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Prescription of Maintenance Interventions by the New Generation of Eurocodes for Climate-Change Resilient Structures

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1 Impact of Climate Change-Induced Corrosion

The new generation of structural Eurocodes will include climate change (CC) adaption measures to enhance the climate resilience of infrastructures across Europe. Within the impacts upon structures caused by CC, corrosion has been identified as a priority theme, as it has been estimated that the maintenance and repair costs worldwide resulting from the acceleration of the corrosion process due to CC might be of hundreds of billions of dollars annually. In this context, this paper focuses on the adaptation strategy to be applied to the new generation of Eurocodes concerning the corrosion of reinforced concrete (RC) structures.

RC corrosion refers to the phenomenon of the corrosion of the steel reinforcement of concrete caused by the infiltration into the concrete members of carbon dioxide and chloride. Carbon dioxide concentration levels, temperature and atmospheric humidity are the principal environmental drivers of corrosion.

In Europe, by 2010, CC might reduce relative humidity (up to 10%) and increase air temperature (up to 10^0C in North Europe). It is noted that there is an important level of the uncertainty in these estimations linked to the uncertainty regarding the trajectory of greenhouse gas emissions, which depends on factors such as the economic and societal trends. Although this type of uncertainty cannot be reduced, the consideration of an optimistic or a pessimistic climatic scenario might differ in billions of euros in the long term. This should be kept in mind when updating the structural codes.

Several studies have analysed the impact of CC in the reliability and service life of RC structures. For instance, Saha and Eckelman (2014) estimate reductions of the service life of the existing buildings in Boston around 26 and 15 years caused by the carbonation and chlorination processes, respectively.

2 Adaptation Measures

In line with most of the structural codes, materials and composition and cover depth are the main decision variables that can be modified in order to improve the durability of RC members to CC-induced corrosion. Nevertheless, it is estimated that adaptation measures such as increasing design cover by up to 8 mm or increasing concrete compressive strength by one grade would imply an increment of 1-3% of the construction costs (Stewart et al, 2012). Other authors (e.g., Bastidas-Arteaga and Stewart, 2016) have addressed the cost-benefit analysis of increasing the cover thickness to 5 or 10 mm in different structural components under different climate scenarios, concluding that in many cases, this measure is not cost-effective. The efficiency of these measures will depend on the climatic conditions and the future discount rate.

Keeping in mind the impact that Eurocodes has in the economy of the State Members, standardising adaptation measures in a context of high uncertainty, where if the impact of CC is underestimated by considering very optimistic scenarios, it would result in a significant reduction of the service life of new infrastructure and buildings, or if it is overestimated, in unnecessarily expensive investment. Apparently, there is not a fair solution.

3 Resilience-Based Approach

A resilience-based approach is proposed to address this issue because it adds a temporal dimension to the problem by proposing several strategies to increase the preparedness level of the system, allowing for an adaptive response over time. Therefore, adaptation measures should be twofold. On the one hand, the measures addressing the impact of CC that is certain should be implemented in the design stage, through modifying materials, mixtures and layout. On the other hand, the uncertain impact of CC should be covered in a post-design stage, that is, through maintenance. In that regard, Eurocodes should prescribe specific maintenance in relation to climate change.

It is noted that some of the required maintenance interventions are usually less cost-effective than the measures adopted in the initial design. Therefore, the most cost-effective design should not cover only the values of CO_2 concentration levels, temperature and atmospheric humidity associated with a high probability of occurrence, but more uncertain values to minimise the life-cycle cost. In other words, the new generation of Eurocodes should provide a design value for the corrosion drivers that will be established based on both, the uncertainty regarding the future value of the corrosion driver and the cost-effectiveness of the adaptation measures.

4 Conclusions

The impact of CC on man-made systems has a large component of uncertainty, given that the future climatic scenarios mainly depend on the evolution of the global sociopolitical context. A resilience-based approach is proposed to address the issue, which aims to provide the required adaptive capacity to the new structures to be able to respond to the uncertain future minimising the investment under unlikely scenarios. In that way, the strategy can be summarised as a climate change-adapted design plus an in-design maintenance plan. Specific actions, such as mapping the future climate-related drivers of corrosion, the determination of the design values of these drivers, and the prescription of maintenance activities, should be further investigated.

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