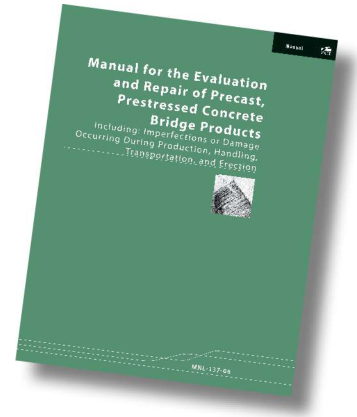
PERSPECTIVE

Defining the Service Life of Bridges

Relationship of service life to the repair of precast/prestressed concrete bridge components

by the late Dr. Dennis R. Mertz, University of Delaware, and Edward P. Wasserman, Modjeski and Masters



Confusion exists among bridge owners and designers regarding the terms *design life* and *service life* as evidenced by the fact that the two are often used interchangeably. Article 1.2 of the American Association of State Transportation Officials' *AASHTO LRFD Bridge Design Specifications*[1] defines design life and service life as follows:

- **Design Life:** "Period of time on which the statistical derivation of transient loads is based: 75 yr for these Specifications."
- **Service Life:** "The period of time that the bridge is expected to be in operation."

The definition of *design life* clearly delineates the intent of the authors of the specifications: Bridges designed in accordance with the AASHTO LRFD specifications should be able to resist the transient loads identified therein, projected over a 75-year period (the design life) with the uncertainty associated with its calibration.[2] The AASHTO LRFD specifications do yield bridges able to resist the transient loads of 1994 (the year of the publication of its first edition) projected over a 75-year period with the uncertainty associated with its calibration.[2] To be specific, the probability of a member "failing" because the applied loads exceed its capacity at the strength limit states in a 75-year period is 2 in 10,000, corresponding to a target reliability index β of 3.5.

However, the definition of *service life* is clearly not related to the design life or the probabilities associated with it. It is simply an expected period of operation. Thus the AASHTO LRFD specifications were not intended to result in bridges with a 75-year service life (or any other period) with any certainty. Indeed, the probability of a bridge designed in accordance with the AASHTO LRFD specifications reaching a certain service life is unknown. This bears repeating: the AASHTO LRFD specifications do not currently define service life for bridges.

The AASHTO LRFD specifications do not currently define service life for bridges.

The use of the term design service life, a combination of the load and resistance factor design (LRFD) definitions, in fédération internationale du béton (fib) Bulletin 34: *Model Code for Service Life Design*[3], among other relevant literature, is confusing and misguided. The authors would propose that the term target service life, much as the term target reliability index of the AASHTO LRFD specifications, is better terminology. The target reliability index represents the approximate reliability associated with the application of the AASHTO LRFD specifications strength limit states based upon the calibration of the specifications, as discussed previously.

By employing the partial probabilistic format of LRFD, the designer is not required to make probabilistic calculations. Service life and component deterioration are not well enough quantified to allow such calibration and are not of a nature to allow a quantification of the effects that can be readily represented in some probabilistic calculation. Thus, while the proportioning and detailing of components using the provisions of the AASHTO LRFD specifications represent good practice based upon experience, it cannot be associated with a specific service life in years. Such durability provisions are termed "avoidance of deterioration" and "deemed-to-satisfy" approaches in fib Bulletin 34.

If and when service life performance data becomes available, efforts should be made to quantify and calibrate the effects. Efforts to quantify and calibrate service life are under way with projects such as the Federal Highway Administration's Long-Term Bridge Performance Program and the newly initiated NCHRP 12-108, which will culminate in a guide specification for service life design of highway bridges.

An example of bridge owners' confusion is represented in the project goals and objectives of a current design-build project in its Instructions to Proposers. One of the stated goals and objectives is "providing for a serviceable structure with a service life span of 100 years before major maintenance is required." While the future bridge owner is misguided in asking for a specific number of years of service (which cannot be guaranteed or even estimated with any degree of certainty despite the best efforts of some to claim this is possible), it rightly recognizes that the service life of a bridge is not necessarily defined by its replacement, but many times by merely a decision point for considering a major preservation action.

In a similar vein to the discussion of the previous example, some owner agencies have followed suit or have stipulated criteria such as target material property limits for concrete with the expectation of improving service life. Such requirements can be sound actions. However, if the specified material properties are not met, there is no scientific basis for determining a reduced service life. A more rational approach contractually is to set incentive/disincentive clauses to adjust unit prices based on actual performance versus target performance. Owners should be further cautioned that the properties that can be achieved in a laboratory may not be what can be achieved in the field environment, and set reasonable targets.

Likewise, cases have been reported where contractors' requests to repair damaged precast concrete beams have been rejected on the premise that any damage, even if properly repaired, will automatically reduce the service life of the element. To hold such an opinion without the benefit of an engineering investigation is misguided. Successful repairs can be made in most instances by assessing the nature of the damage, its location, and the final stresses present in the repaired area after the successive stages of dead load and live load applications for both the service and strength limit states. The needed assessments can be determined and quantified by qualified engineers through calculation and competent engineering judgment. This is important, as deviation from specifications and plans can occur at any stage of constructing a project, with precast/prestressed concrete products being only one example.

To this end, Precast/Prestressed Concrete Institute (PCI) has published a *Manual for the Evaluation and Repair of Precast, Prestressed Concrete Bridge Products*[4] for the use of owners, engineers, and fabricators to help guide a rational approach to the decision-making process. The introductory chapter of this manual provides a step-by-step outline for conducting investigations that lead to well-reasoned engineering decisions, followed by discussion as to causes and remediation. Successive chapters provide proven acceptable repair details and guidance on implementation of repairs that can reasonably assure those repairs will meet the target service life intended. The ultimate value of this manual depends on the sound investigation and engineering judgment of an owner-engineer-fabricator team working together in good faith to solve the problem at hand.

References

1. American Association of State Highway and Transportation Officials (AASHTO). 2014. *AASHTO LRFD Bridge Design Specifications*. 7th edition, AASHTO, Washington, D.C.
2. Kulicki, J. M., Z. Prucz, C. M. Clancy, et al. 2007. *Updating the Calibration Report for AASHTO LRFD Code*, NCHRP Project 20-07/186 Final Report. National Cooperative Highway Research Program (NCHRP). Washington, D.C.
3. fédération internationale du béton (fib). 2006. *Model Code for Service Life Design*. Bulletin 34, Lausanne, Switzerland: fib.
4. Precast/Prestressed Concrete Institute (PCI). 2006. *PCI Manual for the Evaluation and Repair of Precast, Prestressed Concrete Bridge Products* (MNL-137-06), 1st edition, PCI, Chicago, IL.

EDITOR'S NOTE

For more information regarding test procedures for long-service-life patch materials, see the Yang et al. paper from the March-April 2016 issue of PCI Journal. *This research was funded by the Tennessee Department of Transportation.*