AC 2012-4080: CREATION OF A STRUCTURAL ENGINEERING PROFESSIONAL MASTER'S DEGREE PROGRAM

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Creation of a Structural Engineering Professional Master's Degree Program

Abstract

Due to the complexity of contemporary practice, top-tier structural engineering firms hold the master's degree as the minimum level of education for new hires. In addition, the American Society of Civil Engineers (ASCE) recommends a master's degree or the equivalent of 30 credits beyond a bachelor's degree as part of the minimum body of knowledge for licensed professional engineers. Finally, students whose end goal is a career in professional practice have indicated a preference for graduate programs focused on design knowledge essential for the advancement of structural engineering practice. These needs provided the opportunity for the creation of a new professional master's program in structural engineering at Lehigh University.

Launched in summer 2008, the program is led by a full-time professor of practice with industry design experience and guided by an executive advisory board, composed of representatives from all areas of the building design and construction profession.

The hallmark of the 30-credit, 10-month program is a 9-credit, 3-course design project sequence in which student teams design a real-world structure from initial concept to final construction documents. An individual project assignment, as well as technical elective courses, allows students to tailor the program to their unique interests and career goals. A laboratory class provides hands-on learning of structural behavior. Interaction with industry leaders through seminars, field trips, and externships provides students ample opportunity to network with professionals and gain an understanding of their chosen industry.

Assessments were conducted to determine the viability of the proposed program with respect to industry and students. Engineering firms were surveyed to provide feedback on the proposed program elements as well as to gage the potential job market for graduates. Undergraduate students were surveyed to determine interest in the program and to gather student feedback on key program elements. Goals of the program and key features were refined per the assessment results.

This paper discusses the creation and execution of the structural engineering professional master's program, including market research, goals and features, and student recruitment. Initial assessment results from graduates, employers, and advisors, evaluating the effectiveness of the program at preparing students for professional practice are presented.

Background

Today's global structural engineering projects are technically complex and require careful coordination with multiple disciplines over a short time frame to produce innovative, safe, and efficient structures. Top-tier structural engineering firms hold the master's degree as the minimum level of education for new hires.[1,2]

The American Society of Civil Engineers (ASCE) Policy 465 supports the attainment of a body of knowledge achieved through education, experience, and examination, for entry into the profession as a licensed professional engineer. ASCE recommends that the education component of the body of knowledge be achieved through a master's degree or 30 credits beyond a bachelor's degree.[3] This additional education provides the technical breadth and depth to tackle modern challenges.

Additionally, undergraduate engineering programs are pressured to increase the required number of credit hours for humanities courses, while reducing the total number of credits required for engineering majors to a value similar to that required for other majors.[3] These pressures result in a reduction of technical depth of current bachelor's degrees.

Many students with a career goal to enter engineering practice prefer a professional-based master's program over a research-based program. Students are also interested in achieving graduate degrees in as short a time frame as possible and entering professional practice quickly, largely due to the high cost of education. Furthermore, an advanced degree frequently provides a quicker path to leadership positions within a company.

In recent years, the Council of Graduate Schools began promoting the development of Professional Science Master's (PSM) degrees, an innovative graduate degree designed to provide students with advanced mathematical and technological knowledge, while developing practical skills valued by industry.[4] The significant growth of such programs nationwide indicates their acceptance by institutions of higher education as an integral part of graduate studies and supports the need for graduates of such programs. In recognition of this initiative, the P.C. Rossin College of Engineering at Lehigh University adopted an enhanced focus on developing such practice-oriented master's degree programs in selective, market-driven areas.

In light of the college initiative for professional master's programs, ASCE's support for education beyond the bachelor's degree, engineering firms preference for students with advanced degrees, and student preferences for professional-based graduate programs, the department of civil and environmental engineering determined that the creation of a project-based master of engineering in structural engineering program would fill a void and meet the needs of the industry, students, professional societies, and the university.

Program Development

The civil and environmental engineering department submitted a proposal to the P.C. Rossin College of Engineering outlining the mission statement and goals of the program, as well as describing the key features of the proposed program. The mission statement is:

> *To produce professionally-oriented graduates who have both in-depth technical understanding and a global perspective of structural engineering practice. These full-service engineers will have the skills to identify, evaluate and manage cost and performance decisions throughout the major stages of life in large-scale structural systems.*

The program goals include:

- Provide a thorough understanding of the structural engineering design process, from inception to construction
- Provide a deep, intuitive knowledge of the behavior of structures through full-scale destructive testing of structural components and systems
- Provide advanced analytical and design tools essential to the practice of contemporary structural engineering
- Provide a practical appreciation of the economic, environmental, societal, ethical, health and safety contexts in which structural engineers work
- Provide a flexible array of elective course offerings that allow graduates to customize a program tailored to their particular interests and career goals.

In order to meet the mission statement, a 30-credit, 10-month, design-focused master of engineering (M.Eng.) program was created. The program begins in July with an intense summer session and culminates the following May. Typical "one-year" master's programs require students to complete five courses during the fall semester and five courses during the spring semester. This demanding schedule can result in students dropping classes and having to retake them the following year. Lessening the fall and spring course loads to only four courses each semester by offering two core courses in the summer helps to ensure completion of the program in the 10-month time-frame. Having one less course during the fall and spring semesters also allows more time for the students to devote to their group and individual design projects. Table 1 indicates the credit breakdown for the program. Table 2 shows a comparison to the existing research-based Master of Science (M.S.) program which also requires 30-credits, but over an approximate two-year period.

The nine credits of design projects and three credits of laboratory testing are new courses developed for the M.Eng. program and offered exclusively to the M.Eng. students. The required structural mechanics and analysis courses, as well as the technical electives are the same courses already offered and taught to the M.S. and Ph.D. students.

Table 1. Master of Engineering Curriculum Requirements

Required Credits	**Description**
9	Design Projects
3	Laboratory testing of structural components and systems
6	Required structural mechanics and analysis courses
12	Technical electives

The main focus of the program is to learn structural engineering through the design of an actual structure. Students work as a group to design a major structure including initial code review, system selection, design development and construction drawings over the course of the 10-month program. The selected project is typically a structure designed by one of our industry partners. Students receive all relevant data and architectural drawings for the project from the industry partner. At the end of each semester, students provide a written report and present their findings to the faculty and to the executive advisory board.

Students also complete a small group project on a topic of their choice, allowing the exploration of a structural engineering area that excites and inspires them. Students are required to select a practicing engineer or faculty member to mentor them on their project.

Our faculty strongly believes that students gain a better understanding of structural behavior when they see it for themselves. In the structural behavior laboratory course, students test a number of full-scale members and systems to failure. This visual understanding of structural behavior aids students in their coursework and later in their career.

Table 2. Master of Engineering and Master of Science Curriculum Comparison

Semester	**Master of Engineering**	**Master of Science**
Summer	*Design Project I* *Structural Behavior Laboratory*	
Fall	*Design Project II* Mechanics and Behavior of Structural Members Technical Elective Technical Elective	Mechanics and Behavior of Structural Members Structural Dynamics Technical Elective
Spring	*Design Project III* Advanced Structural Analysis I Technical Elective Technical Elective	Advanced Structural Analysis I Finite Element Method in Structural Engineering Technical Elective
Fall		Technical Elective Technical Elective
Spring		Thesis Technical Elective

One unique feature is that the program is led by a professor of practice with extensive professional design experience. This person serves as director of the program and teaches three courses, Design Project I, Design Project II, and Design Project III. The professor of practice serves as a resource for students, providing technical guidance and a real-world perspective as they work on the group design project.

The program is guided by an executive advisory board of firms. These firms assist in the selection of the group design project, evaluate student design project presentations, share technical knowledge, mentor students, advise the professor of practice and guide the program to stay current and relevant to industry needs. These firms also provide scholarships to qualified students.

Due to the hands-on nature of the design projects and structural behavior laboratory course, the program is only offered to in-residence students. Currently, there are no plans to offer the program to online students.

Resources for this program are shared with the department of civil and environmental engineering. The new three-course design project sequence is taught by the professor of practice hired for the program. The new laboratory course is taught by the existing faculty. All other

courses for the program are pre-existing and the additional enrollment is partially supported through enhanced funding for teaching assistants. Administrative staff resources are shared with the department. This program capitalizes on existing resources and creates a new program to attract additional students with minimal additional resources.

Market Assessment

As part of the program development process, a market assessment of the structural engineering industry and students was conducted to evaluate the validity and viability of the program.

An industry assessment was conducted in the spring of 2007. The goals of the assessment were to obtain feedback from leading architectural/engineering design firms and construction firms regarding key elements of the proposed program and to obtain data regarding the potential job market for graduates of the program. A list of 525 companies was created based on university contacts and ENR's top 500 design firms list. Each company was mailed a detailed description of the proposed program and was provided with a brief survey to complete. Of the 525 surveys issued, 57 (11%) were completed.

The industry was asked to review the proposed program description and evaluate the extent that certain key elements add value to the program. Survey respondents evaluated whether they agree strongly, agree, neutral, disagree, or strongly disagree that each key feature listed adds value to the proposed program. Table 3 indicates the program features ranked by the percent of respondents who strongly agree or agree that the key element adds value.

Table 3. Industry Market Survey – Extent Key Feature Adds Value to Program

Key Feature	% Agree Strongly	% Agree	Total % Agree Strongly or Agree
Interaction with executive advisory board members and firms	73%	25%	98%
Focus on design projects	66%	30%	96%
Leadership by professor of practice	57%	39%	96%
Opportunity to learn structural design through group design project	30%	55%	85%
Flexibility to pursue individual interests through small project	33%	51%	84%
Opportunities for large-scale testing in laboratory	37%	45%	82%
Flexibility to pursue individual interests through elective courses	39%	41%	80%

Table 4 shows the breakdown of respondents with respect to interest in hiring graduates from the program. It is important to note that a few of the respondents worked for companies that had more of an environmental engineering focus.

Table 4. Industry Market Survey – Interest in Hiring Graduates

Key Feature	% Agree Strongly	% Agree	Total % Agree Strongly or Agree
Interest in hiring graduates from this program	41%	46%	87%

In general, the industry was pleased and supportive of the program and offered specific comments about some of the key elements, which were implemented where feasible.

In the spring of 2007, letters were sent to 28 schools requesting the opportunity to visit and meet with students to conduct a market assessment of potential students. Visits were made to 13 schools and one undergraduate research program. The proposed program was presented and students were asked to provide their views on the proposed program key features, the proposed program goals, and their interest in the program. Surveys were completed by 249 students.

Students were asked to evaluate whether they strongly agree, agree, neutral, disagree, or strongly disagree that they understand the benefit of each key feature to the proposed program. Students were also asked to evaluate how each key feature impacts the possibility that they would apply to the program. Tables 5 and 6 show a breakdown on each key element and the percent of respondents who agree strongly or agree.

Table 5. Student Market Survey – Understand Benefit of Key Feature to Program

Key Feature	% Agree Strongly	% Agree	Total % Agree Strongly or Agree
Focus on Design Projects	55%	44%	99%
Opportunity for large scale testing in laboratory	60%	37%	97%
Opportunity to learn through group design project	49%	48%	97%
Flexibility to pursue interests through small project	50%	43%	93%
Flexibility to pursue interests through electives	54%	38%	92%
Leadership by professor of practice	60%	31%	91%
Multidisciplinary nature of program	45%	46%	91%
Interaction with executive advisory board members and firms	45%	45%	90%
Ability to complete in less than one year	58%	29%	87%
Ability to complete two courses in summer	37%	45%	82%

Table 6. Student Market Survey – Feature Positively Impacts Possibility that I Would Apply

Key Feature	% Agree Strongly	% Agree	Total % Agree Strongly or Agree
Focus on Design Projects	41%	43%	84%
Flexibility to pursue interests through electives	50%	33%	83%
Opportunity for large scale testing in laboratory	54%	28%	82%
Flexibility to pursue interests through small project	41%	40%	81%
Opportunity to learn through group design project	38%	43%	81%
Ability to complete in less than one year	60%	19%	79%
Leadership by professor of practice	46%	33%	79%
Multidisciplinary nature of program	35%	42%	77%
Interaction with executive advisory board members and firms	36%	39%	75%
Ability to complete two courses in summer	22%	33%	55%

Students were also asked to consider four of the goals of the program and to evaluate the value of the goal and whether the proposed program adequately addresses the goal. Tables 7 and 8 summarize the results of the program goal assessment.

Table 7. Student Market Survey – Assess Value of Program Goals

Key Feature	% Agree Strongly	% Agree	Total % Agree Strongly or Agree
Thorough understanding of structural engineering design process from inception to construction	63%	32%	95%
Deeper intuitive understanding of the behavior of structures through full scale destructive testing of structural components and systems	53%	41%	94%
Advanced analytical and design tools essential for contemporary structural engineering design practice	47%	47%	94%
Wide array of course offerings to allow graduates to develop a program tailored to their own particular interests and career goals	54%	39%	93%

Table 8. Student Market Survey – Assess Whether Program Adequately Addresses Goal

Goal	% Agree Strongly	% Agree	Total % Agree Strongly or Agree
Thorough understanding of structural engineering design process from inception to construction	47%	43%	90%
Deeper intuitive understanding of the behavior of structures through full scale destructive testing of structural components and systems	46%	42%	88%
Advanced analytical and design tools essential for contemporary structural engineering design practice	34%	51%	85%
Wide array of course offerings to allow graduates to develop a program tailored to their own particular interests and career goals	51%	40%	91%

Program Refinement

As a result of the industry and student assessments, and input of the hired professor of practice, a few modifications were made to the proposed program and two new features were developed.

The group design project was initially intended to be designed by the class as a whole. Due to concerns of students not performing work equally and not having the opportunity to learn about all of the design elements, the group design project was altered to be a small group design project with teams of three to five students competing to complete the design of the same structure.

The small project was originally intended to be a small group project, but since there is little opportunity for students to do their own work and shine as individuals, and since the project is intended for students to focus on a topic of personal interest, this element was changed to an individual project.

Comments from the industry strongly indicated that the elective courses should be primarily from the field of structural engineering. They also advised that the number of elective courses taken in fields such as business and architecture should be limited to two courses maximum.

Building upon the relationship with the executive advisory board, two new program features were created. The first is the externship program where students have the opportunity to spend a week at a sponsoring company during one of the breaks between semesters. Externships provide students an opportunity to experience the professional world of engineering prior to graduation, reinforcing their education and informing their career goals. They also provide the executive advisory board firms additional mentorship opportunities. Students perform tasks such as shadowing engineers, performing calculations, reviewing drawings, visiting job sites, investigating structural problems, and studying the company culture.

The second added feature is the seminar and field trip series. Members of the executive advisory board and other respected professionals are invited to give lectures to the students on hot topics

in the industry. These lectures highlight concepts addressed in class and introduce new ones. Field trips to construction sites and fabrication facilities compliment the seminar series and transport learning outside of the walls of the classroom.

Recruiting and Marketing

The program enrollment is predominantly domestic students having just completed their bachelor's degree in civil engineering. Additional categories of students targeted for the program include students returning to school after a few years of work experience, students from non-engineering majors such as physics, math, and architecture, and international students. The few architecture and physics students who have enrolled in the program were required to complete a year of undergraduate structural engineering courses prior to starting the M.Eng. program, to ensure they had the appropriate level of knowledge to be successful in the program.

Multiple methods are utilized to recruit students. A number of students in the program's inaugural class learned about the program through the student survey conducted. Information sessions were also held at engineering firms in large cities and undergraduate students at area schools were invited to attend. Since it is often difficult for students to get off campus to attend information sessions, additional information sessions were scheduled at select universities and undergraduate research experience programs. Email campaigns were conducted with letters to professors at engineering schools and to students taking the GRE who had indicated civil engineering as their area of interest. Additionally, representatives from the college of engineering routinely attend graduate school fairs, a few of which are dedicated to enhancing diversity in graduate engineering programs. Finally, on-line information outlining the program to interested students was created initially on the college of engineering website and expanded recently to the department website.

It is difficult to measure the most effective method of recruiting students to the program. All of the methods listed above have helped to recruit at least one student. Certainly word-of-mouth and recognition of the program has increased since 2008.

The executive advisory board is recruited through visits to companies. The initial target list for companies to support the program was created based on companies with existing relationships to the department. Since membership on the executive advisory board is linked to sponsorship of a student scholarship, it has been a challenge to recruit firms during the current economic downturn.

Three-Year Assessment

The program was initially offered in the 2008-2009 academic year. In 2011, following the completion of the third year of the program, assessments were conducted of the executive advisory board, alumni, and the alumni's employers to evaluate if the program is meeting its goals and preparing students for professional practice. In addition, each feature of the program was surveyed to evaluate the effectiveness and obtain any feedback for improvement. Effectiveness was evaluated on a scale of very effective, effective, neutral, somewhat effective, and not effective.

The audience included 7 current and past executive advisory board members, 55 alumni, and 55 alumni managers/employers. Electronic surveys were returned from 6 (86%) executive advisory board members, 38 (69%) alumni, and 11 (20%) employers. Executive board and alumni surveys were emailed directly to the recipients. The employer surveys were emailed to the alumni and the alumni were asked to forward it to their manager. The inability to directly access the managers via email is thought to have impacted the low number of returned surveys from employers.

Tables 9 and 10 display selected results from the executive advisory board survey. Tables 11, 12, and 13 summarize selected results from the alumni survey. Tables 14, 15, and 16 report selected results from the employer survey.

Table 9. Executive Advisory Board Survey – Effectiveness of Program at Meeting Goals

Goal	% Very Effective	% Effective	Total % Very Effective or Effective
Provide thorough understanding of structural engineering design process from inception to construction	33%	67%	100%
Provide deeper intuitive understanding of the behavior of structures through full scale destructive testing of structural components and systems	67%	17%	84%
Provide advanced analytical and design tools essential for contemporary structural engineering design practice	67%	33%	100%
Provide project management and communication skills necessary for professional practice	33%	67%	100%
Meet current needs of industry	67%	33%	100%

Table 10. Executive Advisory Board Survey – Effectiveness of Key Features

Key Feature	% Very Effective	% Effective	Total % Very Effective or Effective
Effectiveness of group design project	40%	60%	100%
Value in individual project in addition to group design project	20%	40%	60%
Effectiveness of externship	20%	60%	80%
Effectiveness of seminar / field trip series	60%	20%	80%

Note: Curriculum was evaluated with an open comment question.

Table 11. Alumni Survey – Effectiveness of Program at Meeting Goals

Goal	% Very Effective	% Effective	Total % Very Effective or Effective
Provide thorough understanding of structural engineering design process from inception to construction	50%	47%	97%
Provide deeper intuitive understanding of the behavior of structures through full scale destructive testing of structural components and systems	55%	40%	95%
Provide advanced analytical and design tools essential for contemporary structural engineering design practice	60%	37%	97%
Provide project management and communication skills necessary for professional practice	32%	53%	85%
Meet current needs of industry	42%	50%	92%

Table 12. Alumni Survey – Effectiveness of Key Elements

Key Element	% Very Effective	% Effective	Total % Very Effective or Effective
Effectiveness of group design project	51%	46%	97%
Value in individual project in addition to group design project	24%	32%	56%
Effectiveness of externship	27%	30%	57%
Effectiveness of seminar / field trip series	65%	35%	100%

Note: Curriculum was evaluated with an open comment question.

Table 13. Alumni Survey – Preparation for structural engineering practice

Key Element	% Very Well	% Well	Total % Very Well or Well
Rate your preparation to enter practice compared with peers from other schools	54%	32%	86%

Table 14. Employer Survey – Effectiveness of Program at Meeting Goals

Goal	% Very Effective	% Effective	Total % Very Effective or Effective
Provide thorough understanding of structural engineering design process from inception to construction	36%	55%	91%
Provide deeper intuitive understanding of the behavior of structures through full scale destructive testing of structural components and systems	27%	18%	45%
Provide advanced analytical and design tools essential for contemporary structural engineering design practice	36%	55%	91%
Provide project management and communication skills necessary for professional practice	64%	18%	82%
Meet current needs of industry	27%	64%	91%

Table 15. Employer Survey – Effectiveness of Key Elements

Key Element	% Very Effective	% Effective	Total % Very Effective or Effective
Effectiveness of group design project	10%	60%	70%
Value in individual project in addition to group design project	10%	50%	60%
Effectiveness of seminar / field trip series	10%	60%	70%

Note: Curriculum was evaluated with an open comment question.

Table 16. Employer Survey – Preparation for structural engineering practice

Key Element	% Very Good	% Good	Total % Very Good or Good
Ability of graduates to "hit the ground running"	70%	20%	90%

In general, the program is successful at meeting its goals and students are well prepared for professional practice. A voluminous amount of open comment data was received from the three-year assessment surveys.

At the writing of this document, collection of survey data just closed. In the next few months the complete data including open comment responses will be reviewed with the dean, department chair, and department faculty. Implementation of feedback received will be included in the future plan for the program.

Summary

The new professional master's degree program in structural engineering at Lehigh University is successful at meeting the program goals and preparing students for professional practice. Time

spent during the creation of the program on industry and student market analysis proved to be valuable in shaping the program from the onset. Continual evaluations and adjustments to the program will occur as necessary to ensure that the program meets the needs of industry, students, and the university.

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