Reinforcing the Future: Advancing Concrete Bridge Knowledge at the University at Buffalo

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There is no doubt that designers of modern bridges stand on the shoulders of the giants of engineering who preceded them. But a modern bridge is far from our grandparents' bridge. Today's bridges must meet more criteria than ever before. They need to be functional, safe, resilient, durable, redundant, adaptable, sustainable, aesthetically pleasing, and, of course, structurally efficient and economical. So how do we check so many boxes? We invest in research and education that empower us to create new structural materials, systems, and construction methods. We study how in-service bridges respond to complex loads and environmental conditions. And we make sure that our field is welcoming and accessible to all bright minds. The Institute of Bridge Engineering at the University at Buffalo (UB) was established more than a decade ago to address some of these needs. I started my academic career at UB with these ambitions in mind in 2013.

For many people, the word "professor" is synonymous with teaching, but at research-centered universities like mine, the professor is also a researcher who generates new information to share with the next generation. My research has revolved around structures that are rapidly built, can be repaired or replaced for resiliency after extreme loading, and that are serviceable after environmental deterioration. What better tool do we have than precast concrete for rapid construction, replacement, and durability? In this article, I provide examples of bridge-focused research at UB, which has been made possible by the hard work of many talented undergraduate and graduate students, as well as

Testing of a precast concrete rocking column with ultra-high-performance concrete at the base column segment. Photo: Dr. Cancan Yang.

At the University at Buffalo, additively manufactured strain-hardening fiber-reinforced concrete shells are being investigated for bridge applications to leverage the concrete's exceptional crack-width control and durability. Photo: Pranay Singh.

collaborators both within and beyond the field of civil engineering.

Research for Resilient and Serviceable Bridges

One way to create repairable bridges is to use advanced materials where they are needed and in a cost-efficient manner. My colleagues and I showed through testing of self-centering segmental bridge columns that even without mild steel reinforcement in the column base segment or between segments, there is virtually no damage due to large lateral drifts when ultra-high-performance concrete (UHPC) is used for the base column segment.[1] And our research on fiber-reinforced concrete extends beyond UHPC. We are investigating whether strain-hardening fiber-reinforced concrete shells can reduce crack sizes and mitigate the durability-reducing effects of detensioning cracks in pretensioned concrete girders.[2] To create shells in the shape of common pretensioned concrete girders and to one day be able to create free-form beams, we explored additive manufacturing—also known as three-dimensional (3-D) printing. Our initial flexure test findings show that bond failure at the interface between the additively manufactured shell and core concrete is not an issue.

Artificial intelligence (AI) has already penetrated our daily lives, and students are chasing opportunities to develop AI skills and applications in bridge engineering. In one study, our research team used machine learning to look for correlations between shear cracks in concrete beams and structural health indicators like stiffness and loading corresponding to crack widths. We then created a data-driven, web-based evaluation tool for bridge owners to prioritize repair. This work was partially funded by the precast concrete–focused University Transportation Center (TRANS-IPIC), of which UB is a member.[3]

My final research examples involve modeling as a powerful tool for understanding prestressed concrete structures. When it comes to a composite, nonlinear material such as concrete, aligning simulation predictions with test measurements can, in and of itself, be a learning experience that offers insights into numerous factors that affect structural response. For a National Cooperative Highway Research Program study (NCHRP Project 12-118), our research team has expanded the work of our collaborators at Purdue University with simulations that help us understand flexure and shear strength of prestressed concrete beams with bonded and unbonded strands.[4] In another study, we used similar simulations to verify strain measurements of optical fiber sensors embedded within the epoxy coating of prestressing strand as a step toward monitoring prestress for in-service bridges.[5,6] (For a description of this technology, see the article in the Fall 2024 issue of *ASPIRE*®.) That work was

Bridge inspection field work for a research project with former graduate students Lissette Iturburu Al-tamirano and Mauricio Diaz Arancibia, and Larry Mathews of the Association for Bridge Construction and Design of Western New York. Photo: Dr. Pinar Okumus.

Undergraduate students visiting the Sidley Precast plant in Thompson, Ohio, pose with star-shaped reinforcing bars, one of which was later decorated for the holidays. Photo: Dr. Pinar Okumus.

also conducted with Purdue University with funding from the Federal Highway Administration.

Educating the Next Generation of Bridge Engineers

Research can be a winding road that does not always provide immediate rewards. Some research questions need to be answered using tomorrow's technology; funding can shift with changing priorities; and implementation can take years, especially for fundamental research. In contrast, teaching can offer instant gratification, particularly when students reach their full potential, producing work around the world that makes us feel delighted and, if we are lucky, envious.

UB offers a master of science degree and a certificate concentrating on bridge engineering with remote course options. Responding to the needs of the industry, we cover subjects such as prestressed concrete design, advanced concrete materials and design, hazard (earthquake, wind, and fire) engineering, risk and reliability, bridge management, public policy, and emerging technologies, among others. A course on prestressed concrete bridge design has been in high demand and is taken by students and practicing engineers worldwide. In 2025, participants from the New York State Department of Transportation made up about one-third of the class. The course covers fundamentals of prestressed concrete and bridge engineering, neither of which are typical undergraduate curriculum.

I want to end this reflection on an aspect of teaching that is often overlooked. A bright PhD student destined for a stellar academic career recently told me that he may no longer be considering academia because professors seem to do nothing but work. This comment was a wake-up call for me: However much we love our spirited debates about shear reinforcement over coffee, work does not have to be our only hobby. We need to show students that it is possible to have friends, family, a healthy life, and time off. For me, the friendships I have built at PCI are one example that work and life can coexist.

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