120th ASEE Annual Conference & Exposition
FRANKLY, WE DO GIVE A D*MN
June 23-26, 2013

Paper ID #6624

Structural Elective Course for Special Building Systems

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Abstract

The training of structural engineers in most parts of the world starts by students going through a civil, structural or architectural engineering program. Undergraduate programs are heavily impacted and the high cost of educating the students is resulting in fewer courses being offered that are geared towards practice of structural engineering profession. In order for future engineers to meet the challenges of the twenty first century, the American Society of Civil Engineers (ASCE) has proposed that future licensed engineers attain a recognized body of knowledge (BOK). This may be fulfilled by an accredited undergraduate degree in civil (or related) engineering, a master's degree or approximately thirty credits of graduate or upper level course work and appropriate pre-licensure experience.

The Architectural Engineering department at California Polytechnic State University (Cal Poly) works closely with industry partners (future student employers) and the advisory board to tailor the program so that the graduates are able to contribute to the profession on the first day of their employment upon graduation. The program has a number of upper level elective courses that are aimed at contributing to the BOK.

As the society grows in population and strides into the new century, new technological advances call for more and bigger "big-box" or warehouse type building structures. In the United States, these structures commonly house retailers like Wal-Mart, Costco, Home Depot, etc. and are typically one story buildings with floor areas ranging between 73,000 to 261,000 square feet. The design typically calls for high floor to roof height (20 to 25 feet) and the exterior perimeter is usually concrete masonry walls or concrete tilt-up panels. The need to have large open column-free space results in the construction materials typically used in these structures to include but not limited to: reinforced concrete (tilt-up, cast-in-place), steel (rolled, tubes, trusses), timber (sawn, engineered, glue-laminated, trusses), concrete masonry units (reinforced, grouted, ungrouted), wood sheathing (plywood, oriented strand board), light gauge metal deck, etc.

This paper reports on how this elective upper level design course is taught in a laboratory format. The course incorporates all the above materials (concrete, masonry, timber, steel). The students prepare complete construction documents including all construction details and specifications.

Introduction

The main mission of architectural engineering or civil engineering programs is, but not limited to, prepare the graduates to: pursue post-graduate education, communicate effectively, become licensed professional engineers and pursue lifelong learning. The architectural engineering (ARCE) program at Cal Poly is housed in the College of Architecture and Environmental Design (CAED) together with the departments of Architecture (ARCH), Construction Management (CM), Landscape Architecture (LA) and City and Regional Planning (CRP). Being in the college of "Built Environment", ARCE offers courses that pertain to building design similar to structural engineering programs in other universities. Multidisciplinary collaboration is introduced to CAED students on the onset of their studies by requiring the students to take the same classes for the first two years of their studies.

Mandatory building material design courses in ARCE are offered over a period of two years as shown in Table 1.

Table 1: Mandatory Material Design Courses

Year of Study	Course	Quarter Units	Instruction Format	Max. Number of Students per Class
3	ARCE 303: Steel Design	3	Lecture	36
	ARCE 304: Timber Design	3	Lecture	36
	ARCE 305: Masonry Design	2	Lecture	36
	ARCE 372: Steel Structures Design	3	Laboratory	16
4	ARCE 444: Reinforced Concrete Design	3	Laboratory	16
	ARCE 451: Timber/Masonry Structures Design	3	Laboratory	16
	ARCE 452: Reinforced Concrete Structures Design	3	Laboratory	16

In order to prepare students for advanced topics in the design courses, ARCE students are required to take a minimum of two advanced structural elective courses (6 quarter units) from the list of courses shown in Table 2.

Table 2: Advanced Structural Elective Courses

Year of Study	Course	Quarter Units	Instruction Format	Max. Number of Students per Class
4	ARCE 403: Advanced Steel Design	3	Laboratory	16
	ARCE 410: Integrated Building Envelopes	4	Lecture	16
	ARCE 414: Precast Concrete Design	3	Laboratory	16
	ARCE 447: Advanced Reinforced Concrete Design	3	Laboratory	16
	ARCE 448: Seismic Rehabilitation	3	Laboratory	16
	ARCE 449: Cold Formed Steel	3	Laboratory	16
	ARCE 473: Advanced Timber/Masonry Structures Design	3	Laboratory	16

Courses in Table 1 are prerequisites for the respective courses in Table 2. In the steel structures, concrete structures and Timber/masonry structures design laboratory courses, the students with guidance from licensed structural engineer faculty prepare complete construction documents (structural calculations, structural plans and structural specifications) for pertinent material structures. The faculty member plays the role of the project client and also acts as the building code enforcement agency plan checker.

Real world building structures are not built solely of only steel, reinforced concrete, Timber or masonry. The building system is typically a combination of all the above materials. This is especially the case for the "big-box" type structures that are now common in every urban community. It is due to the need of exposing students to this type of building construction that this advanced structural elective course (ARCE 473) was developed.

Literature Review

ABET accreditation criteria 3 item (h) require engineering programs to provide students with a broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context[1]. Item (k) under the same criteria requires students to acquire an ability to use techniques, skills and modern engineering tools necessary for engineering practice[1]. Most Civil and Architectural Engineering programs offer structural elective courses to students in order to not only meet the ABET requirements but to prepare their graduates to the profession of structural engineering. Most of the elective courses are offered during the final year of study. Typical offered elective courses include but not limited to: advanced reinforced concrete design, prestressed concrete design, advanced steel design, timber/wood design and masonry design.

When one looks at engineering in 2020 and beyond, one has to ask some basic questions about the future engineers such as: (1) who are they, (2) what they will do and where will they do it, (3) why will they do it, and (4) what this implies for engineering education in the United States and elsewhere[2]. Menerick[3] found out that on average, 85% of students who took a high performance learning environment elective course that was learning-centered, knowledge-centered assessment-centered and community-centered felt it was a good use of their time. Dunlap[4] reported that problem based learning (PBL) may help students to experience success, improving their confidence to engage in similar activities in the future and empowering them to pursue challenges in field. By engaging students in learning and problem solving activities that reflect the true nature and requirements of the workplace, PBL may help students feel prepared to work effectively in their field.

Scope

The intent of the course was to expose students to long span industrial/warehouse type buildings where structural steel and reinforced concrete are used in timber/masonry construction. The design of the building system was accomplished by requiring the students to have taken structures design courses in steel, reinforced concrete and timber/masonry (ARCE 372, 444 and 451 respectively) besides a foundation design course. Examples of types of buildings addressed in this course are shown in Figures 1, 2 and 3.

Figure 1: Exterior View of (a) and (b) Warehouse Buildings and (c) School Gymnasium

Figure 2: Interior View of (a) Glue-Laminated Beams and Steel, (b) Wood, Steel Trusses, Steel Girder and (c) Wood and Wood Truss Construction

Figure 3: Interior View of (a) Steel Metal Deck, Steel Beams, Masonry Walls and Metal Studs, (b) Wood, Steel Girder and Steel Column and (c) Pre-manufactured Wood Shear Wall Construction

Instruction Method

The course was taught in a laboratory format by a licensed structural engineer who is familiar with design of buildings using the four materials (steel, reinforced concrete, timber and masonry). The class met three days a week for three hours. The number of students per class was limited to sixteen. Typically, the instructor lectured for at least one hour at every class meeting and the last two hours of each meeting was spent conducting actual building design under the supervision of the instructor. The students worked from architectural plans of an actual (real) building of this type of construction. There were also guest lectures conducted by industry professionals who addressed the structural design using industry pre-manufactured products. These included but not limited to Vulcraft[5] whose personnel addressed application of long span steel trusses, Redbuilt[6] regarding open web wood trusses and Simpson Strong-Tie[7] regarding strong wall application besides other products. Students were also taken on site visits to see firsthand the construction process. Figure 4 shows the class at a construction site.

Figure 4: Class at a Construction Site

Deliverables by students

As an assignment, the students were grouped so that each group had a maximum of three students. The students were required to select a warehouse type building that had all the four materials, visit the building and provide structural framing plans including building sections. Each group presented their work to the rest of the class in form of PowerPoint presentations and sketches. There were individual and group homework problems assigned and a final group design project where the students were given architectural plans and they had to prepare structural construction documents of most economical designs. The students had also to review (plan check) the submitted final design packages of different groups.

Assessment

The course has been offered once and assessed using two methods. The first method of course assessment was conducted as part of the university wide student course evaluation. The students were requested to give feedback on how they liked the course as presented and what should be done to improve the course. 100% of the students said they liked the class. Of the ten students who took the course, 100% of them indicated the activity they liked most was the site visit “as it exposed them to the constructability aspects of the project”. The students liked the grouping format but 100% of them felt that there was too much work (assignments) in the course besides other suggestions.

The second assessment method was having the students review other students' submittals using the rubric given in Appendix A. There were four groups and each group was rated on a scale from 1 to 5 (5 being the strongest) on four items: overall group in-person presentation, general layout of structural building plans and building sections, coordination of buildings plans and building sections and finally if there was enough information to erect the building. In the four groups, the average score for the four items was 4.6/5 (92%).

The course was offered again this year to three students. Student's comments and suggestions were incorporated in the second offering.

Conclusion

The course succeeded in exposing the students to the most common warehouse type building design they will encounter in the industry. The presentation method that involved industry partners and student site visits were very helpful in delivering the course concepts to the students. It was important not to repeat material covered in the prerequisites but to build on the prerequisites as a means of determining best option based on economy, easy of construction and environmental issues.

As engineering educators, faculty should not be afraid to introduce new courses or modify the existing courses to reflect the ever changing technology and society needs.

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Appendix A:

<u>Final Group Presentation Assessment</u>

<u>Presenting Group #_______</u>

<u>Reviewing Group #_______</u>

- Using a scale of ***1*** to ***5***, ***5*** being the strongest agreement or rating, please rate each group on the following:

    1. Overall group in-person presentation---

    2. General layout of plans and sections--

    3. Coordination of plans and sections--

    4. You have enough information to frame building----------------------------

    5. Is there information missing from plans or sections?-----------------------

    6. If your answer in item (5) above is ***yes***, please list what you would suggest be added.