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Service life assessment of chloride affected bridge located in coastal region of India considering variation in the inherent structural parameters

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ABSTRACT

Deterioration of RC bridges due to chloride induced corrosion is a grave concern worldwide. It occurs essentially, when the reinforcement embedded in concrete is exposed to marine or aggressive environments. Over the past few decades, many studies aimed at determining the parameters influencing the service life of structures affected by reinforcement corrosion. The aim of the present work is to put forward a reliable and simple service life model for predicting the useful life or period of RC bridges affected by chloride ingress and to validate the output of the model with the deterioration of an existing RC bridge structure. The application of the service life model has been done in an Indian bridge in the context of coastal environment. Parametric studies have been conducted in the model for examining the effect of various parameters such as water-cement ratio, reinforcement diameter, cover thickness, type of binder and corrosion rate on the variation of service life of the RC bridge structure. The results of the parametric study explained in a detailed manner so as to get an actual insight of the structural degradation mechanism for structures exposed to chemically aggressive environments.

1. Introduction

Reinforced concrete structures are used universally in a wide scale by the building industries due to its durability and price-effectiveness. Nevertheless, it has also become noticeable that corrosion of steel embedded in concrete ends up degrading the structure. Corrosion could occur when a structure is exposed to harmful elements such as chloride ions. Due to corrosion of reinforcement, concrete expands, crack occurs and often results in spalling of concrete cover. These factors lead to premature degradation and could sometimes damage the whole structure. There is a lack of awareness of commonly held deterioration mechanisms, due to which often unsuitable components are used in concrete design mix. Apart from that shoddy workmanship, inadequate curing also contributes toward corrosion of RC structures. Although deterioration of reinforced concrete might also be caused due to other mechanisms such as temperature variation, alkali-silica reactions, frost action, cyclic loadings, fatigue, and sulphate attack, however, the reinforcement corrosion is by far accepted as the most prominent deterioration mechanism. Deterioration by corrosion due to chloride ingress is an emerging problem throughout the world. Service life prediction is therefore important for both existing and planned structures. For the existing concrete structures, the estimation of remaining service life could be useful for planning maintenance and repair. While for the planned structures, the prediction may be used for designing concrete mixes to attain a certain design lifetime.

However, concrete is alkaline in nature and due to which it naturally protects the embedded reinforcing bars (rebar) by forming a film of passivating layer around it. This passive film forming around the steel surface, acts as a protective layer to prevent the steel corrosion [35]. Many variables could affect the passive film's stability and could break it down. The accumulation of chloride ions is considered to be prominent among all of them. Once the chloride content around steel bars surpasses a certain threshold value of chloride content, the passive layer is destroyed and corrosion starts. Multiple studies have been conducted by different researchers from time to time to estimate the threshold value at which depassivation occurs. American code ACI 201 [2] uses a conventional value of 0.20 to 0.40 per cent by weight of cement to estimate reinforced concrete structures service life. The ingress of chloride ions into concrete is mainly by diffusion mechanism. The ions have to diffuse through the concrete cover to reach the surface of steel reinforcement. So, the cover thickness acts as a barrier against chloride ingression. Therefore, it is considered one of the most important elements in enhancing the concrete structure's service life. Even a small increment in the thickness of the cover could significantly delay the chloride ions from reaching the steel surface as a result of which there would be a substantial increase of service life. There are other

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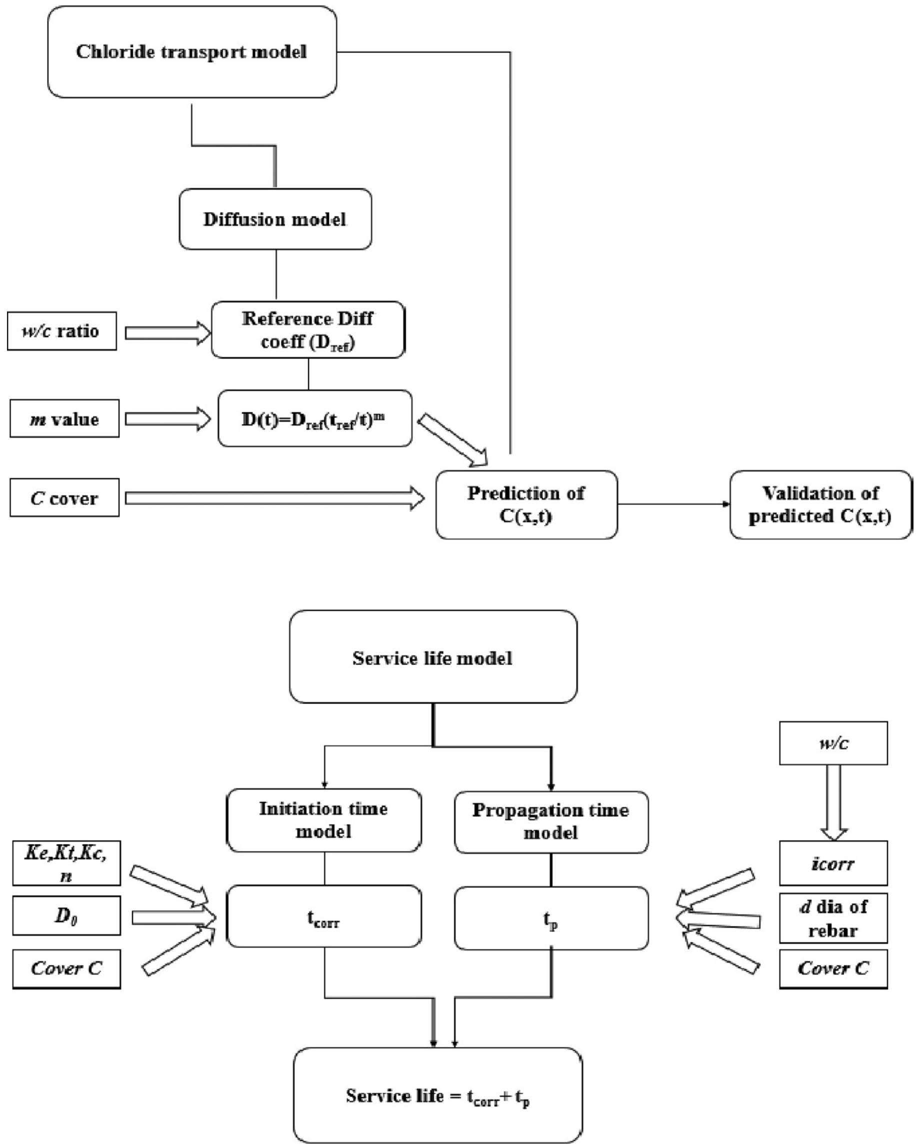

Fig. 1. Modelling workflow for service life prediction.

parameters such as water-cement ratio, supplementary cementitious material, environment conditions and diameter of rebar which also influences the service period of a structure. Keeping in view of the importance of adequate cover thickness, a comprehensive study of the effect of cover thickness on operational life of structures is carried out.

The chloride transportation model is based on the second diffusion law of Fick. The coefficient of diffusion is estimated using the empirical formula suggested by Bentz and Thomas 'life 365 lifetime prediction models [34]. This article combines 'Duracrete model' of initiation period [15] and Morinaga's model [28] for the propagation period. The 'amalgamated' model is used to predict the chloride profiles, time of corrosion initiation, propagation period, time for corrosion crack occurrence and the service life of structure in different environments. The workflow of the proposed model is shown in Fig. 1.

Further, service life models are influenced by many parameters, including everything from material quality, implementation or workmanship during construction to conditions in service environment. Many of these parameters are complex to describe accurately enough in a mathematical model till date. However, the idea behind the present work is to establish a practical and simple usable model where the effect of few of the parameters effecting in service life discussed.

A case study performed in the subsequent part wherein the suggested model is being incorporated to assess the service life of a deteriorating RC bridge and justify the projection with the measured values obtained experimentally. As an application, a typical RC bridge in the coastal region of Gujarat, India is selected and investigated considering the effect of parameters such as concrete composition, water-cement ratio and environment to determine the service life of the structure with respect to varying cover thickness.

The present work also helps with the identification of chloride affected areas in groundwater of India. The presence of aggressive ions such as chloride in groundwater could possess a threat to concrete structures. Chloride ions could directly affect structural components such as foundation which are exposed to groundwater in areas of high-water table or chloride could indirectly enter concrete during its preparation if the chloride affected groundwater is used for mixing or washing of aggregates increases the total chloride content in concrete. Therefore, this study is relevant for providing a basic guideline for safety in such regions. In addition, the salinity of the sea around the Indian subcontinent is studied and mapped to provide a fundamental idea of the amount of chloride to be experienced in case of marine structures.