Elevating the Role of Materials Science in Bridge Engineering Education

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As a new decade begins, we are inclined to reflect on progress we have already made and plan and project our efforts going forward. For those of us working in education, this is also an opportune time to assess how we can best prepare our students and new engineers for future success.

A Century of Progress

In the bridge community, I think it is especially useful to highlight the enormous progress we have made over the last century or more. The timeline in **Fig. 1** shows a few bridges that I view as technological pioneers. While there are many important and noteworthy bridges in communities around the world, I selected these bridges to highlight because they represent early examples of technologies that have made bridges faster to construct, lighter, more cost-effective, more durable, and—most importantly—safer.

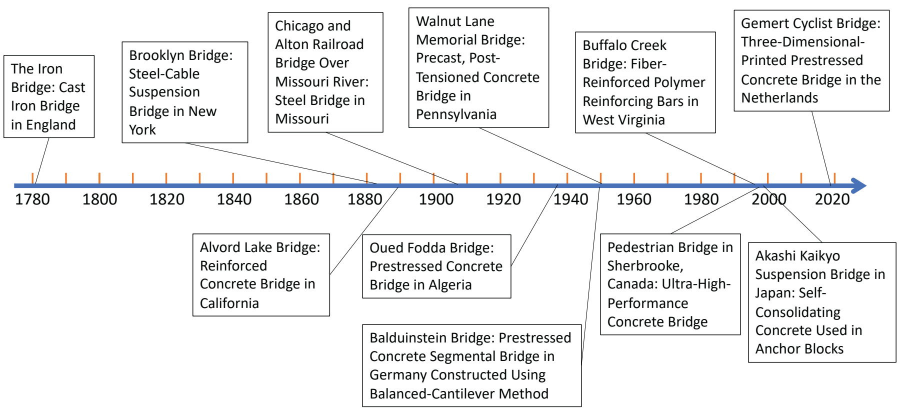

Figure 1. Timeline showing the year of construction for bridges that introduced innovative technologies. All Figures and Photos: Dr. Kyle A. Riding.

These bridges also have something else in common. Each was constructed using new structural engineering designs enabled by the development of new materials. For example, the Chicago and Alton Railroad Bridge over the Missouri River and the Brooklyn Bridge in New York City took advantage of cheap and plentiful steel made possible by the new Bessemer steel process. The Oued Fodda Bridge in Algeria, the Balduinstein Bridge in Germany, and Walnut Lane Memorial Bridge in Philadelphia, Pa., were showcases for the benefits of prestressing concrete in bridge structures. While the concept of prestressing had been theorized for several decades, higher strength concrete and steel made it practical for these bridges.[1]

In recent history, bridge designers have focused on simpler construction and greater durability by using high-performance materials, including fibers in concrete mixtures. Going forward, bridge construction can be semiautomated by leveraging three-dimensional printing, machine learning, and concrete with tailored flow and strength-gain properties.

Pioneering engineers make progress by combining a solid grasp of fundamental engineering mechanics, new knowledge in materials science, and practical construction in their designs. One such pioneer was Eugène Freyssinet. While other researchers had previously tried to embed tensioned wires into concrete to introduce prestressing, Freyssinet successfully designed modern, functional prestressed concrete members for the Oued Fodda Bridge project. He accomplished this by using high-strength steel and concrete and by calculating concrete creep and shrinkage losses.[1] He also pioneered long-line prestressing beds still used by many precast, prestressed concrete plants to cost effectively fabricate bridge members.[2]

When pioneering technology is shown to work well and be economical, it can soon become commonplace. For example, in Columbia, ultra-high-performance concrete (UHPC) proved to be so economical and successful in a four-span, 361-ft-long segmental, post-tensioned pedestrian bridge constructed in 2017 in Medellín, that a second UHPC segmental, post-tensioned bridge, two spans and 98 ft long, was built in Manizales in 2018.[3]

Preparing Engineers to Build the Bridges of Tomorrow

As bridge technologies have become increasingly sophisticated, engineers have needed greater knowledge and control over their materials. Structural engineers in the United States are now called upon to evaluate material options and submittals and to be the final word on their suitability to meet the performance expectations of owners.

However, even as the need for knowledge of materials has increased, civil engineering programs have come under pressure by state legislatures and university administrations to reduce credit hour requirements.[4] For example, in 2018 the University of Florida reduced the number of credit hours required to obtain a bachelor of science degree in

This segmental, post-tensioned pedestrian bridge in Medellín, constructed in 2017, is the first ultra-high-performance concrete bridge in Colombia.

civil engineering from 131 to 128; many other universities in the United States have made similar reductions.

Today, undergraduates majoring in civil engineering typically take only one course on materials, with a couple of weeks at most dedicated to each civil engineering material. Engineers certainly need a deeper knowledge base than that to make critical decisions about material performance in bridges and to make breakthroughs in new bridge technologies. So how do we elevate the level of materials science knowledge in the structural engineering community? Here are a few suggestions.

First, structural engineering master's programs should include a materials science course as a core competency. Partly as a response to dwindling credit hour requirements at the undergraduate level, master's degrees have become the de facto entry-level degree for many structural engineering firms. Adoption of a materials science course as a master's requirement could help raise the knowledge level of engineers responsible for specifications, acceptance, and design. I believe that a concrete materials or composite materials course would give structural engineering students a good foundation for future learning on the topic. If your university does not offer a graduate course in structural materials, it may be possible to take an online course through another university's distance education program and transfer the credits to your university.

Universities looking to train faculty to teach a graduate concrete materials course will find that the annual professors' workshop on concrete materials, pavements, and structures cosponsored by the American Concrete Institute (ACI) Foundation and the Portland Cement Association (PCA) Education Foundation is an excellent place to start.

A second way to increase materials science knowledge is by using professional development hour (PDH) requirements as an opportunity to learn. Peers and new hires should also be encouraged to participate. Excellent materials science courses are offered by several organizations. Here are some prominent offerings:

- The PCA course *Design and Control of Concrete Mixtures* is offered regularly. For more information, visit *https://www.cement.org/Learn/education/design-and-control-of-concrete-mixtures-course.*
- The National Ready-Mixed Concrete Association (NRMCA) offers a series of courses on concrete technology with different levels of certification as a concrete technologist. NRMCA courses on concrete fundamentals, concrete durability, and other topics are offered around North America. For more information about the program, schedule, and locations of courses, visit *https://www.nrmca.org/products/conferences.asp.*
- The ACI University has a wide range of web-based courses with continuing education credits. To learn about ACI courses on a variety of concrete topics, visit *https://concrete.org/education/aciuniversity.aspx.*
- Local ACI chapters often host speakers at events that include a dinner or other activity. To find your local chapter, visit https://concrete.org/chapters/findachapter.aspx.

My final suggestion is to encourage new hires to use free web-based resources. For example, free lectures by world-renowned professors and engineers have been posted on YouTube. Also, ACI offers free videos of excellent presentations on a variety of new materials and structural concepts, including recent technology developments at https://concrete.org/education/freewebsessions/completelisting.aspx.

Conclusion

Bridge engineering has come a long way in the past century. Much of this progress was steered by clever engineers using materials science to enable new bridge load-support systems. Materials science will continue to yield great advancements in bridge design and durability and should be an integral part of the formal and continuing education of bridge engineers.

References

1. Sanabra-Loewe, M., and J. Capellà-Llovera. 2014. "The Four Ages of Early Prestressed Concrete Structures." *PCI Journal* 59 (4): 93–121.
2. Freyssinet, E., and J. Seailles. 1930. *France Patent No. 680547.*
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4. Myers, J.J. 2018. "Developing a Greater Feel for Structural Engineering." *ASPIRE* 12 (2): 36–38.

EDITOR'S NOTE

Technical institutes play a vital role in promoting continuing education opportunities for new and experienced engineers. PCI offers eLearning modules on many transportation topics, including "Materials and Manufacturing of Precast, Prestressed Concrete." See page 41 of the Winter 2020 issue of ASPIRE® *for additional information and a sampling of other course options.*