Capstone Project: Competition Challenges Students

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Abstract

The capstone design project for engineering students is a culminating experience. At this institution, the senior capstone experience also requires construction of what is designed. This approach forces engineering students to see a project from beginning to end, from concept and design through construction. Like engineering and construction companies that compete for jobs through a competitive bid process, the National Steel Bridge Competition can be used as a capstone experience that challenges civil engineering students by having them compete against engineering students from other schools. This paper examines the successes and significant challenges from the student and faculty perspective of having the National Steel Bridge Competition as a senior design and construction capstone experience.

Keywords

Capstone experience, senior project, ABET, and steel bridge competition.

Introduction

The senior capstone design project is a culminating experience where civil engineering students have the opportunity to uses the skills that they have developed as an undergraduate to solve a significant open-ended real world problem. Many national competitions have developed over the years that may be used for senior project. These competitions require critical engineering thinking and the product must meet a very complex set of specifications requiring students to work and manage in teams. Contests such as: the ASCE National Concrete Canoe Competition (American Society of Civil Engineering); the PCI Big Beam Competition (Precast/Prestressed Concrete Institute); and the ASCE/AISC National Steel Bridge Competition (American Institute of Steel Construction) are good examples of competitive projects that may be used for senior capstone experiences as long as they help meet ABET accreditation requirements (Accreditation Board for Engineering and Technology).[1-4]

ABET and the Senior Capstone Experience

At Western Kentucky University (WKU), the capstone design project for engineering students is a culminating senior experience where students are required to not only design but to also build. Senior capstone design experience courses are a primary source of providing physical and/or electronic documentation of achievement of the "Program Outcomes" as required by ABET.[4] These outcomes as specified in criterion 3 of ABET criteria must demonstrate and measure and are referred to as items (a)-(k). These outcomes include:

(a) an ability to apply knowledge of mathematics, science, and engineering;
(b) an ability to design and conduct experiments, as well as to analyze and interpret data;

(c) an ability to design a system, component, or process to meet desired needs within; realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;
(d) an ability to function on multidisciplinary teams;
(e) an ability to identify, formulate, and solve engineering problems;
(f) an understanding of professional and ethical responsibility;
(g) an ability to communicate effectively;
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;
(i) a recognition of the need for, and an ability to engage in life-long learning;
(j) a knowledge of contemporary issues; and,
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

For faculty coming up with a design/build senior project experience that can be completed by a small team of engineering students in consultation with local engineering professionals in one to two semesters can be challenging. Many national student competitions may be suitable for senior project. One such project which provides a culminating design and construction experience is the National Student Steel Bridge Competition.

National Student Steel Bridge Competition

The National Student Steel Bridge Competition is a contest that tests the knowledge and practicality of teams of university civil engineering students from ASCE Student Chapters and Clubs from across the nation and world. During the 2015-2016 academic year, over 3,000 civil engineering students from the United States, Canada, Mexico, and China competed, building over 223 steel bridges. A total of 18 regional conferences were held where student teams competed in hopes of qualifying for the national competition.

Each student project team will ideally develop a large model steel bridge from conception and design through fabrication, erection, and load testing that meets all specifications and optimizes structural performance and economy.[3] Some institutions may not have the facilities and guidance necessary to properly make and erect the steel bridge and may work with a local commercial fabricator. However, the students are fully responsible for the requirements and their design, and they must coordinate and monitor the construction process. All bridges must adhere to the specifications as provided in the official rule book. For 2016, the specification which covers every detail and requirement of the competition is 50 pages in length, and every year the requirements change and become more detailed and complex. This helps to keep challenging future engineering student teams as well as to prevent previous submission of an existing bridge. In order to be competitive, each team will need to consider and balance real engineering issues such as: spatial constraints, material properties, strength, serviceability, fabrication, erection processes, safety, esthetics, project management, and cost. For example, the dimensions of the bridge are scaled downward from a real life full scale bridge at a ratio of 1:10, so the resulting model bridge is typically approximately 20’ long, where each member must fit into a box that is 6” wide x 4” deep x 3’-0” long. Bridge width and clearances must also be considered as required by the specifications. The winning student team must successfully

consider: bridge lightness, quickest team construction time, lowest bridge cost, strength capacity, lowest total weight, and most aesthetic.

May of 2017 marks the 25th anniversary of the National Student Steel Bridge Competition when student teams from 13 engineering schools first completed. The competition continues to evolve, challenging a new generation of civil engineering students.

Student Team and Faculty Challenges

There are many challenges faced by the student team and the faculty advisor. These challenges have been categorized and grouped as shown in Figure 1. Student team organization is one of the most significant challenges. Students must elect co-captains to lead the team. Other important lead positions include the purchasing officer, quality/specification reviewer, competitive designer, fabricator, and bridge builder. Electing these positions and motivating non leadership positions can be difficult. However, once the co-captains develop a timeline when project completions dates are due and regular meeting dates are also established, students tend to come together and move the bridge project forward. Getting all the students to read and understand the bridge specifications as well as to properly document all of their ideas and concepts for the bridge design in the Engineering Science Notebook for ABET can also be challenging.

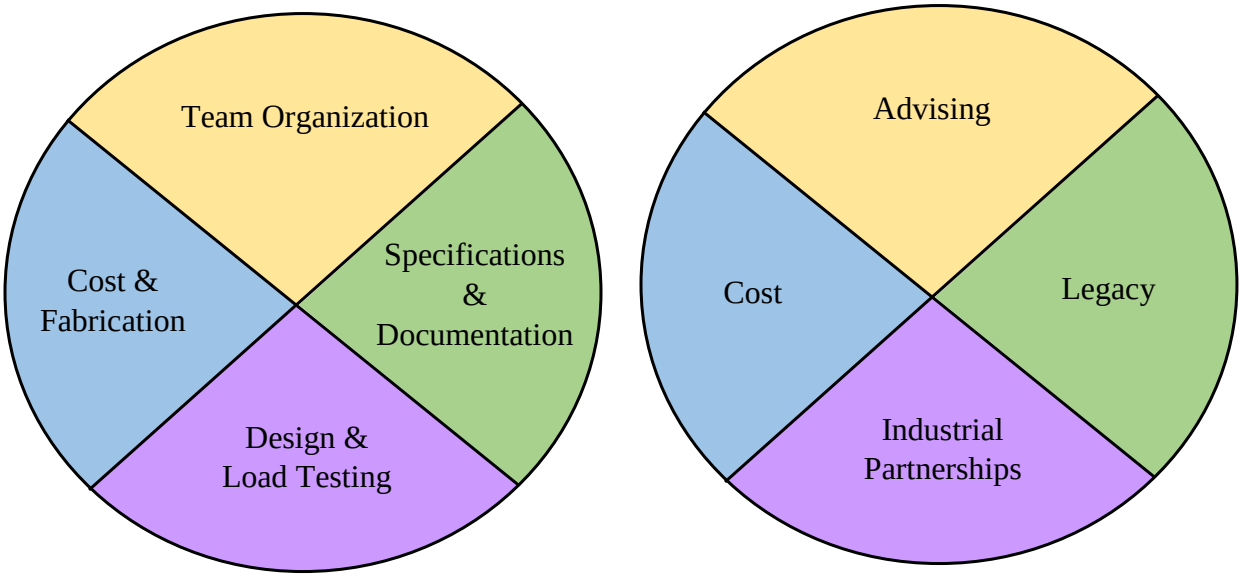

Figure 1. Challenge groups

Once the bridge is optimally designed based on computer analyses, the students must create a cost estimate and timeline for the bridge. Only a very limited budget is provided annually which forces the team to communicate with local engineering companies, fabricators and steel providers for assistance. Then, the bridge must be fabricated by the students or under their direct supervision. To do this, all of the steel must be ordered, cut to size, welded, and all connections made. Finally, the bridge is assembled and load tested. However, the students are often

surprised by why the actual bridge deflections are so much larger than the results the computer model. In addition, civil engineering students typically have a difficult time understanding the importance of truss and beam bracing. The students are very comfortable at designing a truss or beam from their mechanics courses but bracing (beam and truss stability) is a more challenging concept for them. At the ASCE 2014 Ohio Valley Student Conference, over half of the bridges, seven in total, failed due to improper bracing. Often during load testing and final product review, last minute problems with the design can be modified as needed. Of the entire process, load testing is the most important part for the engineering students. It forces the students to see how their pencil and paper design actual behaves in the real world, and this is critical.

Details are important. In one instance, the student team at WKU designed and fabricated a bridge where every connection on the entire bridge had 3/8" diameter bolts. However, the specifications stated clearly that all bolts must be larger than 3/8" diameter. In 2016, the student team designed and fabricated a beautiful red steel arch bridge. All members can only be a maximum of 3'-0" in length. The center steel arch piece was redesigned a couple of times due to connection issues and ended up being longer than the allowed length. Unfortunately, this violation was caught during the regional competition and the team was penalized. See Figure 2.

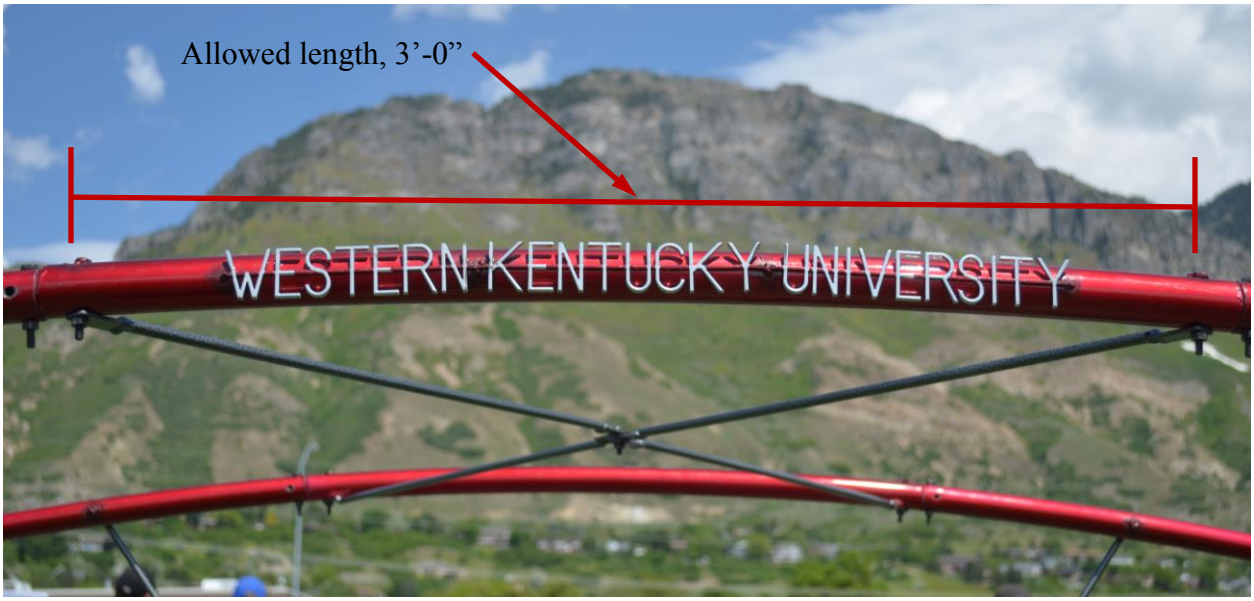

Figure 2. Center steel arch member, longer than allowed

From the faculty perspective, the challenges are effectively advising the student team and to help get underclassmen involved to increase student participation and legacy. Building legacy is important in terms of creating a strong culture of excitement and success, and the best way to do this is to get sophomore and juniors involved. The underclassmen need to do more than watch, observe, and help as needed. They are needed and are an integral part of the team. They have a voice and actively participate in every process of bridge development from concept through design, fabrication, and erection. This builds legacy, increases student awareness regarding the steel bridge competition, and helps build momentum for future years. Monitoring costs and how to purchase materials and equipment can also be taxing as well as effectively managing partnerships with local industry. It is important not to burden local industry but to try to partner

with them for mutual benefit. Despite the significant challenges that occur every year when trying to rally students to build a competitive bridge, the successes are even more significant and have a lasting impact on the students and the institution.

Successes and Student Impact

For the past four consecutive years, the WKU Student Steel Bridge team has qualified at the regional competition for the National Steel Bridge Competition. However, it is not about winning competitions; it is about engineering students using their newly found talents and energy and coming together as a team and to create and build something to be proud of and compete. After months of hard work all while they are studying for other classes and having other responsibilities, the competition arrives. The entire team travels to the host school where the competition is to take place. Engineering students from over a dozen other engineering schools come together to talk and discuss their bridges. Friendships are made and the competition can become fierce as students practice prior to the competition. At the competition, each team must erect their bridge based on the geographical limitations as set by the rules and the number of students on the build team. The competition resembles a sporting event but with many teams present, where the referees (judges in this case) watch every detail during team erection, inspection of the final product, and load testing of the bridge. See Figure 3.

Figure 3. Team bridge assembly and load testing at the competition

Engineering alumni have reported on post graduate surveys that being a part of the team helped to build their confidence as a young engineer and improved their ability to work in teams. See Figure 4. They also indicated on the survey that this helped in making the transition from engineering student to practitioner and has had a lasting impression on their undergraduate engineering education.

Summary and Conclusions

At this institution, the capstone design project for engineering students is a culminating experience requiring hands-on fabrication and construction of what is designed allowing engineering students to see a project from beginning to completion, from concept and design through construction. The National Steel Bridge Competition can be used as one such capstone

experience challenging civil engineering students by having them compete against students from other schools. Despite the significant challenges that occur every year including the cost of travel to the competitions and rallying the students to build a competitive bridge, the successes are even more significant and have a lasting impact on the students and the institution. The real value is not about winning nor being successful at the competitions, it is about engineering students competing and building what they designed.

Figure 4. 2014 WKU Steel Bridge Team

References

1 American Society of Civil Engineers (ASCE), National Concrete Canoe Competition: Rules & Regulations, ASCE, 2017, pg. 1-60.

2 Precast/Prestressed Concrete Institute (PCI), PCI Big Beam Competition, PCI, 2016, pg. 1-7.

3 American Society of Civil Engineers/American Institute of Steel Construction (ASCE/AISC), 2017 National Student Steel Bridge Competition, ASCE/AISC, 2016, pg. 1-40.

4 Accreditation Board for Engineering and Technology (ABET), Criteria for Accrediting Engineering Programs: 2016-2017, ABET, 2016, http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2016-2017/.

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