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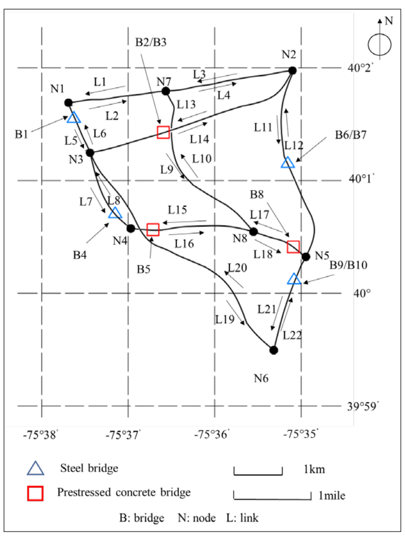
Locally Sourced Corrosion-Resistant Steel May Minimize Maintenance Costs and Extend Life-Cycle of Bridge Networks

A research team from Lehigh University, a consortium member of the Region 3 University Transportation Center at Pennsylvania State University, examined the potential of using corrosion-resistant steel girders to replace corroded carbon steel girders in several aging steel bridges in a specific transportation network. The corrosion-resistant steel under examination is A709-50CR (formerly known as A1010), a steel locally sourced in Pennsylvania. According to results of the team's recent studies, A709-50CR can help bridge owners save money, reduce traffic delays, and cut greenhouse gas emissions.



Xu Han and Dan M. Frangopol

Figure 1. Bridge network in Chester County, PA

Carbon steel bridges that are under severe chloride exposure due to deicing salts or marine environmental effects require frequent maintenance and repair actions to maintain an adequate performance level during their service life. Although carbon steel bridges have a relatively low material cost and very good material strength, the low corrosion resistance of carbon steel can result in severe deterioration of bridges—resulting in very high maintenance costs during their service life.

The transportation network studied by the researchers is located in Chester County, PA (see Figure 1). Pictures of two of the steel bridges in Figure 1 are shown in Figures

Google Maps

Figure 2. Picture of Bridge B4

Google Maps

Figure 3. Picture of Bridge B6

2 and 3. Network risk is selected as the performance indicator of the transportation network. This risk quantifies the expected failure consequence of the transportation network. The consequence considered is multi-faceted, including rebuilding cost of bridge structures and user cost incurred upon traffic users due to extra travel time and distance when a bridge or a group of bridges is not functioning. Reliability index (an index related to the failure probability of structures) profiles are also needed to obtain the expected failure consequence (see Figure 4).

For the corroded carbon steel bridges, two different types of maintenance actions are considered. One is to replace corroded carbon steel girders with new carbon steel girders, the other is to conduct the replacement using

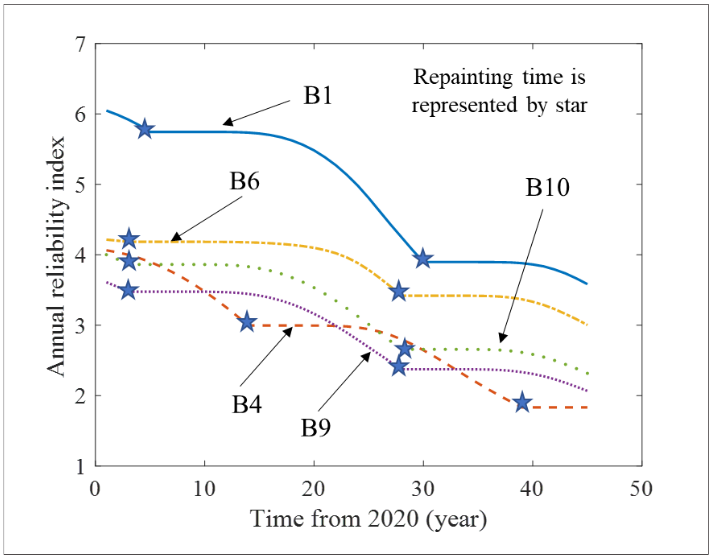


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Figure 4. Annual reliability index profiles of the steel bridges in the network.

girders made of A709-50CR. By comparing the values of performance indicators associated with these two types of maintenance actions under the same maintenance budget, whether it is economically advantageous to use A709-50CR in the life-cycle maintenance actions for steel bridges can be indicated from a bridge transportation network perspective.

At least six bridges have been constructed with A709-50CR steel in the United States in five different states including California, Iowa, Oregon, Pennsylvania, and Virginia. A709-50CR girders have not yet been used to replace corroded steel girders in real-world engineering projects. The results of the research will impact, and potentially accelerate, state DOT decision making regarding this type of replacement.

Dan M. Frangopol, the Lehigh research team leader, said they are trying to determine the life-cycle maintenance solution to these corroded bridges to maximize the performance of the entire bridge network, consisting of both steel and prestressed concrete bridges. "There is a trend that life-cycle management strategy is laid out from an infrastructure system perspective, in which interactions among the performances of different structures within a bridge network system are considered. This is a leap forward from deciding on life-cycle maintenance actions for each bridge in the network separately," Frangopol added.

The research team previously examined the cost-effectiveness of using A709-50CR girders to replace corroded carbon steel girders for individual steel bridges. The results show that the advantage of using A709-50CR girders to conduct girder replacement compared with using new carbon steel girders for an individual steel bridge becomes pronounced under stringent requirement of decision-makers on the risk level.

The team also investigated the impact of several significant factors on the life-cycle maintenance solutions for individual steel bridges subjected to corrosion, including the correlations among resistances of different girders, redundancy of the superstructure of bridges, and performance indicators of bridges. For a multi-girder steel bridge, a high correlation among girder resistances leads to a more critical life-cycle risk profile, and therefore, requires an increase of maintenance budget if the acceptable risk level remains the same. Alternatively, a more redundant superstructure helps decrease the maintenance budget.

About This Project

About this Project: The Lehigh research team is led by Dan M. Frangopol, Xu Han, and David Y. Yang. Lehigh University is a consortium member of the Region 3 Center for Integrated Asset Management for Multi-Modal Transportation Infrastructure Systems (CIAMTIS) at Pennsylvania State University (https://r3utc.psu.edu/). More details about the Lehigh team's research may be found here: https://cpb-us-e1.wpmucdn.com/sites.psu.edu/dist/c/89826/files/2020/11/CIAMTIS-LU-CIAM-UTC-REG6_s.pdf and here: https://cpb-us-e1.wpmucdn.com/sites.psu.edu/dist/c/89826/files/2022/08/Investigation-of-the-Benefit-of-Using-Novel-Corrosion-resistant-Steel-in-New-and-Existing-Bridges-in-Pennsylvania.pdf