Spatial Characterisation of Chloride-induced Corrosion of Bars in Concrete

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Summary

Chloride induced corrosion, caused primarily by de-icing salts or salt spray in marine environments, is one of the most common deterioration processes in reinforced concrete. It often causes a localized loss of section, known as pitting, which can lead to a significant reduction of the structure's service life. In order to predict the impact of this phenomenon on the mechanical properties of the reinforcing bars in concrete a thorough analysis of its characteristics is needed. At present, most of the models found in literature describe uniform corrosion and those that do address localized corrosion focus on a simplified definition of the reduced cross-sectional area of corroded rebars without due attention to physical characteristics and spatial variability. This may be attributed to the limitations of current non-automated and largely heuristic methods used in evaluating the corrosion characteristics on the surface of reinforcement. Automation of the corrosion measurement method would lead to the development of comprehensive corrosion models considering both systematic and random features of the deterioration process. In this paper, experimental results from corroded bars are processed using 3D scanning techniques and characterised using spatial analysis tools, thus preparing the ground for probabilistic corrosion modelling based on random field concepts.

Keywords: Chloride induced corrosion, reinforced concrete, reinforcement bars and spatial variability.

1. Introduction

Chloride induced corrosion has been modelled as having two main stages: chloride penetration and corrosion propagation. Chloride induced corrosion's propagation has mostly been modelled defining corrosion as uniform in terms of the relation between corrosion current and consequent corrosion loss or remaining cross-sectional area with time. Few models have been developed for localized corrosion. They all follow the same approach, namely adjusting cross-sectional area loss through empirical factors based on maximum pit depth measurements typically made under laboratory conditions. Spatial distributions of corrosion have so far received limited attention, possibly because of their complexity both in terms of obtaining the data and in their interpretation. The few studies that exist have taken different considerations on the type of spatial variability (1D, 2D) and have used different spatial modelling techniques. Therefore, it can be said that the distribution of cross-sectional loss due to corrosion is yet to be modelled fully and with clear reference to the physical characteristics of the underlying deterioration process. A key problem is the difficulty in obtaining sufficiently accurate and detailed measurements due to the apparent lack of an automated method to extract the necessary data from physical samples. The development of an automated method would further spearhead physical experimentation, leading to statistically significant databases from which modelling parameters could be estimated.

The use of 3D computerized imaging has been considered as a powerful solution to the current status. Therefore, the objective of the present paper is to exploit 3D laser scanning for the assessment of rebar corrosion by presenting an automated procedure for the acquisition of corrosion depth data together with the first steps involved in spatial analysis.

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2. Methodology and Data Validation

The proposed methodology for the acquirement of the data comprises two steps: the obtaining of corroded rebars from accelerated corrosion experiments carried out in the laboratory and the 3D imaging of the rebars.

In order to obtain the corroded rebars, circa sixty reinforced cylindrical concrete specimens were subjected to an accelerated corrosion testing program, aimed at achieving a pre-determined percentage of area loss, using the imposed current method. Faraday's Law was used to calculate the required time interval needed to achieve a certain percentage of corrosion for a fixed corrosion rate. After completing the accelerated corrosion tests, the cylinder specimens were broken up and the rebars were extracted, cleaned and weighted.

A 3D laser scanner was used for scanning the corroded rebars. Following an alignment procedure, filtering and initial post-processing of the data is carried out in order to add any lacking data and eliminate redundant data. The scanned samples are then imported to the analysis software where they can be inspected (see Figure 1) and visually compared with the actual bars.

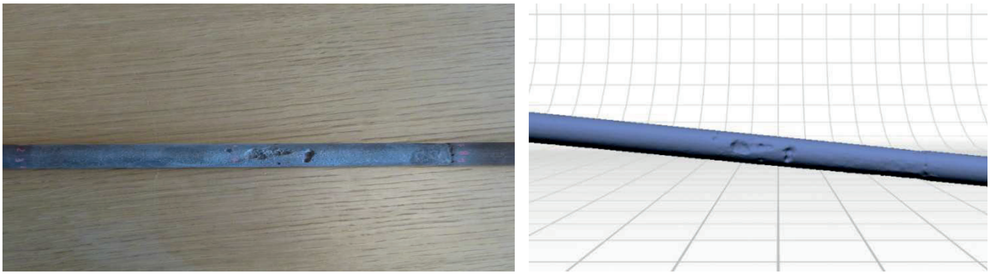

Fig. 1: Typical corroded rebar and its scanned image.

Comparison between manual measurements and those extracted from the scanned specimens has indicated that accuracy of the order of 0.1mm can be achieved on pristine bars with regular "pits". For the purpose of automating the quantification of pit depths, an ideal cylinder (i.e. with the nominal radius of non-corroded bars) was chosen as reference. The deviation between this ideal cylinder and each of the corroded rebars was calculated at regularly spaced intervals along the longitudinal and circumferential direction.

3. Representation and Visualisation of the data

The resulting measurements have also been processed to produce a number of different plots and possible visualisations (pictorial, graphical and lattice). Once a qualitative analysis of this database has been completed, quantitative methods of spatial data analysis will be employed to reveal statistical moment properties and the correlation structure, leading to random field modelling techniques.

4. Conclusions

A methodology for the characterization of corrosion on the surface of the rebars in concrete is proposed. The automation of the acquisition of corrosion depths by means of the 3D scanning of the rebars and post inspection with 3D analysis tools will allow a more thorough study of the corrosion process and its spatial characteristics. Results have been processed to produce a number of different plots and possible visualisations. Once a qualitative analysis of this database has been completed, quantitative methods of spatial data analysis will be employed to reveal statistical moment properties and the correlation structure, leading to random field modelling techniques.