AC 2011-2019: SIMILAR CONSECUTIVE BRIDGE DESIGN PROJECTS FOR FRESHMEN AND SOPHOMORE LEVEL ENGINEERING COURSES

Emre Selvi, Muskingum University

Emre Selvi is an Assistant Professor of Engineering at Muskingum University, New Concord. He received his academic degrees in Mechanical Engineering; B.S. and M.S. from Middle East Technical University and PhD from Texas Tech University. Prior to starting his PhD in 2004, he worked as a Design and Production Engineer for Aselsan Inc. over four years. His research interests are high pressure material science and engineering design, especially as it relate to educational environments.

Sandra Soto-Caban, Muskingum University

Sandra Soto-Caban received her BSEE and MSEE from University of Puerto Rico, Mayagez Campus, and her PhD in Electrical Engineering from Michigan State University. She is an Assistant Professor of Engineering at Muskingum University in New Concord, OH. Her interests focus on engineering education and electromagnetics, especially electromagnetic characterization of materials.

Richard S Taylor, Muskingum University
Dr. William R Wilson, Muskingum College

Similar Consecutive Bridge Design Projects for Freshmen and Sophomore Level Engineering Courses

Abstract

The study takes place within a newly established engineering science major program at a liberal arts university. The department has a goal of embedding elements of engineering design throughout the entire curriculum. Because each course includes different subjects, design projects are customized depending on the content of the course. This paper is going to present similar design projects assigned in two consecutive courses where the same students worked on them by using different means. In the Introduction to Physics and Engineering course, freshmen students built a bridge made from spaghetti and glue. They tried to design one that would carry the maximum load without making any computational analysis. The subsequent year, in the Statics and Dynamics course, they constructed another bridge with similar size but this time using a bridge set with load cells. They performed calculations and measured the forces in their system to have a design with smallest compression members. These projects enabled the students to see the improvements on a design when an engineering approach was used and to realize their own progress after one year. They also individually served well for the design project purposes of their courses. Details of the projects will be provided and discussed in detail.

Introduction

Beginning in the fall semester of 2008, Muskingum University began offering a newly established engineering program. After investigating the similar programs and ABET accreditation process, one of our primary goals became to apply and develop engineering design across the curriculum. Starting by an introduction to engineering course in the first semester, our curriculum consists of design embedded courses each semester. However, that brings a challenge to us, engineering educators, to prevent this emphasis from shadowing the subject material of each course. Design work should not be a separate entity, but a contributory tool which can be used to support the teaching of the courses' fundamentals[1]. Upper division courses are easier to incorporate design projects due to the knowledge levels and skills of the students. On the other side, creating good design projects for lower division courses are more difficult because the students don't have the analytical skills and maturity level to attack complex design problems. Therefore, designing a good design project, especially for the lower division courses, became a stimulating issue for many engineering educators[2].

The first-year design courses, or so called cornerstone (design) courses, emerged as a means for students to be exposed to some flavor of what engineers actually do while enjoying the experience of learning the basic steps of the design process and applying them to a simple problem. Cornerstone courses focus more heavily on conceptual design methods because first-year students can do a reasonable conceptual design without the detailed technical knowledge which they will acquire later in the curriculum. Many educators agree that the main objective of these courses is to provide freshmen students with a realistic, rewarding, and successful introduction to engineering[3]. However, due to the simple and introductory nature of the contents,

usually the design projects of cornerstone courses are not visited again in the later courses of the curriculum.

We thought that if we can find a cornerstone project which would be addressed later in the curriculum, students could see the improvements on a design when engineering approach is used and realize their own progress after studying engineering courses. For that purpose, we assigned two similar design projects in the Introduction to Physics and Engineering and in the Statics and Dynamics courses. The students designed a bridge in their freshmen year by using only given spaghetti and glue, and without making any computational analysis. In their sophomore year, they designed a similar bridge again, this time by applying the concepts they learned about statics and by using experimental tools. This paper describes these projects and discusses our experiences and opinions about the benefits gained from them.

Description of Design Projects

Freshmen Project

Building a spaghetti bridge is a famous cornerstone design project and worldwide annual competitions are being organized by many different institutions since the Okanagan College held the first one at 1983[4]. We purchased the rules applied in these competitions and assigned the project after we discussed the basic elements of design process in the lectures. The students were required to build a bridge by using only the given spaghetti and glue as the material. The purpose was to construct a bridge what will carry the heaviest load while still meeting the stated specifications. The maximum allowable weight and the dimensions (like the maximum height, the minimum deck width, the maximum size of gaps in the bridge deck, etc.) of the bridge were specified. Furthermore, the bridge shall be free-standing and must span two level surfaces which are one meter apart.

The students first worked individually to make a research and gather data, generate ideas, and make a preliminary design. Then, they worked in groups of three or four to build a bridge and write a report. The report included a literature review section where they examined basic truss types, a list of ideas they generated as potential methods and solutions for the design, a sketch of their bridge, and the discussion of how they decided on their design. Finally, their bridges were tested till they fail with an exciting competition where they saw significantly different construction techniques and patterns of their friends' designs. A few examples of the spaghetti bridges are shown in Figure 1.

Figure 1: Examples of spaghetti bridge designs.

Sophomore Project

The project was assigned while we studied the concepts of beams and trusses in the Statics and Dynamics course. Each group, consisting of two or three students, was assigned to design a bridge again but this time by using the given bridge set from Pasco company[5]. The bridge set consisted of Lego like beams and joints that could be used to build a bridge, load cells that enable to measure the forces on the beams, and interfaces that transfer the data to a computer where the students could output their measurements. The size specifications of the design were very similar to the ones of the spaghetti bridge, like it should span a distance of one meter and had constrained dimensions. The purpose of the design was to have the smallest compression beam member under the loadings placed at predefined locations of the bridge. The students were required to both present their theoretical calculations and their measured values.

At the end, they wrote a report where they again examined the basic truss types but in more details than the spaghetti design report. In their report, they also drew the free body diagram and showed the statics analysis of their designs, stated the assumptions they made in their analysis, compared their theoretical calculations and their measurements, and discussed on their results. Pictures of some bridge designs and equipments used to measure the forces on the beams are shown in Figure 2. Examples of a student's sketch, a sample analysis, and a table of calculated force members are shown in Figure 3.

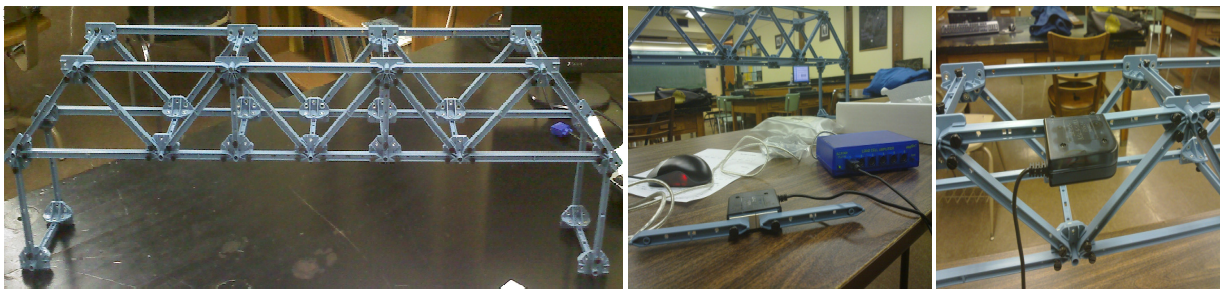

Figure 2: Pictures of some designs and bridge set equipments.

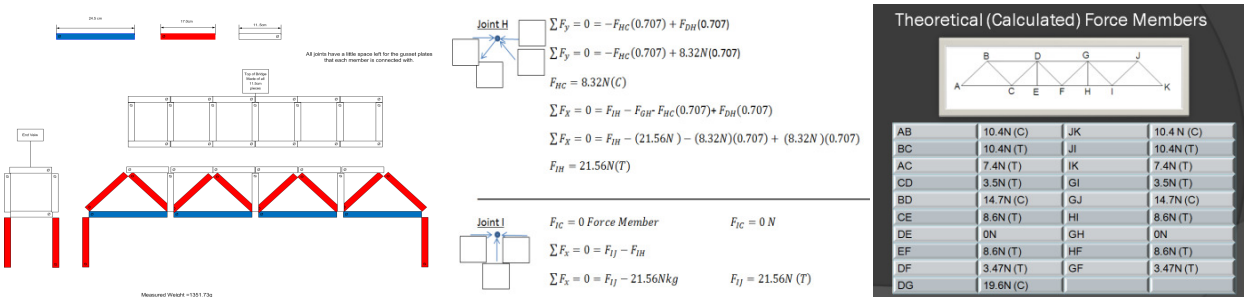

Figure 3: Examples of a student's sketch, a sample analysis, and a table of calculated forces.

Student Feedback

In order to evaluate the effectiveness of these projects, a questionnaire was prepared to be filled by the students who took both courses. We did not want to direct the students into a favorable answer and tried to learn what they thought and what they could suggest to improve the effectiveness of the projects. Therefore, we asked open-ended questions instead of multiple choice questions and gave them one week to fill the questionnaire, and bonus points to the ones who properly filled it. Questionnaire consisted of six questions that asked students to make comments on;

- how their point of views and approaches differed in two projects,
- how learning engineering concepts effected their designs,
- what did they think about the importance of qualifying in engineering profession before they start creating solutions for the society's needs,
- what did they think about working on similar projects in two different lectures,
- if they learned anything different by working on the projects that they wouldn't have learned from the lectures,
- their suggestions and additional comments that would make the projects more beneficial to the future students.

An initial evaluation of the questionnaire yielded the following common comments of the students;

- They comprehended that using engineering approach enabled them to work on more complex problems and make more conscious designs.
- They realized that redesigning and refining their ideas would improve their end results.
- They loved testing what they calculated, which also guided them to go back and check their calculations if there was a significant offset between the results.
- They gained a better insight of the effects of the assumptions they made.
- They had better understanding of why trusses are constructed the way they are.
- They became more aware of the consequences of inadequate qualification in engineering.
- They enjoyed working in teams.
- They wanted more materials in bridge set to make more creative designs.

Discussions

As a result of our observations and students' feedback, we believe that these design projects served well for our purposes. We achieved our goals of teaching them in consecutive courses, as well as they individually provided some other aims of teaching a design project.

Discussion on teaching similar design projects in consecutive courses
Some students do not decide on their career on engineering until their sophomore year or later. There is a definite need to motivate these students and show them the benefits of studying engineering. We believe that these projects enabled them, as well as the more determined students, to better realize their self-improvement after one year and to understand the importance of studying engineering profession. They experienced that learning engineering concepts provides them necessary skills to attack the problems more effectively and consciously.

Furthermore, the students witnessed how quickly some of the spaghetti bridges had failed even they seemed very strong. They also saw that they might do some mistakes in their calculations which could lead to crucial consequences. Then, they had the opportunity to find their errors and improve their designs by using engineering techniques. Consequently, we believe that the students became more aware of some issues in code of ethics for engineers[6] after working on these projects. They had better understanding of why engineers shall undertake assignments only when qualified by education or experience in the specific technical fields involved and why engineers shall continue their professional development throughout their careers.

Discussion on freshmen design project

The freshmen course was team taught by two of our department's professors and we rotated teaching the course every year with other two, so a total of four professors taught the lecture in two years. We all agree that spaghetti bridge was a beneficial cornerstone project which enabled freshmen students to learn about the design process and work together in a team. It also helped students to see that engineering can be an exciting profession where they can utilize their creativity and imagination to solve the problems. As mentioned before, spaghetti bridge project has long been employed by various institutions and numerous literatures could be found which discuss different aspects and benefits of it. From our point of view, it satisfied our goals of teaching a design project in an introduction course.

Discussion on sophomore design project

Redesign is an important tool in education since students gain better understanding and much more knowledge when they had the opportunity to redesign[7]. In this design project, the goal was to minimize the highest compression force in the beam members. Therefore, most of the students aimed to find the maximum compression member and tried to minimize it by changing their designs, which was indeed a redesign. That necessitates them to carefully examine their bridge's truss, which led them to better comprehend why the trusses are constructed the way they are.

It has been observed that students enjoy and learn better from laboratory lectures when they are connected together as a single project rather than a discrete set of unrelated exercises[8]. By means of the bridge design project, students did not only perform an experiment with beams and load cells but they used those equipments to test and improve their designs. They also had the opportunity to observe some reasons that caused the calculated and the measured values to be different. They saw that their bridges were mildly deflected which was not taken into consideration in their calculations or they figured out that if they do not make the connections properly, the values they measure will differ considerably. Eventually, students had performed an experimental work that would assist in their designs and provide them meaningful data.

The students' comments about this design project show that they want more and various materials in order to make more creative designs. Providing them with these materials in the future would lead to more complex designs and analysis where they could experience more concepts. Besides, the results of their designs could be used in some upper level courses as example problems or mini-designs. For example, students can calculate the resulting stress in these beams or they can select the best material for their designs that would minimize the weight or cost. By this way, they would realize more that how detailed a problem could be analyzed by using different aspects of engineering.

Conclusion

Our department has a goal of integrating the design across the engineering curriculum. We think that if we relate the subjects of different engineering courses, the students could better realize the benefits of studying engineering profession and see their own self improvement. For that purpose, we assigned two similar bridge design projects in consecutive freshmen and sophomore courses. We believe that these projects successfully served for our purposes as well as they individually satisfied the design project goals of their courses.

Bibliography

1. Wilczynski V. and Douglas S.M., "Integrating Design Across the Engineering Curriculum: A Report From the Trenches", Journal of Engineering Education, Vol. 84, No.3, 1995
2. Pike M., "Designing a Design Project", ASEE Annual Conference, Session 1268, 1998
3. Dym C.L., Agogino A.M., Eris O., Frey D.D., and Leifer L.J., "Engineering Design Thinking, Teaching, and Learning", Journal of Engineering Education, Vol. 94, No.1, 2005
4. Okanagan College, "Spaghetti Bridge Contest", http://www.okanagan.bc.ca/departments/engineeringtechnologies/spaghettibridge.html_, accessed January 17, 2011
5. Pasco company, "Structures System", http://www.pasco.com/featured-products/structures-system/index.cfm_, accessed January 17, 2011
6. National Society of Professional Engineers, "Code of Ethics", http://www.nspe.org/Ethics/CodeofEthics/index.html_, accessed January 17, 2011
7. Neumann K.E., "The Importance of Redesign: Students Gain So Much More Knowledge and Understanding When They Take Time to Redesign", The Technology Teacher, Vol. 63, 2003
8. Evans, A., Davies T., and Wilks S., "Is Your Laboratory a Turn-off?", International Journal of Electrical Engineering Education, Vol. 39, No. 3, 2002