According to,

- ISO 9224 (2012)
- ISO 9223 (2012)

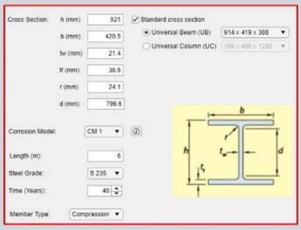
$$d(t) = \begin{cases} r_{cor} t^{B}, & t \leq 20 \\ r_{cor}\,[20^{B} + B\,(20^{B-1})\,(t - 20)], & t > 20 \end{cases}$$

3. Analytical Framework

Formed based on,

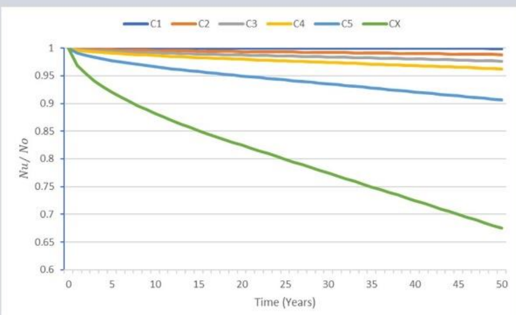
- EN 1993-1-1: General rules and rules for buildings
- EN 1993-1-5: Plated structural elements

4. Designed Programme



Results

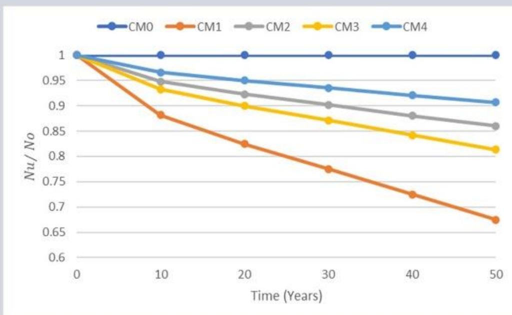
Effect of Corrosivity Category



Capacity Reduction Factor

$CX > C5 > C4 > C3 > C2 > C1$

Effect of Corrosion Loss Model



Capacity Reduction Factor

$CM1 > CM3 > CM2 > CM4 > CM0$