

Do We Teach or Do They Learn?



The devil is in the details

by Dr. Oguzhan Bayrak, University of Texas at Austin

This year marks the fifteenth year of my teaching career at the University of Texas. Prior to joining the University of Texas, I taught a few structural concrete design classes to civil engineering students at the University of Toronto and to students at the school of architecture at Ryerson University. Whereas the topics of my classes were reasonably similar, I was able to observe different learning patterns exhibited by engineers and architects at an early stage in my teaching career.

I had to use different explanations, perspectives, and teaching techniques when teaching architects than those I had previously used for engineers. Architects and engineers possess different sets of talents and backgrounds. During my formative years as an educator, I witnessed first-hand that structural engineering education was a function of the audience and that it was a complex task.

This early teaching experience proved to me that an effective teacher is one who thoroughly knows her/his subject matter and takes the time to prepare lectures and classroom presentations that are well suited for the audience. With that preamble, I will focus on teaching bridge engineering at the University of Texas.

I had not had the opportunity to teach a bridge engineering class until Spring 2015 semester, despite the fact that I have spent a great majority of my career at the University of Texas conducting research on a variety of topics that relate to concrete bridges and bridge engineering. As I write this article, we are nearing the end of the semester and it is an opportune time for me to take a step back and reflect on the semester from a teaching and learning point of view. More specifically, I will focus on designing reinforced concrete bridge substructures using the strut-and-tie method (STM).



2015 Concrete Bridge Class, University of Texas at Austin: From left to right, Chris Williams, Albert Aquavanna Limantono, Gabriel Polo, Paul Biju-Duval, Chase Slavin, Dylan Chuey, Katelyn Beiter, Wiam Al Aawar, Amir Reza Ghiami Azad, Randal Shinn, Melvin Goh, Caroline Weston. All Photos: Katelyn Beiter.



2015 Concrete Bridge Class Project at the University of Texas at Austin.

In designing reinforced concrete foundations and bridge bents, one must separate disturbed or discontinuity regions (D-regions) from Bernoulli or beam regions (B-regions). While using legacy methods (for example, sectional design methods for shear, flexure, and the like) in designing B-regions is appropriate, their use in designing regions where plane sections do not remain plane (that is, D-regions) is not advisable. Naturally, the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications* acknowledge this fact and include detailed provisions to be used for the application of this method in bridge design.

However, to the best of my knowledge, most structural designers have been reluctant to use STM in designing bridge substructures. This reluctance can be understood to a great extent by considering the relatively recent introduction of this technique in our

design specifications. This reluctance can be further explained by considering the tremendous flexibility offered by STM. In other words, this design technique is considerably less regimented than our legacy design techniques and therefore it leaves a substantial amount of room for creativity and a perceived element of risk coupled with that freedom.

Considering all of the challenges listed previously, I decided to devote a great majority of my bridge design class to discussing this technique and its application to a variety of concrete bridge components. I did not stop there, I decided to go further. I assigned a project in which student teams designed a substructure element by using STM, and presented their designs in class in the form of an interim submission.

Next, the design teams were asked to build the elements they had previously designed at the Ferguson Structural Engineering Laboratory and to conduct tests on the laboratory specimens stemming from their designs. The ultimate goal was to observe the behavior of the test specimens they had designed.

As I write this article, students taking my class are almost ready to test their specimens. With that said, even before the structural testing, they have already developed substantial understanding in regards to the practicality of their designs. They had to live with the constructability issues that stemmed from some of their design decisions.

For example, the team that employed bent bars (truss bars) in their design had to spend additional time in assembling their reinforcing bar cage in relation to the team that utilized an orthogonal grid in their design, to support the same design loads. Conversely, the design involving bent bars utilized a lesser quantity of reinforcement in relation to the design in which the orthogonal reinforcement was used.

What is the moral of this story? Well, it does not appear that we can get something for nothing in structural engineering.

Next, the student teams will load their test specimens to failure to observe their structural behavior. The cracking

From the Mouths of Students

At the end of the semester, I asked students in my first bridge engineering class to reflect back on what they had learned. When asked, "Can you please summarize your experience with the class and/or the project?," I received the following responses:

"This class has given me a unique learning experience where theoretical concepts are put to the test (literally!) and hands-on experience with lab testing procedures has enhanced my engineering education in a way that traditional classroom-style teaching is not able to achieve."

"The Strut-and-Tie Method has presented itself as a tool all bridge engineers should adopt to gain a full understanding of the forces transferring through deep beams."

"During this class, it has been exciting to learn about soon to be implemented techniques while, at the same time, having it firmly fixed in reality, with an emphasis on construction considerations and the unique opportunity to work through a class problem from design to construction. It's one thing, in a class, to listen to a lecture on constructing a beam, but another to get to experience it for yourself."

"Dr. Bayrak's class, based not just on structural theories, but engaging us, students, in hands-on lab experience, is a fun and complementary way to understand the real challenges in fabrication, understanding the behavior of the members we design."

"Bridge class, with all its components (including but not limited to the project), has been an enlightening and rather comprehensive entry into the world of strut-and-tie modeling of concrete bridges for me as it involved both learning and applying strut-and-tie modeling not only on the levels of theory and design, but also on the levels of construction and (soon) testing."

"It has been a pleasure to finally get some hands-on experience in the lab, which up until now has been an opportunity that I have regrettably missed out on. In addition, it has been interesting to learn something new and fresh (STM) that I and many others have little to no experience with."

"It was a great design-build team effort to optimize deep beam reinforcement using strut-and-tie theory, and even extending those concepts for curved reinforcement in a reverse curvature bending configuration. So it is definitely an interesting project."

patterns observed at service load levels and those observed at ultimate will serve the purpose of explaining the load transfer mechanisms.

Student comments I have received to date indicate that our students greatly value the emphasis I placed on STM. Students in my class are able to identify the load paths that are so essential in substructure design such as compression fields, tension fields, reinforcing bar anchorage, stress concentrations under bearing pads, role of crack control reinforcement, and the list goes on. Ultimately, the most important aspect of STM, or substructure design for that matter, is the need to clearly visualize the load paths created by various design loads and design the substructure elements accordingly.

Equally important are the reinforcing bar details such as column-to-cap connections, column-to-foundation connections, detailing of the ledges of the inverted-tee caps, and hanger reinforcement details, just to name a few. Whereas the concrete element has no way of knowing the methods employed in its design, its structural behavior will most certainly be influenced by its reinforcement detailing. Students taking my bridge engineering class will soon observe the influence of their reinforcing bar detailing decisions on structural behavior. Undoubtedly, the students will learn the fact that the devil is in the details, and quite frankly, no design method forces a structural engineer to think through all of the primary details better than the STM in the context of reinforced concrete design. 