Joint Transportation Research Program

Principal Investigator: Samuel Labi, Purdue University, labi@purdue.edu, 765.494.5926

Program Office: jtrp@purdue.edu, 765.494.6508, www.purdue.edu/jtrp

Sponsor: Indiana Department of Transportation, 765.463.1521

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Increasing Bridge Deck Service Life

Volume II—Economic Evaluation

Introduction

Deterioration of bridge decks is a primary factor limiting the lifespan of bridges, especially in cold climates where deicing salts are commonly used. Research has been previously performed to mitigate deterioration by controlling deck cracking using improved design methods, such as bar spacing and cover requirements, or by decreasing the permeability and porosity of concrete through the use of high performance concrete. While these methods can improve performance and extend service life, chloride and moisture ingress, as well as cracking, cannot be eliminated. Full-depth cracks that are caused by restrained shrinkage allow for corrosive conditions at early ages in both the top and bottom reinforcement mats. Therefore, corrosion of the reinforcing steel ultimately occurs. However, the service life of the deck has the potential of being significantly improved if corrosion resistant reinforcement is used.

While epoxy-coated reinforcement has become standard practice to improve corrosion resistance, this reinforcement type is not immune to corrosion. Its performance is highly dependent on the condition of coating. The coating can be damaged even with special care during manufacturing, transportation, and construction. Therefore, the use of other corrosion reinforcing materials has significant potential to provide improved performance. The objective of this research program was to examine the efficacy of using alternative materials in a bridge deck from both technical and economic perspectives. Technical criteria include bond strength, cracking performance, and corrosion resistance, while economic criteria comprise agency and user costs associated with construction, replacement, and rehabilitation over the life cycle.

Findings

The study developed a systematic framework for evaluating these alternative reinforcing materials on the basis of their life-cycle cost. Case studies involving different scenarios of bridge and operating characteristics were used to demonstrate the methodological framework, and to develop nomograms (decision support charts) for the material selection. On the basis of the results of the analysis and the case studies, it is recommended that deck reinforcement material for any future INDOT bridge deck design should be selected only after carrying out a life-cycle cost analysis among other considerations; such analysis should be preceded by establishment of the decision contexts and, consequently, values of the identified input parameters for the life-cycle cost analysis. From a general perspective, it is recommended that INDOT considers for inclusion in its bridge design or rehabilitation manual, the decision to support nomograms that specify the conditions at which each material is optimal from a life-cycle perspective.

Nevertheless, avenues exist that could be addressed or explored further to fine-tune the selection process for appropriate deck reinforcement material alternative for any specific bridge project. First, mathematical models describing the time-dependent, chloride-induced corrosion deterioration processes could be incorporated to provide more precise estimates of the life-cycle activity profiles for each material type.

Secondly, the laboratory experiments carried out as part of this research (see Volume I of the report) could be followed by full-scale field studies. For this, it is recommended that a few bridge reconstruction or deck replacement projects should be selected from INDOT's long-range plan or bridge program through an experimental design; for these bridges or decks, INDOT should apply the three material types in a controlled experimental setting. The costs (initial construction and subsequent maintenance), work durations, and the physical condition and service lives of the bridges or decks having each alternative material should be closely monitored and recorded over several decades. Doing this would validate or refine the assumptions made in this study. The experimental design could include climatic region (northern and southern Indiana), highway classes, traffic volume, and bridge size.

Implementation

Based on the research conducted in the economic evaluation, a software tool, RM-LCCA, was developed that can be used by INDOT and design consultants. The economic evaluation methodology presented in this study provides a platform to assess the life-cycle costs of different types of bridge deck reinforcement materials based on their corrosion resistance as well as their economic efficiency. The analysis outcome from the RM-LCCA electronic tool can help bridge engineers and practitioners identify the optimal reinforcement alternative for a given bridge on the basis of its expected service life, schedules for rehabilitation and deck replacement, and the accompanying costs to the highway agency and bridge users. The service life of a bridge deck, even for the same reinforcement alternative, can change due to factors such as increased loading, rapid changes in the surrounding environment, and upcoming new policy decisions that can affect the short-term and long-term service life of preservation treatments. For the estimated preservation years, the user can incorporate the probability that the treatment timings will be different from what is specified as the average. By running the tool several times for different values of the input variables, the user can simulate the outcome corresponding to different combinations of the input variables. It is envisioned that as the benefits of corrosion-resistant reinforcement alternatives are tested and become recognized, their demand will increase, leading to higher production and lower unit prices.

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