Benefits of the FHWA-NHI Strut-and-Tie Modeling Workshop

An Attendee's Perspective

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To meet the current and future needs of our ever-changing society, engineers must keep their skills and knowledge up to date. Such discipline is required of new graduates and more-experienced engineers alike. Even if you are fully qualified, it is essential that you keep abreast of changes in the engineering profession. Continuing education courses can strengthen and broaden your knowledge base, and they will help you master needed skills at any stage of your career. Continuing education is also a requirement of licensure in most states.

We can, of course, take webinars and online courses to learn about new bridge construction practices and improve our bridge design skills. However, when I participated in the "FHWA-NHI Strut-and-Tie Modeling (STM) Workshop" at the 2018 PCI Convention and National Bridge Conference in Denver, Colo., I was reminded of the unique value of collaborative and interactive education—there is nothing quite like being in the room with industry authorities and informed colleagues.

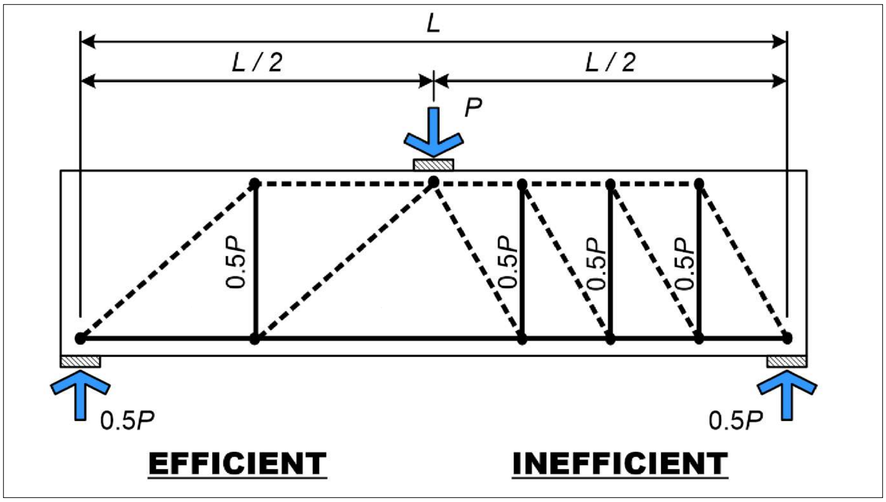
STM has long been established as the preferred analysis method for deep beams and disturbed regions in concrete structures. STM is appropriate for analysis and design of bridge elements such as beam ends, diaphragms, corbels, beam ledges, deep beams, and pile caps.

Despite the importance of STM, introductory concrete design courses typically do not cover the topic, and many design engineers do not feel confident about their understanding and use of the method, especially if they have been using a traditional sectional analysis requiring a two-step design process—one for flexure and one for shear. With the American Association of State Highway and Transportation Officials' (AASHTO's) recent adoption of new STM provisions in Section 5 of the *AASHTO LRFD Bridge Design Specifications*,[1] engineers must clearly understand and be able to apply the concepts and details of STM.

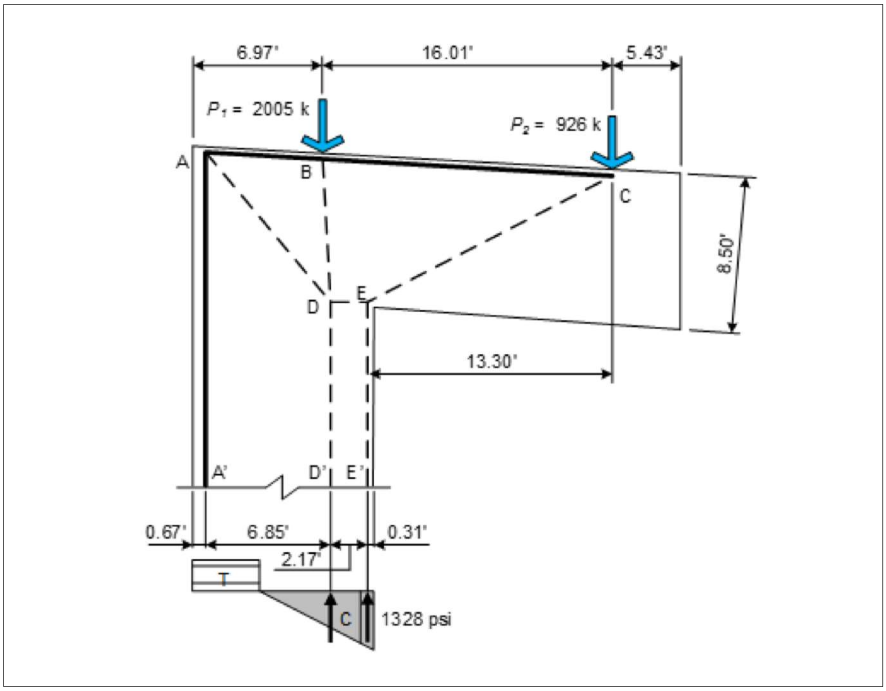
The STM workshop I attended was run by the Federal Highway Administration (FHWA) and National Highway Institute (NHI) and geared toward bridge engineers at all levels of STM experience, from beginner to advanced. When I attended it, I was not a novice in STM. I was first introduced to the method as a PhD student at the University of Minnesota nearly 30 years ago, thanks to Professor Cathy French and her progressive technical course content, and I have since included a few lectures and homework to introduce STM to my own students in a graduate-level bridge design course. Therefore, for me, the workshop offered an excellent opportunity to sharpen my STM skills and gain some practical experience. The workshop was also well suited for introducing students to STM, especially when curriculum requirements and other course content limit the classroom time available for some technical topics.

In the workshop, industry experts presented an in-depth introduction to STM fundamentals and then guided attendees through simple to advanced STM scenarios commonly seen in bridge engineering. Attendees actively participated, defining truss systems and evaluating designs.

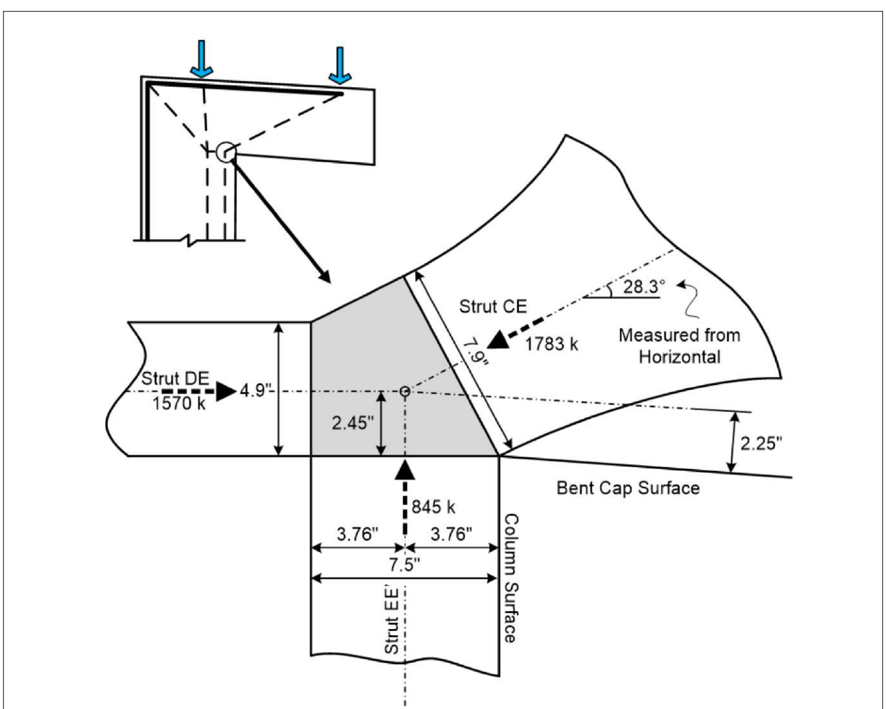
The following are critical points from the workshop to keep in mind when working with STM:



An example of efficient and inefficient strut-and-tie models. All Figures: Federal Highway Administration.



Strut-and-tie model of a cantilever bent cap.



Example of geometry and forces at a node.

- STM uses an engineering art approach, where stress flows are visualized into trusses, resulting in many possible solutions. Preparing the STM model includes defining B- and D-regions, proportioning concrete compression struts and reinforcement tensile ties, and identifying nodes where struts and ties intersect. Proper implementation and analysis will result in an efficient concrete member design, with quantities and layout for reinforcement and bearing areas, and consideration for serviceability requirements.
- Understanding of fundamental concepts is necessary to accurately implement STM. For example, the efficiency of a strut-and-tie model depends on load path; therefore, the most efficient model is a truss representing a direct load path. An efficient model, as shown on the previous page, will optimize the shear reinforcement. Boundary conditions are also critical in STM applications.

The workshop I attended engaged participants through a variety of STM example problems. The cantilever bent cap example was especially interesting to me. Maintaining equilibrium in the truss is particularly important with the unbalanced loading of the cantilever. Strength checks, which are necessary for the struts, ties, and nodes, included an enjoyable level of geometry for defining nodal dimensions. Crack-control reinforcement and anchorage requirements for ties were also addressed.

The workshop unquestionably exceeded my expectations. It helped me hone my STM skills and acquire practical experience through engaging discussions with a diverse cadre of bridge engineers. The workshop was extremely informative and well organized, and it challenged participants to blend their creative and critical thinking skills as they came to understand the proper use of STM. Based on the in-depth discussions facilitated by the expert instructors, I can assure you that there is undoubtedly a need for this training at all levels of the profession.

Reference

1. American Association of State Highway and Transportation Officials (AASHTO). 2017. *AASHTO LRFD Bridge Design Specifications*. 8th ed. Washington, DC: AASHTO.

EDITOR'S NOTE

All figures provided by FHWA for this article were developed for the NHI Course No. 130126, Strut-and-Tie Modeling (STM) for Concrete Structures, *Publication No. FHWA-NHI-17-071. This course was the topic of an article in the Winter 2018 issue of* ASPIRE®. *Additional discussion of this course is planned for future issues.*