AC 2009-1583: PREPARING STUDENTS FOR THE ENVIRONMENT OF THE PRACTICE OF CONSULTING ENGINEER

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Preparing Students for the Environment of the Practice of Consulting Engineer

Abstract

In the United States of America, the body of knowledge required for an individual to be allowed to take the engineering licensing examination, which on passing allows the individual to be in responsible charge of engineering projects, is usually defined by laws and regulations of each state. In California, the shortest path taken by most individuals is one where the individual graduates from an ABET accredited undergraduate program; passes the Engineer in Training (EIT) examination and works under the supervision of a licensed engineer for two years (one year if the individual has a Masters degree in relevant field).

In order to better prepare the student to enter the practice of engineering, and thus give the student an immediate level of comfort with the real world environment, practical design needs to be directly incorporated into the teaching of design.

This paper presents teaching methods used to teach undergraduate architectural engineering design courses, where the discipline of concentration is structural engineering. The format used exposes the students to instructors that are current consulting engineers and to courses that are modeled in line with the structural engineering profession. The theory, of construction materials (concrete, steel, masonry and timber) is covered for each material at element level in a lecture format. Design using the materials at a system level (building) is then taught in a laboratory format. In this later format, the students prepare complete construction documents (structural calculations, structural plans and structural specifications) for real projects using architectural plans. This "learn by doing" format has proven-over time-to prepare the students to the same environment that the students face after graduation.

It is generally an accepted fact in the structural profession in California that, graduates from Architectural Engineering program (ARCE) at California Polytechnic State University (CAL POLY) "hit the ground running from day one". This is attributed to the familiarity, of the design office environment, obtained during their undergraduate education. The familiarity is acquired through the design laboratories taught by design professionals.

Introduction

A browse of any university catalog[3,4,5] under the departments of structural engineering, architectural engineering or civil engineering programs show that almost every program share the same main mission of preparing graduates as a minimum to:

(a) pursue post-graduate education,
(b) communicate effectively,
(c) become licensed professional engineers and
(d) pursue life-long learning.

How each program delivers the courses necessary to meet these mission objectives is very different as can be seen from the graduation requirements of future structural engineers in Table 1.

Most of structural engineers in California, as well as in the nation are educated as an option in civil engineering program. In most civil engineering programs, to graduate, a student must select the structures option and one more from; geotechnical, transportation, environmental and water resources. This has not changed with time irrespective of the changes that have taken place in the structural engineering consulting practice. There are the voluminous reference codes that go with the ever growing and changing design codes. This is due to availability of new materials and advances in complex computer analysis procedures that have been developed in the past few decades.

A recent report[1] indicates that the U.S. is not meeting an ambitious goal set in 2005 of doubling engineering graduates by the year 2015. There is also the proposed change to make the master's degree be the first professional degree to enable practice in civil engieering[2]. Can engineering educators convince themselves that they are preparing undergraduates to be ready for the practice of consulting engineers as those who graduated from the very same institutions of learning thirty years ago if a masters degree is required to join the profession?

Most engineering programs teach fairly the same breadth of engineering fundamentals and prepare students to take the Fundamentals of Engineering (FE) or the Engineer-in-Training (EIT) national examinations after their junior year of study. Different states have different requirements for licensure to P.E. or S.E. In California, the shortest path taken by most individuals is one where the individual graduates from an ABET accredited undergraduate program, passes the Engineer in Training (EIT) examination, works under the supervision of a licensed engineer for two years (one year if the individual has a Masters degree in relevant field) in order to acquire practical knowledge and experience necessary for taking the examination. The success of the candidates getting licensed as soon as a they meet the state's minimum requirements depend on:

(a) the individual's self motivation,
(b) how well the candidate was prepared to the engineering environment by their college and
(c) the practical training given by the employer.

Educators have a major role on how and how soon graduates adjust to the environment of consulting structural engineering and may influence their students' motivation by observing how passionate the educators are about the profession.

Consulting Engineer and faculty experience

A consultant (from Latin *consultare* meaning to discuss) is a professional who provides advice in a particular area of expertise. A consulting engineer is usually a professional in a specific field of engineering and has a wide knowledge of the subject matter. Typically, a consulting engineer works for an engineering consultancy firm that provides engineering services to multiple and changing clients.

In order to prepare students for the environment of the practice of consulting structural engineer, it is important first and foremost to have instructors that have experience in that environment. In the ARCE program at CAL POLY this is achieved by recruiting faculty that have had several years of structural engineering experience. There are two tracks to tenure and promotion:

(a) The traditional theoretical track followed by most universities where the faculty member must have attained a Ph.D. degree in structural engineering or relevant field. At ARCE the candidate is also required to have a few years of experience in the structural engineering profession. This is usually verified by professional engineering (P.E.) licensure.
(b) The practitioner track where the individual is required to have a Masters degree in structural engineering or relevant field, be California licensed structural engineer (S.E.) with at least ten years experience as a structural engineer.

Currently in ARCE department, of the thirteen full time faculty members,

(a) three have Ph.D.'s,
(b) five have Ph.D.'s and are California licensed P.E.'s.,
(c) three have MS and are California licensed S.E.'s and
(d) two have Ph.D.'s and are California licensed S.E.'s.

This shows that, with seventy seven percent of the faculty licensed P.E.'s in California and thirty eight percent licensed as California S.E.'s bring the environment of the consulting engineer to the ARCE program. This human resource data is an envy of any structural engineering consulting company. The faculty in the practitioner track (five of the thirteen) engages in full time structural engineering consultancy. The structural engineering consultancy usually occurs during the summer which helps in keeping them current of the changes in the structural engineering profession as a whole and is part of their professional development. The benefit however is to the students as the faculty members bring back the latest tools in the profession back to class in a timely manner.

Design Courses

At CAL POLY, architectural engineering students are taught for the first two years in the same class with architecture (ARCH) students and construction managements (CM) students. This exposes the students to the teams they will eventually work with in the industry of built environment. It also teaches the students at a very early age of their future career the multidisciplinary communication tools required by the profession.

Structural engineers apply the fundamental engineering principles (statics and dynamics) and complex mathematical analysis methods (finite elements, non-linear analysis etc) to construction materials in design. The main design goal is to provide clients with the most economical structure and a minimum goal of safeguarding life safety of the occupants of the structure when it is subjected to any loading phenomenon. It is therefore paramount that educators prepare students with heavy doses of structural design in all the materials they will encounter in the industry.

Design courses in ARCE are taught in junior and senior years. The courses are sequenced in pairs where the material behavior (characteristics) and element design courses are taught to juniors. The first half of the pair comprise of:

ARCE 303 Steel Design (3 units)
ARCE 304 Timber Design (3 units)
ARCE 305 Masonry Design (2 units)
ARCE 444 Concrete Designs (3 units)

These courses are taught in lecture format common to most other civil engineering programs. The difference however occurs in that, as is common in some programs to teach large number of students in large lecture halls holding as many as 200 students as in Figure 1; the maximum number of students per class is limited to between twenty four and thirty two. A typical instruction class is a smart room as shown in Figure 2. Along with these element design courses, the students take a Structural Systems Laboratory (3 units) course. In this course, the students build building models to reinforce overall building geometry (three dimensional), building stability and load flow through the entire building system.

The second half of the pair comprise of:

ARCE 372 Steel Structures Design Laboratory (3 units)
ARCE 451 Timber and Masonry Structures Design and Constructability Laboratory (3 units)
ARCE 452 Concrete Structures Design and Constructability Laboratory (3 units)

This later set of laboratory courses is the jewel and pride of the ARCE program. They are modeled in line with the California special seismic licensure examination that the students will eventually have to take to be licensed as California S.E.'s. The courses are taught in laboratory format meeting three times a week for three hours each meeting (for a total of nine hours a week). For each of the laboratory courses, the students use the element design courses as prerequisites and architecture courses to prepare complete structural construction documents (structural calculations, structural plans, sections, details and specifications) for real buildings that the instructors bring to class from their practice. The laboratory courses are limited to sixteen students per class and are usually conducted in smart rooms with layout as shown in Figure 3. This is also where the "learn by doing" comes to fruition similar to the old medical expression of:

"see one, do one, teach one".

One condition on enrollment of the design laboratory courses is that the student cannot take two of the above three courses from the same instructor. By limiting the number of students to sixteen and exposing the students to different instructors, who themselves have different backgrounds in the structural engineering consulting profession, the students get accustomed to working close to their supervisors on a one to one basis. Before graduating, the students are exposed to working for different supervisors not to mention the "all nighters" or whatever it takes to get the job done. This is key in preparing the students for the environment of consulting structural engineers that they will face on graduation.

Conclusion

In order to succeed in preparing students for the environment of the practice of consulting engineer, there is a need experienced faculty, a clear understanding of the new trends of

construction materials and construction methods. There is also a need to expose the students to design courses in all materials they will use in construction and finally a need for adequate facilities.

The faculty should:

- Develop in the profession at the same pace as that expected of the students.
- Strive to acquire terminal licensure in field of practice (P.E. or S.E.) in their state.
- Be prepared to hire and retain licensed professional even if they do not have Ph.D.'s.
- Not allow unlicensed faculty to teach design courses.
- Review appointment, retention and tenure requirements to allow consulting practice to constitute acceptable professional development activities.

Design Courses and facilities:

- Offer design courses covering steel structures, timber structures, masonry structures and concrete structures.
- Teach the design courses in laboratory format and have the students prepare complete construction documents and building models where appropriate.
- Screen students and discourage students from taking design courses in different materials from the same instructor.
- Limit the number of students in the design classes to sixteen.
- Teach the design classes in smart room with drawing board type desks.

University	Department	BS Degree	Units to Graduate	Upper Level Design Units to Graduate
California, Berkeley	Civil & Environmental Engineering	Civil Engineering	121 -124 (Semester)	16
California, Davis	Civil & Environmental Engineering	Civil Engineering	184 (Quarter)	18
California, Los Angeles	Civil & Environmental Engineering	Civil Engineering	185 – 190 (Quarter)	18
California, San Diego	Civil & Environmental Engineering	Structural Engineering	184 (Quarter)	24
California Polytechnic State	Civil & Environmental Engineering	Civil Engineering	196 (Quarter)	22
California Polytechnic State	Architectural Engineering	Architectural Engineering	204 (Quarter)	36

Table 1: Comparison of BS graduation requirements

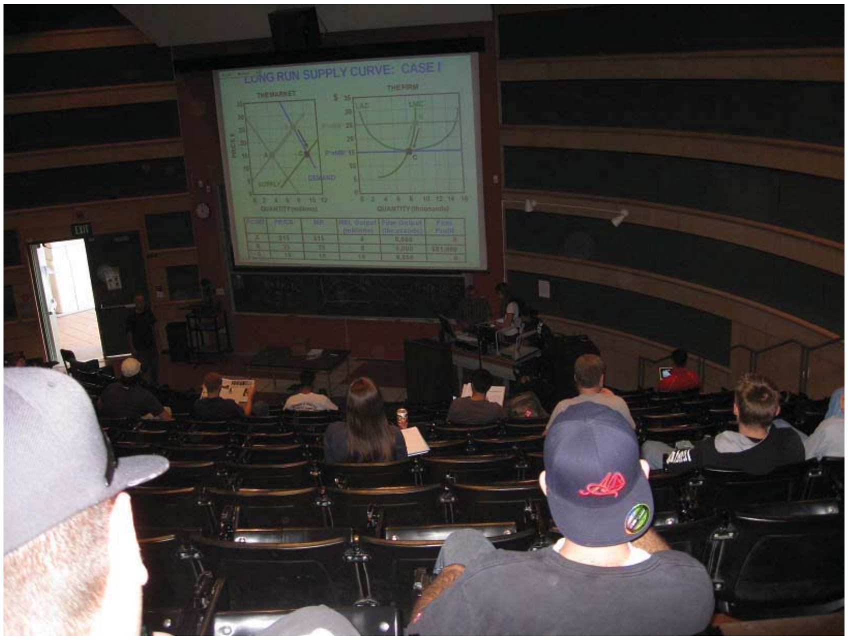

Figure 1: Typical lecture Hall (interior)

Figure 2: Typical smart room used for element design courses

Figure 3: Typical smart room used for laboratory design courses

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