Uniform Service Life of Bridge Elements through Design and Preservation

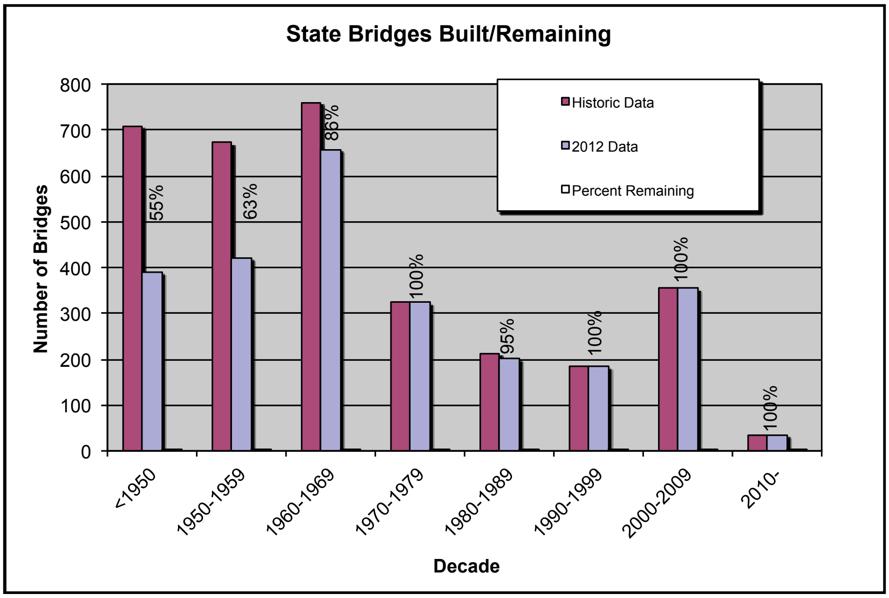
Service-life-design plans may be the key

by Bruce V. Johnson, Oregon Department of Transportation

The average age of bridges in the United States is nearing 50 years. This means that agencies are spending a greater proportion of the limited transportation funding maintaining these aging bridges and when necessary, replacing them. The graph shows the number of bridges built during various decades and those remaining in Oregon. This chart shows that there are many bridges in service that are over 40 years old with growing needs. In Oregon the elements that consume the most maintenance resources are

- decks (patching, sealing, and overlays),
- steel girders (painting and fatigue mitigation),
- expansion joints (resealing, patching, and replacements), and
- bearings (cleaning, painting, and replacements).

While only some areas of the country have major issues with corrosion on substructures and scour issues, maintenance crews throughout the nation spend significant resources preserving decks, joints, and steel bridges.



Percent of state-owned bridges still in service in Oregon by decade. Figure: Oregon Department of Transportation.

Extending Service Life of New and Existing Bridges

Many questions are raised when considering design lives of bridges:

- Why doesn't a bridge deck or deck joint last as long as most superstructures and substructures and is that a realistic goal?
- Would it be more cost effective to design and construct a deck or expansion joint that would last 100 years without major rehabilitation?
- What would the design specifications for a 100-year deck joint look like?
- Would the stresses need to be limited to some very low value?
- Would you need to design three or more redundant deck sealing systems to avoid corrosion and the constant maintenance needed to maintain cathodic protection systems?
- How can you limit the build up of debris that is the killer of all sealing systems without consistent maintenance actions?
- Should we just be more explicit about the need for scheduled maintenance and preservation actions to achieve the service life we want?

The aviation and nuclear energy industries have concluded that both service-life design and preservation actions are the only way to ensure desired performance and safety. Is it time for the civil engineering discipline to take a similar structured approach to service life and preservation?

Two very different approaches can be considered to extend service life. One approach is to design and construct using indestructible materials at a greatly increased first cost. Bid prices to construct a 100-year bridge element would likely be higher than one intended for a 50-year life.

The other approach is to design and construct with ordinary materials, and require inspection and maintenance activities at specified intervals to keep the structure safe and in serviceable condition throughout the service life. This practice is consistent with the aviation and nuclear industries, where safety is paramount but indestructible materials sometimes cannot be used due to their cost (or weight).

Several agencies are working to develop a systematic, rational method of designing bridges with elements that have a uniform service life. Bridge designers do this to a certain extent today, but for the most part it is done subjectively. Decisions regarding deck joints, materials such as high-performance concrete, high-performance reinforcement, and bridge type are sometimes justified by seeking longer service life, but normally without developing detailed life-cycle costs over the desired years of acceptable service life. One challenge in taking a more-structured approach to design for service life is that we do not have readily available, easy-to-use tools for analysis.

Deck sealing was completed by Oregon Department of Transportation bridge maintenance crew. Photo: Oregon Department of Transportation.

Nor do we have the substantiated performance metrics of all the different elements used in bridges needed for analysis. In developing these metrics it would be preferable not to be driven entirely by past practices, because the industry is making progress using more durable materials, improving design detailing, and increasing construction quality. That means projections from old data may not provide the best answers for service life estimation. But, it seems clear that complete historic performance data that includes tracking the impact of preservation and maintenance is the best starting place.

Three reports are to be released in the future that may assist with development of this rational, detailed approach:

- SHRP2 Program R-19A, "Bridges for 100-year Service Life" (early 2013)
- SHRP2 Program R-19B, "Bridges for 100-year Service Life—Calibration" (early 2014)
- NCHRP Project 14-23, "Practical Bridge Preservation Actions and Investment Strategies" (early 2015)

Design for service life may include the use of improved materials and structure configurations, or may include a detailed plan for expected preservation actions to extend service life, or some combination of both. Either way, a designer should be able to issue a service-life-design plan with a high expectation that the structure will provide the intended service life, at least with respect to predictable deterioration mechanisms. Extreme events at levels higher than predicted by probabilistic design methods could always threaten the expected service life, but environmental mechanisms such as corrosion and load effects such as live loads or abrasion, would be covered in the service-life-design plan.

This concept is not new because it has long been an integral part of design of mechanical structures used in airplanes and nuclear facilities. We are at a point where rational service-life design is possible and considered worth the effort for major, significant bridges. It may be that owner agencies will choose to use this process only for those bridges, but as the procedures are streamlined and tools are developed and presented that are very easy to use, and have been correlated to achieve results close to actual experience; the process could be extended to routine bridges.

Developing a service-life-design plan can also be extended to existing bridges based on their existing design or in the development of a rehabilitation project. In the case of an existing bridge, elements with a short service life can only be covered by a plan for preservation or maintenance actions. If the service life design is conducted as part of a rehabilitation project, there would be options for increasing the life by use of high-performance materials or a combination of planned actions.

One of the benefits of extending this process to routine bridges is that a preservation program could be developed as a roll up of the planned actions for bridges. A program of preservation developed from actual planned actions could be a very persuasive method for targeting limited budgets for preservation. Defining needs and executing a more systematic program of preventive maintenance and preservation actions for the entire inventory may be the only viable solution for retaining the effectiveness of our highway system.

fib *Approach*

The Model Code for Service Life Design, published by the International Federation for Structural Concrete (fib) in 2006, provides the following four approaches for service life design. These are:

1. full probabilistic design,
2. partial probabilistic design,
3. deemed to satisfy design, and
4. avoidance of deterioration design.

Option 1 is intended for use on exceptional structures. Option 2 is a deterministic approach where material resistance and environmental loads are considered using partial safety factors. Options 3 and 4 are similar to those found in today's standards such as the *AASHTO LRFD Bridge Design and Construction Specifications*.

The fib code is directed more towards European practices. No comparable documentation based on U.S. practices currently exists. For more information about designing concrete bridges for longer service life, the reader is referred to the following American Segmental Bridge Institute (ASBI) publication: *Design and Construction of Segmental Concrete Bridges for Service Life of 100 to 150 years* by Steem Rostam. Available at www.asbi-assoc.org. Click on publications and ASBI Technical Reports and then scroll down to the bottom of the list. The Rostam paper was also reprinted with permission in the Jan.-Feb. 2008 issue of the *PCI Journal.*

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Bruce Johnson is a state bridge engineer with the Oregon Department of Transportation in Salem, Ore.