

Concrete Bridges: 100 Years of Advancements

by Dr. Reid Castrodale

Perhaps you, too, have been getting the emails or have seen the announcements—2014 is the centennial of the American Association of State Highway and Transportation Officials (AASHTO). Its website, centennial.transportation.org has a lot of interesting information on the organization's activities and the advancements in transportation, and especially highways, in the last 100 years.

In the spirit of AASHTO's centennial, I began to reflect on the last 100 years of concrete bridges in the United States. Concrete bridges were already in service when AASHTO, then called the American Association of State Highway Officials or AASHO, was formed in 1914. Concrete bridges at that time were limited to short span slab, T-beam, or frame structures and some impressive arches with relatively long spans that used the compressive strength of concrete to great advantage. A few of the concrete bridges that were in service in 1914 are still in service today, a testament to the durability of the concrete as it was used in those early bridges.

Since 1914, significant advances in many areas have enabled concrete bridges to become more widely used and to achieve longer and longer spans. The wide and current use of concrete for bridge superstructures is shown by data in *Bridges by Year Built, Year Reconstructed and Material Type for 2013*, a report prepared by the Federal Highway Administration (FHWA) using the National Bridge Inventory (NBI) database (Fig. 1 and 2). For bridges built in 2012 on all systems, 78% of the number of bridges and 76% of the deck area were for bridges with superstructures classified as concrete or prestressed concrete. While there are some limitations to the precision of the NBI data when used in this way, these numbers show that concrete is being used for the superstructure system for the majority of bridges being built in the United States. Concrete is also used for the vast majority of bridge decks and substructure elements, although quantitative data for these items is not readily available.



Construction on the Third Avenue Bridge in Minneapolis, Minn., began in 1914 and was completed 4 years later. It uses open-spandrel concrete arches to span the Mississippi River. Photo: John A. Weeks III.

Today's concrete bridges differ from those of a century ago in many ways, but there are still strong similarities. Concrete has matured as a construction material, but it still has more potential to be explored. I'll take a look at several areas where changes have occurred in the last 100 years, and also consider a few opportunities for the future.

This is not intended to be an exhaustive list or a highly technical discussion. It is just intended to be a few observations from my involvement in the concrete bridge industry over the last 30 plus years, which is a brief period compared to the period over which concrete has been used in the United States.

Concrete Bridge Materials

We are using basically the same materials to make concrete that were used 100 years ago. But through refinements and new materials, we can now make concrete that

- has much higher strengths,
- can easily flow into congested areas,
- can achieve high strengths very quickly,
- can develop reinforcement in very short distances,
- has significantly reduced permeability, and
- can even absorb carbon dioxide.

These and other improvements have addressed concerns with the performance of concrete structures and have allowed advancements in the use of concrete for bridges. Many of these advances have been made possible by the introduction of new materials, especially admixtures and supplementary cementitious materials. And now, there are even new types of cement that are being developed that may reduce the impact of cement manufacturing on the environment. With the advances in concrete materials, concrete bridges can now be reasonably expected to have a service life of 75 to 100 years, if bridges are designed and constructed with the expected level of quality.

Prestressed Concrete

The innovation that has had the greatest effect on increasing span lengths for concrete bridges is the concept of prestressed concrete. This innovation—which was made possible only because of the development of high-strength steel reinforcement along with ways to anchor it and use it in concrete structures—has enabled the spans of concrete bridges to increase to a remarkable degree. Designers continue to develop new ways to employ prestressing to continue to build longer concrete bridge spans,

including the splicing of large precast concrete elements. Prestressed concrete structures and elements designed in accordance with the specifications are very robust and can be expected to provide excellent service for many years.

Concrete Bridge Design

Design of concrete bridges has changed in a number of ways, but one of the most significant for complex structures is the introduction of computers to do the many calculations that are necessary for more complex bridges such as box girders erected as cantilevers and cable-stayed structures. These and some other types of bridges have ever changing loads and stresses during construction that must be tracked and adjustments made if the final product is to perform as intended. The long-term effects of creep and shrinkage along with the effects of temperature changes and gradients are now evaluated to provide better solutions. Without the increased computational speed of computers, it would be nearly impossible to successfully build these complex structures.

Concrete Bridge Construction

As advances in materials and designs have occurred, the construction industry has kept up by finding ways to construct these longer-span bridges. Concrete bridge construction

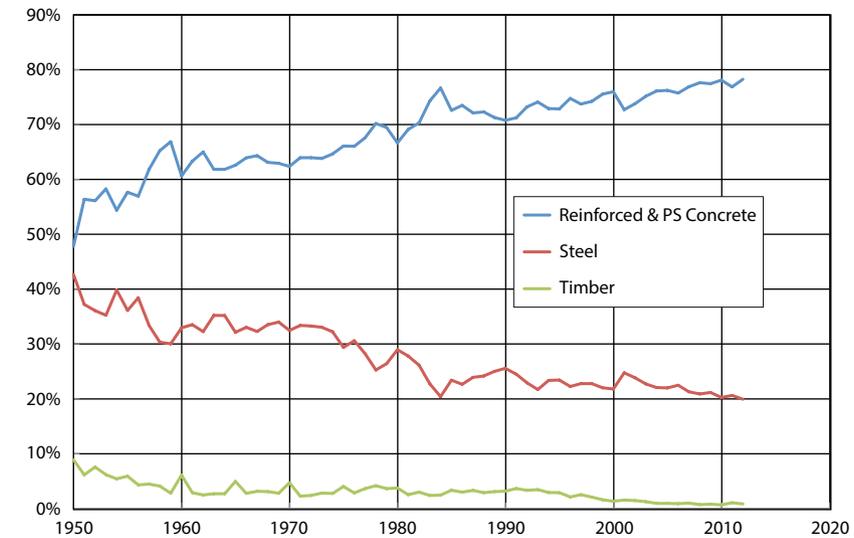


Figure 1. Relative number of new bridges constructed each year, classified by superstructure material using 2013 National Bridge Inventory data. Note: PS = prestressed concrete, which includes pretensioned and post-tensioned structures. Data source: FHWA Report “Bridges by Year Built, Year Reconstructed and Material Type” for 2013. Figure: PCI.

has made advances in many ways as materials, techniques, and equipment have steadily developed, allowing the construction and handling of longer spans and larger elements. Erection equipment has also been developed to allow construction of cable-stayed concrete bridges.

Public Expectations

The public has begun to raise their

expectations for bridges. In some situations, they now expect aesthetics to be incorporated into new structures that occupy prominent places in public spaces. They also expect bridges to be constructed more quickly, so they will not be inconvenienced by the delays caused by construction. Fortunately, concrete bridges can address both of these expectations by the ability of concrete to take many attractive forms and also to be used in ways that accelerate bridge construction, such as prefabricating elements.

Conclusion

Much has changed since 1914 in concrete bridge construction, making possible remarkable advances in the life span and span length of concrete bridges. There is no reason to think that the pace of innovation will slow. Instead, there are many areas in which further improvements are on the horizon. I am confident that we will be able to use these advances to improve concrete bridges so that this amazing material will remain a key part of transportation structures for the next 100 years. ▲

EDITOR'S NOTE

For the summary report of the FHWA National Bridge Inventory (NBI), see www.fhwa.dot.gov/bridge/nbi/no10/yrblt_yrreconst.cfm

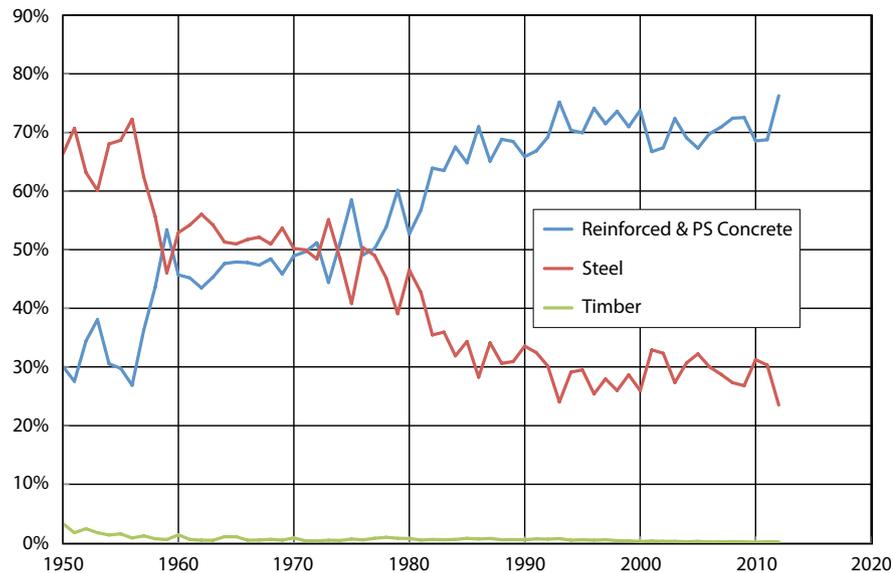


Figure 2. Relative deck area of new bridges constructed each year, classified by superstructure material using 2013 National Bridge Inventory data. Note: PS = prestressed concrete, which includes pretensioned and post-tensioned structures. Data source: FHWA Report “Bridges by Year Built, Year Reconstructed and Material Type” for 2013. Figure: PCI.