# Equipping Engineers to Deal with the Existing Bridge Inventory

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While some historic U.S. bridges date to the late 19th or early 20th century, most of the highway infrastructure was designed and built after the conclusion of World War II. Since the Federal Highway Act of 1956 authorized the interstate highway system, billions of dollars have been invested in the construction and ongoing expansion of that system. Currently, our aging transportation infrastructure is a cause for concern for all of us. In this article, I share a few thoughts about the challenges we face from the perspective of an educator.

To provide context, let us envision a junior engineer with a few years of experience working for a state department of transportation or a firm in the bridge industry. Many of the problems this engineer will face will be related to the condition of the existing bridge inventory, including structures designed and built by earlier generations of engineers and contractors working under different circumstances. This engineer, as part of a group of engineers or as an individual, will likely be tasked with evaluating a bridge that may be showing its age. We all know concrete bridges are durable when they are designed and built properly. However, some of our bridges are deteriorating as a result of alkali-silica reaction, delayed ettringite formation, carbonation, sulfate attack, reinforcing bar corrosion, freeze-thaw damage, or other reasons.

As I frequently say to my students, identifying the problem correctly is more than 50% of its solution. The aforementioned problems are identifiable in routine bridge inspections. As a result, when they occur, bridge owners know about them. The question becomes how to consistently account for aging and deterioration effects in our structural evaluations. An experienced structural engineer can make a series of conservative assumptions and analyze a structure to determine whether repair, rehabilitation, monitoring, or replacement is the most appropriate solution for a specific problem identified in the field. This is our current approach to finding solutions to problems revealed in field inspections. However, two major challenges stem from this approach.

## Establishing Standards for Identifying and Solving Problems

First, because the solutions generated by structural engineers reflect the engineer's individual experiences, the solutions chosen may vary greatly from engineer to engineer. As engineers, we are typically conservative in our approaches when we are uncomfortable about conditions that surround a field problem. Senior engineers can draw from their past experiences while deriving solutions; their familiarity with a challenging scenario gives them confidence so they do not simply default to the most conservative choice. In contrast, engineers who are less experienced may generate solutions that are more conservative, and perhaps more costly, for the same situation.

If our ultimate goal is the responsible allocation of resources available to us, and if lack of experience is the root cause of inappropriate or overly conservative solutions, it seems desirable to generate solutions for structural repair/retrofit that structural engineers and materials scientists of every experience level can use with confidence. Such solutions should be consistent with new design principles and concepts, and desired targets for reliability and conservativeness.

Remarkably, our colleagues at *fib* (International Federation for Structural Concrete) are working on this issue. I am currently involved in the preparation of *fib*'s next Model Code, which is intended to serve as a primary reference document for many national reinforced concrete design codes around the world. The next edition (i.e., Model Code 2020) will be used for both designing new structures and evaluating the existing inventory of structures (including structures experiencing concrete and reinforcement degradation) in a uniform, consistent, and rational manner with respect to structural safety and environmental impact. In other words, responsible allocation of resources is a priority for our colleagues worldwide who are contributing to Model Code 2020. Production of such reference documents is essential, and educators must include them in classes and curricula to prepare students who will tackle problems related to the nation's bridge inventory.

## Ensuring Knowledge Transfer

The second challenge we face as we monitor and maintain our bridge inventory is training the structural engineers who have already entered the workforce. Experienced engineers in the United States are retiring at a rapid pace, and that means institutional memory is being rapidly lost. Although knowledge transfer is taking place as senior engineers train and mentor junior colleagues before retiring, the sufficiency of this "organic" approach is open for debate.

In my view, in addition to this organic approach, we must develop means and methods to help surmount the growing experience and knowledge gap in the workplace. This is a big challenge, which must be addressed on two different levels. First, we must figure out how to create hands-on training opportunities where inspectors and bridge engineers of the future can be trained in a consistent manner.

Second, we must integrate technology into our thinking about how we share knowledge and promote standards. When I watch my two kids (ages 20 and 18) use their smartphones, tablets, and computers, I cannot help but think that the new reality does exist on the internet. Therefore, maintaining and digitizing what is known to us is extremely important. We should create a robust national repository (or repositories) where case studies, knowledge, and solutions can be easily shared with the next generation of bridge engineers. Integration of those resources with repair codes and guidelines will be essential. Soon, perhaps in the next decade or so, paper copies of codes and standards (including repair standards) will be superseded by entirely digital versions. We will need to ensure that accurate and endorsed means and methods for repairing, retrofitting, and/or repurposing the existing inventory of bridges are discoverable and up-to-date online.

## Conclusion

Our nation's leaders are contemplating authorizing trillions of dollars to maintain and improve our transportation infrastructure. At this critical moment, the challenge of how to deal with the existing bridge inventory in a responsible and consistent manner, while being mindful of the resources available to us, is a challenge we must accept. We need to collaborate with and learn from colleagues tackling similar problems in countries with older transportation infrastructures. We also need to introduce new classes, or new modules in existing classes, to our curricula. And we need to expand the means and methods by which we provide training to junior engineers in the workplace, share knowledge, and keep standards up to date. Collectively, such strategies may help us succeed in the most ambitious infrastructure endeavor since the massive expansion of our highway system after World War II.

### EDITOR'S NOTE

*The eLearning courses developed through a joint partnership of FHWA, AASHTO, and PCI are a step in the right direction for providing basic training related to concrete bridges. Courses such as In-Service Analysis Load Rating (T710) provide guidance for evaluating our bridge inventory and are available at no charge. This course and others developed through this same partnership are available at http://elearning.pci.org/.*