Inspectability Design

Bridge Life Cycle Cost Savings

By Jennifer C. Laning, P.E.

Standard practice during bridge design and construction is to consider the biddability of the construction documents, the constructability of the design, and the operability of the asset. Quite often, designers do not consider the inspectability of the bridge over its life cycle. Inspection, required by law on a 24-month cycle at a maximum, presents the bridge owner with costs: labor, equipment expenses, travel impacts, and safety. These costs, especially for complex bridges, signature structures, and high-level river crossings, can be reduced if inspectability is included in the design.

The link between bridge design and inspectability is explored in a paper submitted to the SMT Conference 2010 in New York City, entitled *Designing Bridges for Inspectability*, by Alampalli and Yannotti, and in an ASCE Technical Note by Mahamid, et al., entitled *Structural Design and Inspectability of Highway Bridges*. In the Technical Note, the authors conducted a workshop on structural design and inspection of highway bridges at the University of Illinois at Chicago in November of 2017, with participants from state agencies, design and inspection companies, and academics. Both of these sources, as well as other sources such as the FHWA-IF-11-016 *Framework for Improving Resilience of Bridge Design*, placed a focus on improving current inspection challenges and offered proposed modifications for future design practices, intending to facilitate inspection practice.

During design, inspectability can be incorporated by improving the ability to inspect the bridge visually. Considering bridge type selection and/or bridge details and providing or improving safe access for inspectors in the design phase is essential. The benefits include improved system preservation because the condition of the bridge can be more accurately monitored, improved safety for inspectors and the public during the performance of the inspection, and overall cost savings from increased inspection efficiency.

When considering bridge type selection or design of bridge details, the main objective is to increase the visibility to the inspector by avoiding uninspectable elements. This impacts the owner's ability to monitor and maintain the overall condition of the bridge; because, as noted in FHWA-IF-11-016, "elements that are difficult to inspect are typically problematic to maintain." Flaws, cracks, and section loss can occur in inaccessible areas behind end diaphragms or between the ends of box or tub girders. Truss members, tie girders, tub girders, or floorbeam cross girders often have areas that are constrained by the member itself. A prestressed concrete box beam bridge is constructed with internal webs that are not visible. These same areas are susceptible to the accumulation of moisture, debris, roadway deicing materials, and other threats that contribute to the deterioration of the steel or concrete and loss of structural integrity. The inability to have visual access to bridge components means that inspectors cannot monitor the condition of these vulnerable areas over time. In turn, the deterioration will not be reported and maintenance will not be performed, presenting a challenge to system preservation and resulting in costly rehabilitation versus planned routine maintenance.

Facilitating safe access to the bridge for both inspectors and the public who would be impacted by inspection operations can be accomplished in several ways. One advantage is that improvements to inspection access can be considered at the initial design level or during rehabilitation later in the bridge's life. On signature or large structures, this can be accomplished by providing catwalks, railings around piers, fall restraint systems, tie-offs on deep girders, and locations where rappelling or traveler systems can be attached to the bridge. A frequently undervalued need is a pull-off or staging area at or under the bridge for safe coordination of inspection operations. For highway structures over roadways, railroads, or waterways, the inspection access considerations are less complicated. Still, even small accommodations can make work safer for inspectors over the life of the bridge. Conversations with experienced bridge inspectors have suggested access improvements such as ensuring an accessible abutment seat height, providing a flat area at the top of slopes to stand or place ladders, locating the girder splices over outer lanes to reduce the need for double lane closures, or making the access hatches to steel tub girders or box floorbeam/cross girders more accessible. Inspection equipment access could also be limited by the width of outboard sidewalks or the placement of high fences and luminaire poles, which may obstruct snoopers, or poor ground conditions underneath the bridge that could be used by manlifts or bucket trucks. There are many factors to consider when looking for ways to optimize inspection access, including reducing or eliminating the need to perform lane closures as much as possible, removing or reducing obstacles to production, improving safety, and allowing inspectors to reach as much of the structure as possible.

Wide sidewalks can provide accessibility.

Ultimately, the goal is to improve safety and efficiency, which has the potential to realize cost savings over the life of the bridge. While these modifications certainly would improve efforts toward best practices in design, it is possible that cost increases in design or construction would impact their implementation. However, the cost savings over the life of the bridge can potentially outweigh the costs in design or construction. For example, consider the low cost of planning to place tie-offs or to analyze the access to various portions of the bridge during the design phase versus not having these in place in the future. An example is a signature cable-stayed bridge that cost more than $100 million to build in the 1990s, which was constructed without tie-offs on the top of the pylons to facilitate rope access inspection. In another case, a functionally obsolete lift truss bridge with extremely narrow lanes that required overnight inspections was retrofitted with a maintenance traveler. Design solutions can also include reducing or eliminating the use of certain bridge types or details, like prestressed adjacent box beam bridges or diaphragm configurations at abutments that prevent visual inspection of the beam ends or abutment backwall.

Other solutions include evaluating whether certain areas of a bridge can be accessed by existing equipment configurations (i.e., the largest underbridge inspection vehicle has a 75-foot reach) while in design, and if not, building in methods of access, such as walkways or connections for travelers or rigging. One suggestion in the ASCE Technical Note was an exciting and innovative discussion point regarding the potential use of BrIM as a way to utilize a digital representation to explore the inspectability of a bridge. If the cost of time spent during the design phase to address inspectability is a barrier, perhaps this innovative solution of using BrIM's agility can help in making inspectability part of best practices in bridge design. Many agency manuals require that designers consider inspectability during the design process, so a strong case can be made for including an actual review of the plans specifically for inspection considerations. Having a bridge inspection specialist who reviews the plans can provide useful suggestions early in the process. Potential solutions may include flat areas adjacent to the abutments or locating the hatches for tub girders in the bottom face of the tub and making them large enough for extension ladders. And, including a discussion on inspection access improvements in a rehabilitation may provide some value if the improvements can be included at that time.

The downside for not addressing inspectability is the potential increase in the costs of inspections due to equipment and lane closures needed to perform the inspections every 24-month interval for the life of the bridge. Remember, there are also impacts on traffic and safety during inspections. Inspection-friendly alternatives considered early, if possible, can be significant improvements. Safety for inspectors and the traveling public is the overarching benefit that can be realized by designing for improved inspectability, particularly when many solutions can reduce or remove the equipment and lane closure demands. Equipment such as underbridge inspection vehicles and traffic control setups cost money. Impacts to traffic on already congested roadways result in economic costs, through delays to commuters and the trucking industry, not to mention the cost to the environment from the use of fossil fuels and emissions. By providing alternative methods for access to the bridge, perhaps from beneath or by utilizing rigging, travelers, or walkways, the opportunity exists to be safer and more efficient. Any time that the bridge inspection industry can avoid impacting traffic with equipment and subsequent lane closures, both safety and economic benefits are realized.

Traveler rail retrofitted to accommodate a scaffold system for inspections.

As a bridge inspection subject matter expert, the author encourages more thoughtful consideration of inspectability by bridge designers. Our industry should encourage bridge designers to consider the long-term cost savings of improving inspectability and the corresponding improvement in safety for inspectors and the traveling public.▪

Jennifer C. Laning is Associate Vice President and Bridge Inspection Practice Leader at Pennoni. (jlaning@pennoni.com)