The PVC Bridge Challenge: An Introductory Construction Management Experience

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It is difficult for entering college freshmen and high school students considering possible college majors to get good information about Construction Management (CM) as a career choice. The PVC Bridge Challenge was designed as a project to acquaint students in a 100-level introductory CM course with fundamental CM topics, including reading and interpreting plans and specifications, planning and scheduling a project, cost estimating, safety, personnel management, communication, leadership, and use of technical skills. The project, introduced to 50 CM freshmen in Fall 2007, also will be used as a high school CM summer camp exercise to better inform potential students about what distinguishes CM from the construction trades and engineering.

Key Words: Construction management, competition, leadership development, estimating, scheduling

Introduction

Choice of a college major is influenced by many factors, among them the perceived prestige of the degree and its value in finding gainful employment after graduation (Fiorito and Daffenbach, 1982), and academic preparation, particularly in mathematics (Turner and Bowen, 1999). Construction management (CM) is difficult for high school guidance counselors and college admissions officers to define for high school students seeking a college major. The college major codes used by the SAT and Peterson's Guide do not include construction management, but have a code for the construction trades, and another for construction engineering. The Classification of Instructional Programs (CIP) coding system used by the Illinois Board of Higher Education assigns CM a code of 15 (Engineering Technology/Technicians), a classification that may confuse potential students about the content of a CM curriculum. Because the program at Southern Illinois University Edwardsville (SIUE) is housed in the School of Engineering and has math and science requirements similar to those in the engineering disciplines, students from a high school vocational/technical background who expect that construction will be a technology-oriented program are often academically unprepared for the rigors of the CM curriculum.

To address this issue and give incoming students a clear idea of the expectations and contents of the CM curriculum, the SIUE Department of Construction recently changed its 1-credit hour 100-level course, Introduction to Construction, into a 2-credit hour course of the same name. The revised and expanded course was designed to provide incoming students, both majors and non-majors who want to "sample" the CM program, with an overview of the CM discipline, the curriculum, the faculty, potential employers, and career paths. The 2-hour format also allowed more time to expose incoming and potential students to the technical skills required in the program, and the level of academic rigor that would be expected of students in the CM major. Exercises in the first part of the semester emphasized basic drafting and plan-reading skills, written communication skills, a math review, and construction terminology. The second half of the course introduced estimating and scheduling, construction safety, and an overview of project delivery systems and construction contracting. Finally, the expanded format allowed time to incorporate a major project to assimilate newly-developed skills and knowledge.

In Fall 2007, with the financial assistance of the local chapter of Associated General Contractors, the Southern Illinois Builders' Association, the PVC Bridge Challenge was introduced as the final project in the Introduction to Construction course. The project incorporated plan and specification reading and interpretation, project planning and scheduling, cost estimating, construction safety considerations, personnel management, and building skills. Fifty students, including both newly-declared CM majors, transfer students, and several non-CM majors, took part in the event during the 13th week of the semester in a 5-team, competition format.

Design Concepts

The PVC Bridge Challenge was planned to allow student teams to construct a full-scale structure that met the following design criteria:

1. functional
2. easy to visualize from plans
3. easy to assemble and disassemble for multiple uses
4. low cost
5. safety of students completing the project

After considering a number of possible projects and materials, the faculty design team selected a 24-foot long truss bridge, constructed primarily of 4" diameter PVC tubing and wyes. Tension loads were carried by ½" diameter threaded steel rod. The PVC truss supported compound stringers and 2X6 joists that carried a wood deck constructed of 2X6 lumber. The structure was supported on 6X6 "piers" resting on a concrete floor, and was designed to carry a live load of 100 psf on the deck (Figure 1).

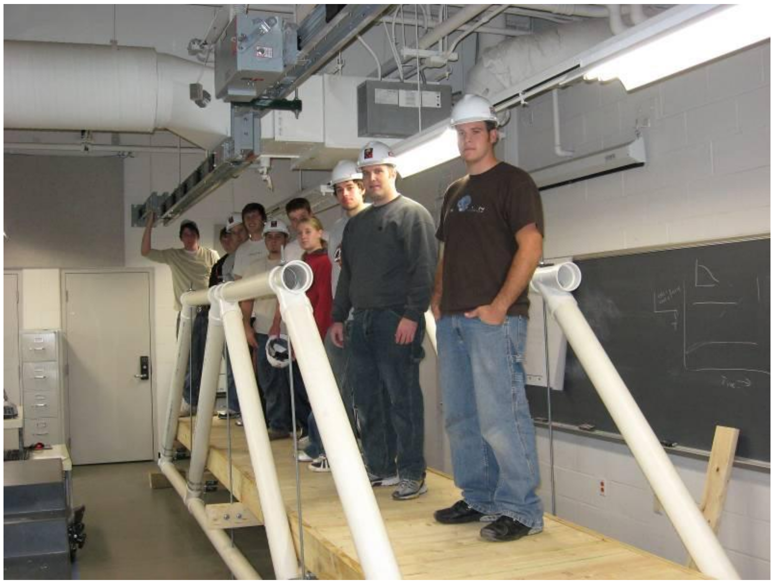

Figure 1. Completed PVC Bridge

A three-dimensional model of the bridge was created using Graphisoft ArchiCAD software, and was used primarily for the designer to examine clearances and connection details. Design drawings were prepared using AutoCAD, and only these 2-D drawings were provided to the students.

The material selection was heavily influenced by the design criteria that students would be able to easily assemble and disassemble the bridge using pre-cut parts and hand tools. It was assumed that some of the students would have no prior experience in construction, so the design drawings, specifications, and construction techniques were made as simple and straightforward as possible. PVC was selected for its ease of assembly, strength in compression, light weight, and relatively low cost. The bridge materials were purchased for about $1,000, and fabrication (cutting all pieces to measure, drilling holes) took approximately 12 hours of faculty time.

The size of the project was influenced by the desire to allow students to construct a full-scale, working structure, but was constrained by the available indoor space in the Engineering Building. After examining available rooms, an L-shaped area in the Soils laboratory was selected, and found to be adequate to construct the desired 24-foot long bridge. The indoor lab offered sufficient space challenges to make the construction interesting, and realistically simulated a tight construction site with overhead and lateral obstacles, a lay-down area (approximately 21’ X 6’) for raw materials, and an assembly area (approximately 30’ X 9’) for the finished structure (Figure 2).

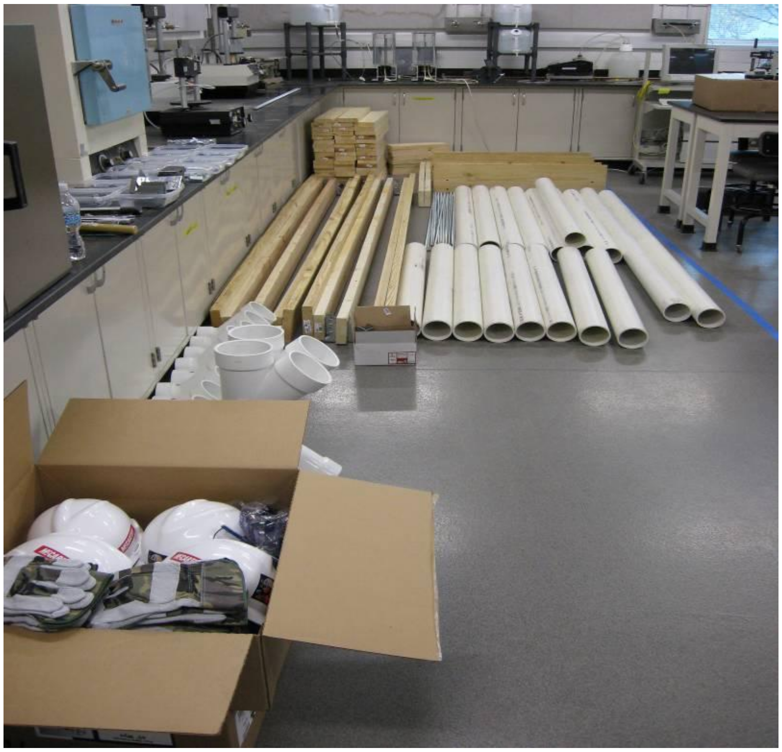

Figure 2. Material lay-down area for PVC Bridge Challenge

Methodology

The PVC Bridge Challenge was structured as a competition to increase student interest, to accommodate the class size of 50, and to test the viability of the project as an introductory CM exercise for future high school summer camps. The concept was loosely patterned on the U.S. Army's Leadership Reaction Course, a physically demanding challenge course that builds team cohesion, encourages creative thinking and innovation in problem-solving, and provides participants with detailed feedback and analysis of strategies (Brown and Dedrich, 2003).

The competition was set for the 13th week of classes. During the 11th week, students were asked to submit their availability on each day of the week, and five teams of approximately ten students each were selected solely on the basis of their availability. This random assignment of team members proved to be a valuable means of helping new students meet and work together with classmates, and was also effective in mixing students of different technical skills. Students were shown draft copies of the drawings in order to get an idea of the type of project they would be constructing.

During the 12th week, students met as teams and were given complete sets of the plans, specifications, and project rules for the first time. Two class periods were allowed for the teams to begin project planning and to make work assignments. During this week, students were allowed to submit Requests for Information (RFIs) to the designer, and received answers in writing. Teams were encouraged, but not required, to work together outside of class. During the second class period, each team was allowed to view the competition area in the laboratory, to see a portion of the completed bridge truss, and to ask questions directly to the bridge designer.

The rules of the competition were kept simple, but stringent enough to impress the importance of pre-construction planning. The space limits were marked on the floor by tape, and penalties were imposed for team members or materials going "out of bounds." Running, throwing, and carrying multiple items were prohibited. Teams were required to have one superintendent, who was prohibited from handling materials or tools during the competition. A materials list and list of all tools available for the bridge assembly were provided, along with prices. Each team was required to submit a list of the number and type of tools it would use (with the cost included in its estimate), in addition to a material and labor estimate. Any additional tools or materials required during the competition would be provided at double the list price. Labor time was charged at the straight rate of $0.60/minute for a laborer and $0.70 per minute for the superintendent. Safety equipment was made available to the teams at no cost, including gloves, safety glasses, and hardhats.

The target time was one hour, based on pre-assembly of the bridge by the faculty design team. All tools needed for the assembly were provided on request, including:

1. 7/16" wrench (3)
2. ¾ " wrench (3)
3. 7/16" ratchet (1)
4. ¾ " ratchet (1)
5. ratchet drive (1)
6. 25' steel tape (1)

Data Collection

During competition week, each team arrived 15 minutes before the start time to turn in their estimates, safety plans, and equipment list, and to be issued the requested items. Two faculty members were present to collect data during the bridge assembly, including:

1. Start and end times
2. Number of workers present
3. Rules violations and penalties
4. Additional materials and equipment needed
5. Qualitative observations (leadership of superintendent, teamwork, response to problems)

Several minor rules adjustments were made during the competition. Teams were allowed to carry multiple pieces of hardware, which were provided in containers. Also, team members were allowed to carry up to six 2X6 deck boards at a time, rather than one piece per person per trip as originally stated. Finally, the superintendent was allowed to use one tool (tape measure) to verify that the specifications were being met, and a small flashlight (not on the original equipment list) was provided to assist in inspecting the installation of threaded rod inside the bottom chord of the truss (Figure 3).

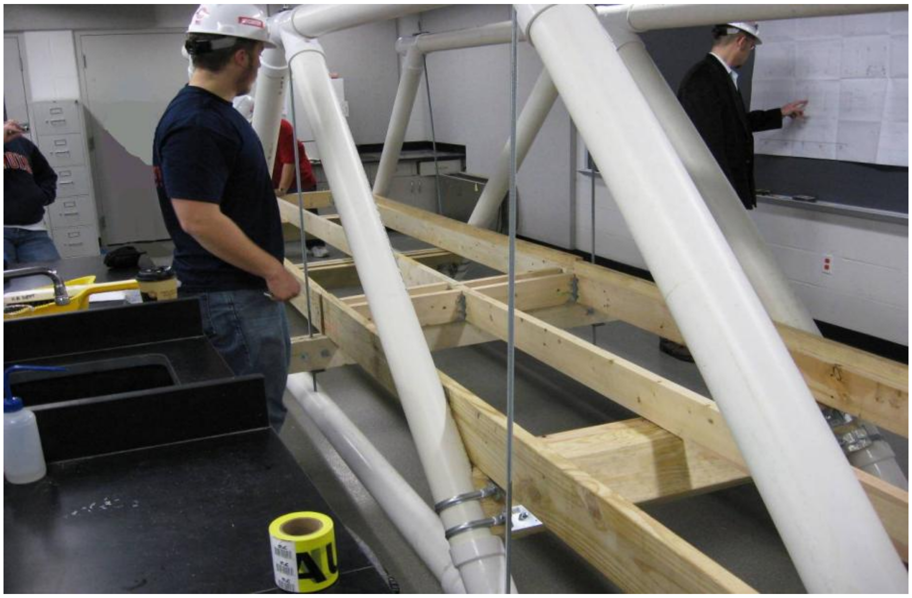

Figure 3. Superintendent studies plans during bridge assembly

Analysis

All teams completed the construction successfully, with times varying from 57 to 82 minutes (average time 71 minutes). However, team size varied from a low of six to a high of ten. Teams employed various management strategies, such as "laying off" team members when various milestones had been completed, or using some team members during the planning and estimating phase and others during construction. Teams employed from 432 to 574 person-minutes to complete the job (Figure 4). Team 4, whose overall time of 72 minutes was close to the average, completed the project using only 432 person-minutes.

Team	Time (min.)	Person-Minutes
1	80	480
2	64	496
3	57	488
4	72	432
5	82	574

Figure 4. Times and person-minutes to complete PVC Bridge Challenge.

The leadership styles of the five superintendents varied significantly and may have had an impact on team performance. Team 1's superintendent was fairly proactive and prepared, but was quiet and did not give many verbal instructions to the team. Team 2's leader was prepared, vocal, and physically active in moving from activity to activity to oversee progress and make suggestions. Team 3's superintendent was passive and quiet, only speaking to note schedule milestones and the time. However, this leader's teammates gave high marks for leadership, noting that this person took the lead in the pre-construction planning, and made ½ size copies of the plans so that each team member could study them, an initiative not taken by any other team. The leader of

Team 4 was knowledgeable about the plans, active about the jobsite, but focused on small details of the assembly rather than the larger issues of constructability. Team 5's superintendent was unprepared, did not bring a copy of the plans to the competition, and seemed unaware of how the bridge would be assembled. When the group ran over the target time by 15 minutes, this leader asked if the team really had to finish.

The cost estimates submitted by the teams were reviewed for accuracy by the instructor and amended to reflect materials not ordered but used during the construction. These materials were charged at double the list price. Materials ordered in error were not deducted from the estimate. For grading the project and determining a "winner," a final cost spreadsheet was prepared by the instructor, showing each teams' final cost based on materials, labor, equipment, and time actually used. Based on this analysis, Team 2 was the competition winner with a time of 64 minutes (496 person-minutes) and total cost of $1322.76 for labor, materials and equipment.

Assessment of individual student performance was also made on the basis of an "after-action review" (AAR) that included a reflection on team members' prior construction experience, team interaction and pre-construction meetings, selection and performance of workers and leaders, observations on strategies employed by the team, success of the project in clarifying what the Construction Management major will encompass, suggestions for future improvements, and recommendations for use of the PVC Bridge Challenge for high school students. Grading of this assignment was done on the basis of grammar, spelling, punctuation, sentence structure and paragraph formation, as well as the quality of the content and completeness in addressing the questions. Feedback to the students was given via written comments on their AARs, as well as a verbal discussion of the project in class. Students were also assessed for their understanding of CM as a professional management practice involved with managing the issues of construction "quality, cost, time, and scope" (cmaanet.org) through a number of questions on the final examination for the course.

Discussion

The after-action reviews by the students indicated that the project was successful in meeting its objectives of informing students what construction *management* is all about. Skills such as estimating and scheduling were developed ("…our team met three times to…discuss estimating, scheduling and building strategies. [Two team members separately] developed…estimates, then compared them to create a final draft. We showed the draft to the whole group to get feedback). Students learned about the importance of pre-construction planning ("The planning stage was much more in depth and important than I ever gave it credit for"); teamwork ("[the project] took a group who hadn't worked together before and made us…adjust to each other's strengths and weaknesses"); and safety ("I banged my head several times, which reminded me of why hard hats are important"). The project introduced interesting personnel management issues ("…there were some times when our performance wasn't so great, especially when we laid off three of our guys, and then had to re-hire them"). Finally, the students discovered that managing a team is more difficult than being a worker. One student observed

> I was surprised at how much this project taught me. At first I thought it was going to be a simple little project…In the past, while working in construction, I had

> been given the plans and told to get the project done. Someone else had always done the scheduling, purchasing of supplies, and other preliminary work. I have always known that someone had to perform these tasks…but I never realized just how much work these parts of the job require…This project showed me that there is as much time spent planning and preparing a for a job as there is time to do the actual construction.

The feedback indicated that students would welcome more "hands on" and team-oriented work during their college careers. The student responses also indicated that the project would be a good way to acquaint high school students with the nature of construction management.

The PVC Bridge Challenge will be featured at the School of Engineering's annual Open House in February 2008, with the completed bridge, plans, specifications, and a DVD of the competition on display. The exercise may be included in a high school summer camp for high school students interested in majors offered within the School of Engineering. It is hoped that this project will be successful in defining "construction management" for students seeking a college major in a construction-related discipline.

References

1. Brown, R. and C. Dedrich. (2003). "SBCT Developing Agile, Adaptive Soldiers." *Military Review*, Vol. 83 Issue 3, pp. 32-41.

2. College Board (2007, December 21). [WWW document] URL http://apps.collegeboard.com/cbsearch_code/codeSearchMajor.jsp

3. Construction Management Association of America (2008, February 1). [WWW document] URL http://cmaanet.org/cm_is.php

4. Fiorito, J. and R. Daffenbach. (1982). "Market and Non-market Influences on Curriculum Choice by Students." *Industrial and Labor Relations Review*, Vol. 36, No. 1, pp. 88-101.

5. [State] Board of Higher Education (2007, December 21). [WWW document] URL http://www.ibhe.org/BHEProgramInventory/Search.aspx

6. Peterson's Guide (2007, December 21). [WWW document]. URL http://www.petersons.com/ugchannel/code/searches/srchCrit1.asp#Majorssearch

7. Turner, S. and W. Bowen (1999). "Choice of Major: The Changing (Unchanging) Gender Gap." *Industrial and Labor Relations Review*, Vol. 52, No. 2, pp. 289-313.