HANDS-ON Education

BY GUSTAVO CORTÉS, PE, PhD

A comprehensive lab experience in school can get students off to a better start in their careers.

UNDERGRADUATE ENGINEERING EDUCATION involves a lot of theory and a lot of equations—but typically not much hands-on time.

Having taken an undergraduate steel design course without a lab and observing two other institutions whose steel design course offered a lab that only included exercises and/or designing a portion of a building, I decided to take a different approach and design a hands-on laboratory for the undergraduate steel design course I taught at LeTourneau University in Longview, Texas.

The lab, offered once per week for two-and-a-half hours, was designed to complement the topics being covered in class. While implementing this alternate approach to teaching a steel design laboratory at an undergraduate level came with a few challenges, these were overshadowed by what turned out to be an immensely fun and informative experience. Following is a snapshot of the lab and its various activities.

Classifying Steel Profiles

What better way to learn about the different steel sections and the use of Tables 1-1 through 1-7 of the AISC *Steel Construction Manual* (available at **www.aisc.org/publications**) than to be given steel sections and asked to determine their profile names? For this activity, students were given a weight scale, a caliper and a tape measure and were asked to identify several typical steel sections, including: W-shapes, S-shapes, channels, hollow structural sections (HSS), angles and plates. They were also given typical structural steel bolts of different diameters, grades and types. This exercise allowed students to observe the many differences between structural steel shapes and to relate the dimension tables given in the manual to actual shapes.

Creating Shop Drawings

For this lab, students were taught about shop drawings and bills of materials. The activity required creating shop drawings and a bill of materials for the AISC Bolt Toolkit (an educational tool provided by the AISC Partners in Education Committee; access it at **www.aisc.org/education**). This exercise also allowed the students to continue learning about steel sections, plates and bolts of different grades. Most dimensions of the kit were not provided, requiring students to measure all the parts before they could create the shop drawings and the bill of materials.

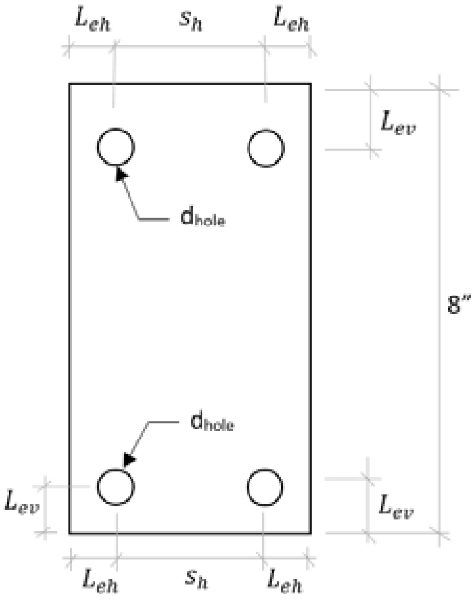
Tension Members

Have you ever have someone ask you, "Is block shear rupture really possible?" Whenever that question was raised in class, I used to show my students a picture from an experiment. But what if you could actually test a specimen that failed in that mechanism? Well, that's what this third activity was all about. Each group was given drawings of four plate specimens, and over a span of four lab sessions, they fabricated the specimens, calculated the capacity for the limit states of yielding, rupture, block shear rupture, bolt shear and bearing and tested their specimens under tensile loading.

▲ A group of students measuring all the parts of the AISC Bolt Toolkit.

◄ An example of the drawings that were provided.

▼ Test setup (left); specimens showing two of the four limit states investigated: rupture and block shear rupture (right).



▼ Students fabricating their test specimens.

Gustavo Cortés (cortesg@outlook.com) is a senior infrastructure advisor with Medair International and was previously an associate professor of civil engineering at LeTourneau University.

Test setup for shear tab connection (left); failed beam in double-angle connection (right).

They also prepared a laboratory report that included all of their findings and a thorough comparison of their analytical and experimental results.

Gravity Connections

For this activity, students learned about gravity connections—specifically, shear tabs and double angle connections. Two W8×10 beams attached to short W8×24 column stubs were tested. The first specimen used shear tab connections while the second specimen used double-angle connections. The main goals of this activity were to go deeper in the theory used for design of gravity connections, including the increase in bolt demand due to eccentricity, to teach students how to use Section 10 of the *Manual* for design of conventional shear tab connections and to compare capacity predictions based on the 2010 AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360-10) available at **www.aisc.org/specifications**.

The first session was used to introduce the lab, discuss the theory and start calculating the specimens' capacity. In the second session, students helped fabricate the two specimens, which were tested during a third session. Both the shear tab and the double angle connections failed due to bolt bearing. After bolt bearing failure of the double angle connection, the force was increased until a failure similar to block shear rupture, but incomplete due to the top flange presence, occurred. Students prepared a lab report presenting the experimental results and comparing them against calculations based on the *Specification*.

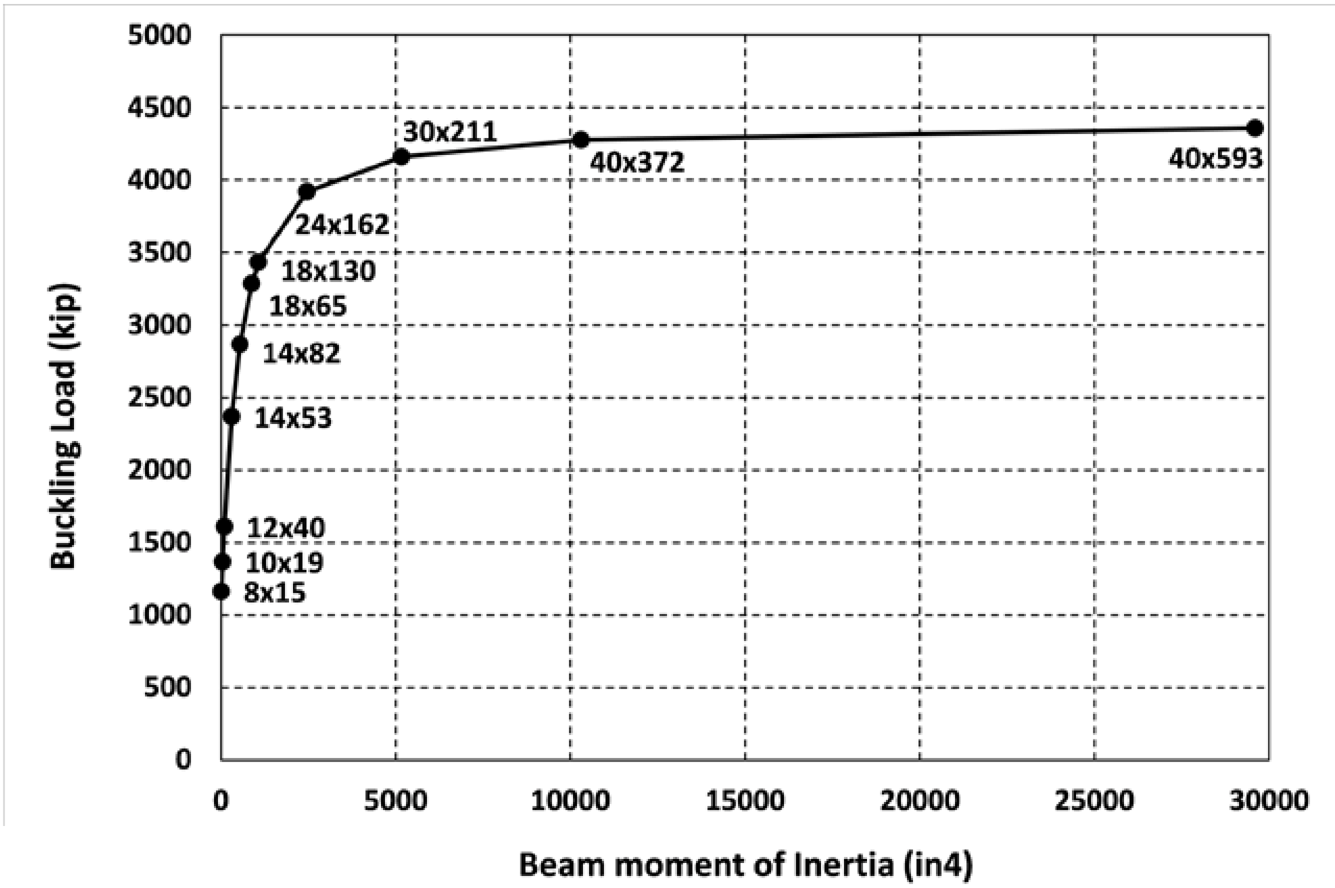
Columns: Virtual Lab

This lab was intended to reinforce the effective length theory used in column design and was based on Learning Module 1 from Mastan2 (**www.mastan2.com**), a structural analysis software ideal for in-class demonstrations. Students compared the column capacity obtained from the *Specification* to their computational results. One of the main takeaways from this activity was observing how end restraints play a major role in the column capacity.

Flexure Members

The last activity covered the topic of flexure. The two main objectives were to show students a lateral torsional buckling failure and also to demonstrate that reducing the unbraced length of the beam, even when the beam span remains unchanged, can increase the beam's flexural capacity significantly. Two tests were performed by applying a mid-span concentrated load to a W8×10 ASTM A992 shape on a 30-ft span. For the first test, the beam had no intermediate braces, causing elastic LTB to control. The same undamaged beam was used for the second test, but four braces were added at equal distances to reduce the unbraced length. For the second test, the beam's capacity reached its full plastic moment capacity (M_p). As with previous activities, students made a report presenting the findings and comparing them against analytical predictions based on the *Specification*.

Creating and implementing this laboratory had several challenges. First and foremost, many of the experiments required additional testing fixtures that had to be designed and built, which represented a significant time and financial commitment. However, this was a onetime expense since these fixtures can now be reused for years to come. Another challenge was coordinating the lab activities with the topics being covered during lecture. The aim was to have students work on activities that covered topics already presented during lectures in order to reinforce



Plot of critical buckling load (about strong axis) as a function of the moment of inertia of the attached beams.

the material taught. Significant planning was required to accomplish this lecture-lab coordination. Another challenge was determining the scope of each individual lab and deciding which limit states to show since only a limited number of specimens could be tested.

While there is an up-front cost to a hands-on laboratory like this one, it can be justified by the long-term benefits. In our case, the students were able to observe the structural behavior of many steel components and/or assemblies, including failure mechanisms, that otherwise are left to their imagination or trial and error in the real world. For us, the learning opportunity far outweighed the challenges of developing the laboratory and provided a memorable, hands-on experience that benefitted students before they graduated and began their structural engineering careers. ■

Test specimen under mid-span load.