LIFE CYCLE MANAGEMENT OF CONCRETE BRIDGE DECKS

The life cycle management of concrete bridge decks project consists of providing effective decision support tools for the performance prediction and life cycle cost analysis of reinforced concrete bridge decks exposed to chlorides from deicing salts.

The innovation of the project is the developed deterministic and reliability-based mechanistic service life prediction model. This model can predict the probability at any time of a deck reaching any one of the following relevant limit states, which include: (1) critical chloride contamination of concrete cover; (2) corrosion of reinforcing steel; (3) cracking of concrete cover; (4) delamination of concrete cover; and (5) spalling of concrete cover. The model enables to undertake a sensitivity analysis of the service life of the deck to the governing parameters, including material properties, structure geometry, and environmental loading. The model provides also the time-dependent overall condition of the deck. Examples of the predictive capabilities of the developed models are shown in the figures on Sheet 3. A life cycle costing model is integrated with the service life prediction model to enable a comparison between the service life and life cycle costs of different design and rehabilitation alternatives.

This innovation originated from a large partnership research project between NRC/IRC's Urban Infrastructure Program and 12 partners, which included provincial, municipal, and federal agencies, and private consultants that own or manage large networks of highway bridges. The objective of the project was to develop decision support tools for service life prediction and rehabilitation of concrete bridge decks. The corrosion-induced damage of reinforced concrete bridge decks is recognized as a major technical and economic problem for highway agencies in North America. The corrosion of the reinforcing steel results in excessive cracking, delamination, and spalling of the concrete, which leads to a loss of serviceability and functionality, and ultimately affects the safety of the traffic and structure. The rehabilitation costs of deteriorated decks account for about one-third to one-half of total bridge maintenance costs.

This innovation will be used by bridge owners, engineers, and consultants to improve the maintenance management of reinforced concrete bridge decks. It will help optimize the design of a new deck or rehabilitation of an existing one to achieve durable and cost-effective structures. This innovation will also help optimize the inspection of bridge decks, and thus will lead to cost savings. Most of the existing service life models predict only the time to onset of corrosion. Some empirical models have been developed, however, their reliability and applicability are limited to a given set of parameters and conditions. On the other hand, some statistical models have been developed, which are qualitative in nature and are mainly based on the subjective parameter of condition rating. These models do not consider the physical phenomena at hand and their governing parameters.

In this innovation, the developed models are based on the actual modeling of the physical phenomena using appropriate mathematical models, that describe the relationships between the governing parameters, including: (i) chloride diffusion into concrete; (ii) depassivation of the reinforcing steel and initiation of corrosion; (iii) expansion of corrosion products, which induce tensile stresses in concrete and lead to cracking when the fracture strength is reached; and ultimately (iv) accumulation of corrosion products, and generation of high tensile stresses in concrete, which result in either spalling or delamination depending on the geometry of the deck and its reinforcement. Furthermore, recognizing the considerable variability of the governing parameters, the proposed innovative model accounts for their uncertainty and provides predictions of the service life in terms of probabilities of reaching any of the five limit states identified above.

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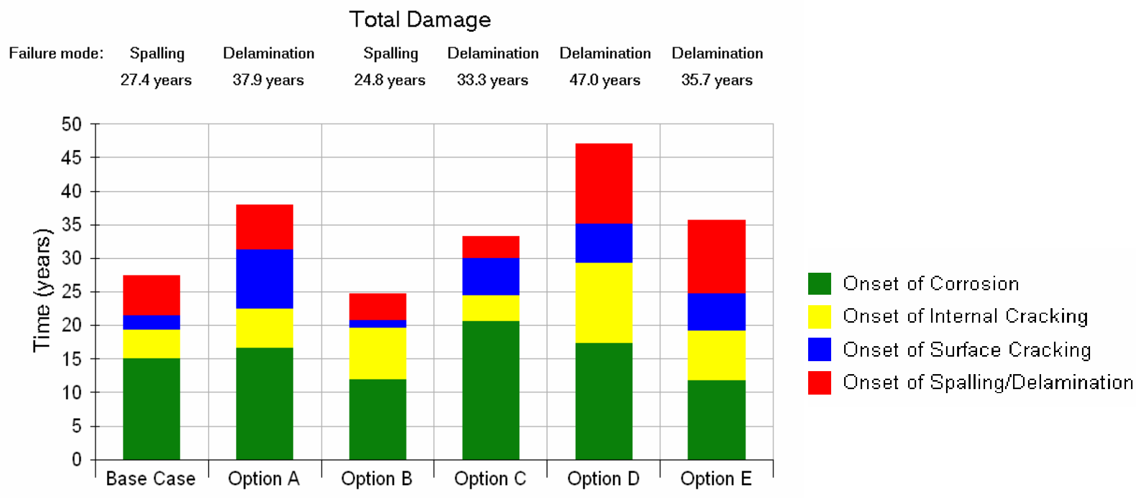

Fig. 1. Deterministic Service Life Analysis of Bridge Decks

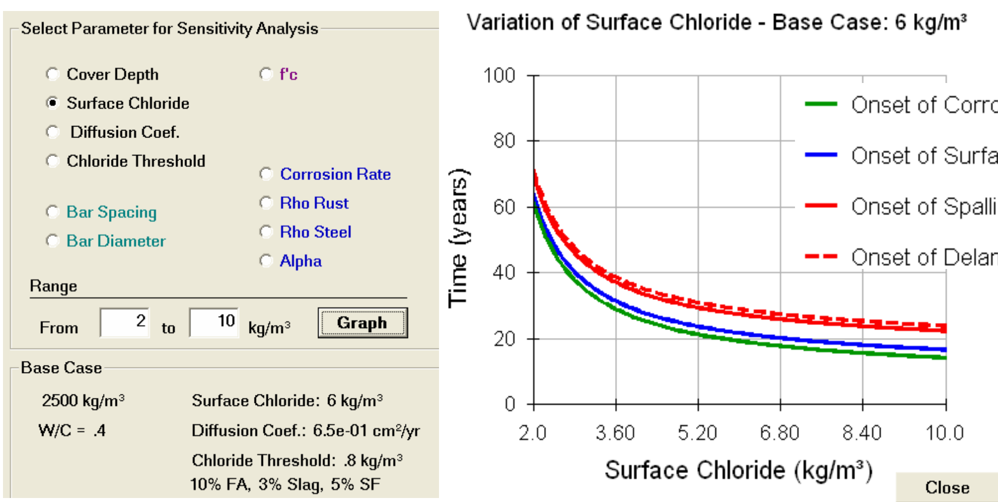

Fig 2. Sensitivity Analysis of Service Life of Bridge Decks

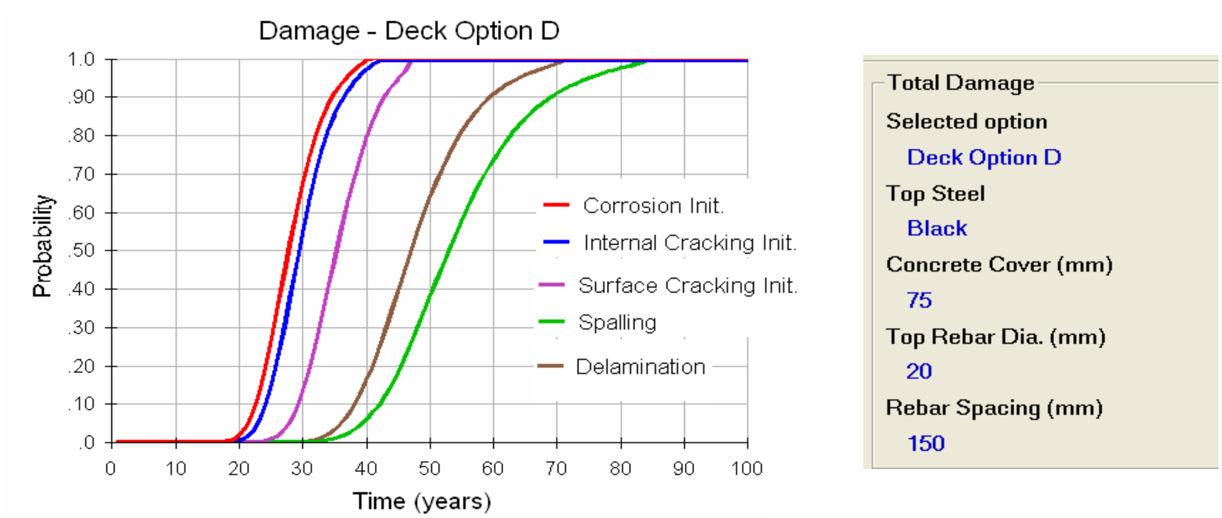

Fig 3. Reliability-Based Service Life Analysis of Bridge Decks

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