A Structural Engineering Master's Program – the Trials and Tribulations

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Abstract

This paper is specifically intended for the advertised session in the CE Division on "current issues affecting graduate CE programs such as double dipping, accreditation of masters programs, combined MS/BS degree, research versus practice oriented masters degrees, etc."

California Polytechnic State University in San Luis Obispo (Cal Poly) is a predominately undergraduate university. Cal Poly has recently expanded master's level graduate programs to support advanced education and faculty-student professional development opportunities. The Architectural Engineering Department in the College of Architecture and Environmental Design (CAED) started a structural engineering master's degree program six years ago and has graduated five separate classes. Since its inception, this master's program has dealt with a variety of issues to include accreditation, blending the program with the undergraduate degree, offering a non-project option, managing the program through continuing education, collaborating with other departments, partnering with industry, and accommodating students who did not graduate from the Cal Poly ARCE undergraduate program. This paper offers a history of this masters program, describes these various issues, presents the current state of the program and makes recommendations for its future.

Introduction

The Cal Poly Architectural Engineering Department's masters program was launched in fall 2007 due to student demand and ASCE policy 465's declaration of the masters degree as the first professional degree for the practice of civil engineering at the professional level[1]. The mission of this master's program is unique in that the focus is to capitalize on the strengths of the Cal Poly Architectural Engineering Department rather than duplicating a conventional graduate program in structural engineering. For starters, the Cal Poly Architectural Engineering Department is the only Architectural Engineering Department west of the Rocky Mountains. Cal Poly is also known for hands on learning, student interaction with faculty, and small class sizes. As a result the Cal Poly Architectural Engineering Department attracts high quality students. Due to the high seismic demands along the West Coast of the United States, seismic design and analysis is a major component of both the undergraduate and graduate Architectural Engineering curriculum. The Architectural Engineering Department faculty is composed of both professors with a Ph.D. degree and an engineering license and professors with a master's degree and 10 or more years of industry experience including a structural engineering license. This unique blend of faculty allows for a wide range of course offerings and a complementary balance of theory and practice.

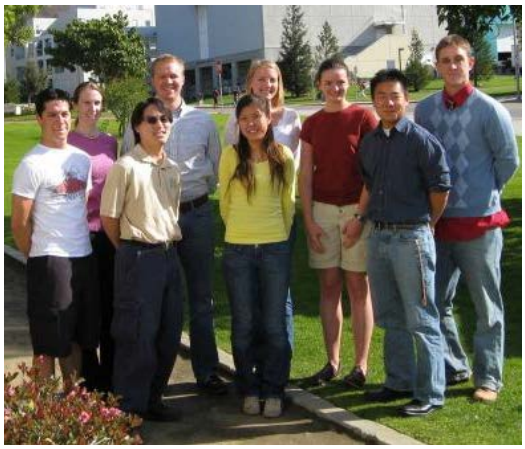
The vision of the Cal Poly Architectural Engineering Department's masters program is to create a uniquely balanced education of practice and theory which prepares graduates to succeed in the building industry. This is done through courses that 1) link analysis, design and constructability, 2) promote interdisciplinary teamwork, and 3) incorporate architectural and construction issues when developing structural design solutions. In addition, there is a focus on improving critical thinking skills as well as the ability to effectively communicate.

History of the Program

Planning for the ARCE master's program dates back decades; however, concrete preparations were made during the 2005-2006 and 2006-2007 academic years. The master's degree is housed in the Architecture Department as a specialization in Architectural Engineering. This connection with Architecture provides students with a unique perspective, specifically through two project-based interdisciplinary laboratory courses taught by Architecture faculty where Architectural Engineering students work on projects alongside Architecture students. In addition, by joining the existing Architecture graduate program, the time line for starting the Architectural Engineering master's program shrank from four to five years down to two years. New programs require California State University approval, a lengthy process, while changes in existing programs only require university approval. Still, due to the rigorous academic senate review process at the university level, two years were required for approval and official start of the Architectural Engineering masters program.

In order to develop a curriculum that embodied the Architectural Engineering graduate program mission and avoided typical graduate program pitfalls, members of the Architectural Engineering masters committee made site visits to California State University civil engineering master's programs at Cal State Long Beach and Cal Poly Pomona as well as architectural engineering graduate programs at the University of Nebraska, the University of Oklahoma, and Kansas State University. The Architectural Engineering Department Head also made a site visit to the University of Kansas. In addition, members of the master's committee held forums with key industry partners in San Diego, Los Angeles, Sacramento, and San Francisco to discuss the program mission, curriculum and graduate projects. The common denominators among the conversations with the university graduate programs were funding pressures, time commitment to serve as project/thesis advisor, prolonged time for students to complete project/thesis, as well as the administrative obstacles. The industry partners stressed the importance of fostering problem solving, clear communication and life long learning.

The Architectural Engineering masters program is available to students outside Cal Poly as well, but due to lack of advertizing, it wasn't until four years later that a student from outside the Cal Poly Architectural Engineering program enrolled in the



The initial class of master's students

The master's students celebrate the completion of their program at an end-of-year banquet

Master's program. This year's incoming class is likely to be composed of nearly 50% students from outside the university. Over the past six years class sizes have ranged from 5 to 16 students, with an average of 10 students per year. Future plans include growth of the graduate program with the addition of a comprehensive exam option.

The core curriculum for the Architectural Engineering masters program is comprised of the following courses:

Cal Poly Students	**Units**		**Outside Cal Poly Students**	**units**
Blended	13		Undergraduate Courses	13
ARCE 501 – Advanced Mechanics	3		ARCE 501 – Advanced Mechanics	3
ARCE 502 – Nonlinear analysis I	3		ARCE 502 – Nonlinear analysis I	3
ARCE 503– Nonlinear analysis II	3		ARCE 503– Nonlinear analysis II	3
ARCE 504– Finite Element Analysis	3		ARCE 504– Finite Element Analysis	3
ARCE 511– Structural Systems Lab	3		ARCE 511– Structural Systems Lab	3
ARCE 598 – Research Methods	3		ARCE 598 – Research Methods	3
ARCH 551– Architecture Studios	5-10		ARCH 551– Architecture Studios	5-10
Project/Electives	4-9		Project/Electives	4-9
Total	**45**		**Total**	**45**

Cal Poly students are able to 'double count' 13 units while students from other universities take undergraduate courses that were not offered in their undergraduate curriculum such as structural dynamics, seismic analysis and design, as well as concrete, steel or timber/masonry design laboratories. The curriculum advances student knowledge and understanding of mechanics and nonlinear analysis and provides project based learning opportunities in the Structural Systems Laboratory and the Architecture Design Studios. Students also have the opportunity to advance their education through electives taught throughout the university based on approval from their graduate advisor.

Master's student Joey Williams tests a fiber reinforced concrete masonry wall on the shake table as part of his project

Master's student Dan Lazzarini tests a post-tensioned masonry wall as part of his project

A main component of the Architectural Engineering masters program is the student project which is equivalent to a thesis at most universities. Graduate student projects have ranged from overseas humanitarian efforts including designing schools in Tanzania and retrofit schemes for buildings in Haiti to experimental research including full-scale testing of masonry walls and forced vibration testing of buildings to analytical studies including assessment of ASCE 41 performance based assessment procedures and sustainability assessment of buildings. The majority of the projects have included industry partners with various levels of involvement from serving as a member of the project committee to providing an advisory role on issues related to industry practice.

A separate 'cold lab' has been designated for the Architectural Engineering graduate students. This lab was recently sponsored by long time industry partner Degenkolb Engineers. As a result, upgrades to the lab will occur on a yearly basis. The graduate lab serves as a classroom for graduate courses as well as a computer lab and study area for graduate students.

Major Issues

Thesis/Project Concerns. For the six year history of the ARCE master's program, there has been a mandatory project requirement and students have pursued three different approaches:

- Student support of faculty research - Despite being a predominately undergraduate institution, faculty members are required to pursue the teacher-

scholar model and meet requirements for research and professional development for tenure and promotion. The assistance of a graduate student in support of these efforts is quite valuable.

- Students collaboration with an industry partner - To maintain the real world connection with the structural design industry that has become a hallmark of the Cal Poly Architectural Engineering undergraduate program, a second project option was to address a problem facing an industry firm. The program solicited projects from structural design firms that typically hire entry-level engineers at the master's degree level. The project committee consists of the master's student, a faculty advisor and a member of the firm that provided the project. The problem is of sufficient technical rigor to warrant master's level work and is not an immediate priority for the participating firm. Many firms supplied summer internships as part of the package. When the project works, everybody wins. The student has a master's degree; the department improves its partnership with industry; the supporting firm has a problem of interest addressed; and if the chemistry is right, the firm has first-dibs on hiring the new graduate. The industry support has been substantial with project proposals received from a number of firms including Degenkolb, Rutherford and Chekene, Forell and Elsessor, ARUP, Englekirk and Sabol, SOM, SGH, KPFF, MHP, John A. Martin and DES.

- Student research of a topic that they developed themselves - Because the department has few research grants, there is little funding to support graduate students, so there is no financial sacrifice for a student who pursues his or her own personal interest.

Master's students are required to formally brief progress on their project each quarter

Master's students Adam Rendon and Ken Singh demonstrate building mode shapes on the mini-shake table

The project presented two main challenges. Most students are satisfactorily completing the course work in the advertised time of one-year, but the completion of the project has caused many students to stay longer than intended or to drop out of the program

altogether. The second drawback is that the project requirement is restricting enrollment to approximately 16 students. Supervising a project requires considerable faculty time and effort on top of extremely high teaching loads (four courses per quarter). The faculty simply could not support a greater number of graduate students who were all completing a project.

The students who struggled the most were those who attempted to develop their own topic. The program's intent was for students to take a research methods course during the Spring quarter of their senior year as an undergraduate. The main objective of the course was to choose a project topic, conduct the literature review and have a well-crafted project proposal by the end of the term. The enterprising student would make progress over the summer and would complete the project in conjunction with course work during their year as a master's student. Some of those students who supported a faculty member's research or contracted with an industry partner were able to meet that plan and timeline. Those who developed their own project often changed topics several times, experienced difficulty in finding a faculty advisor who was interested in that topic, and never received the mentorship found with the other two options.

The solution for the students who are not fully committed to pursuing a masters project has been the development of a non-project option where students can complete coursework only and take a comprehensive final exam. At the time of this writing, the proposal is still being approved by the university academic senate. The students are greatly in favor of this option and it is expected to increase both interest and enrollment in the master's program.

The challenge may very well be how to provide an incentive for some students to still pursue the project option. The availability of graduate student support for faculty has been very helpful. The department does not want to lose the benefit of increased attention and partnership from those high end design firms that had previously been one level removed from hiring our graduates. Currently, the best incentive is the summer internship from a structural engineering firm that comes with the project option. Presumably, these are the firms that a student most wants to work for after attaining their degree.

Blended Program. The Architectural Engineering undergraduate program curriculum contains 204 quarter units and is the largest four year program at Cal Poly. It contains all of the requirements of an ABET-accredited engineering program along with 12 units of architecture studios. It contains more structural engineering content than any other undergraduate program in the country with both lecture courses and design laboratory courses in timber, masonry, steel and concrete. The undergraduate program contains mandatory courses in matrix structural analysis, structural dynamics and seismic design which are offered at the graduate level in many other programs. The two required advanced structural electives in topics such as seismic rehabilitation, cold formed steel, advanced timber/masonry, prestressed concrete, building cladding, advanced steel and advanced concrete are all masters level courses.

Cal Poly allows units above the 180 quarter unit minimum to be double counted towards a master's degree in the form of a blended program.[2] In theory, the program could double count as many as 24 units towards the 45 unit master's program. In reality, the program has chosen to double count only 13 units which still provides a significant incentive for students to enroll in the master's program since they already have about a third of a master's degree when they leave the undergraduate program.

The debate nevertheless continues on how to best use this situation to our competitive advantage. Should we double count even more units and make a master's program even more attractive? Should we attempt to create a five year experience where every student graduates with both an undergraduate degree and a master's degree, similar to the Architectural Engineering program at the University of Nebraska[3]? Should we reduce the undergraduate program to 180 units, allow the undergraduates to depart sooner, and simply move more courses to the master's degree? The biggest argument against such a move is the perceived reduction of quality in the undergraduate degree which the industry partners who hire our graduates and our own students have come to value.

The master's graduate laboratory sponsored by Degenkolb Engineers includes computers with advanced software

Each class of graduate students makes an improvement on the graduate lab for the benefit of those students who will follow.

Mandatory Unit Reduction – California has been struggling with a budget crisis in public education for the past several years. Over the past five years, the State budget has decreased by 44% and the rise in tuition has not covered the difference.[4] The California State University (CSU) is considering a mandate that all undergraduate programs be reduced to 180 quarter units (120 semester units).[5] As with similar mandates in Texas, Minnesota, and Maryland, there is a possibility that ABET accredited engineering programs will receive an exemption for 192 quarter units (128 semester units).[6,7,8] In either case, the master's program will be affected as moving existing undergraduate courses to the master's program is the easiest way to reduce units.

Continuing Education – With the budgetary issues listed above, there has been increased pressure to run programs through the self-support/continuing education program. The financial advantage to using continuing education is that students are charged fees based on instructor salary, department overhead, and university overhead. These fees are more expensive than the State tuition, but the costs of providing the education are covered, unlike the current State system. The CSU Chancellor's office is only approving new master's programs that are run through continuing education. Last year, the only two new master's programs at Cal Poly to be approved for development were Architectural Engineering and Dairy Science, but they were required to be run through self-support.

Administering a program through self-support has proven to have daunting challenges. An executive order prevents running classes through continuing education that are currently run through State support.[9] Even when similar courses are run through both systems, there is a prohibition from putting students on state support in the same classroom as students taking the course through continuing education. There are no good answers to the logistical questions about what happens to the student in the blended program who finds himself/herself taking courses through both state support and continuing education in the same quarter.

The department faculty is uniformly opposed to running a master's program through self-support because the students have to pay more. They also fear that after jumping through the administrative hoops for self-support, the department budget will be reduced by whatever savings are gained. There has also been concern that the current budget model is unsustainable and will have to change at some point. When a more rational budgeting model is adopted, the financial benefit for continuing education may no longer be justified. The self-support system is really designed to provide on-line instruction to people outside campus for a profit and does not currently fit well with a traditional on campus program taught in conventional classrooms. There have been master's programs that have creatively developed on-line certificates that can be combined with on campus classroom instruction to constitute a degree. Developing on-line instruction that might appeal to those in industry as well as the master's program is something to consider for the future.

Graduate students support faculty members in their research

Master's students celebrate their graduation.

Collaboration with Civil Engineering – The Cal Poly Architectural Engineering program is in reality an intense structural engineering program at both the undergraduate and graduate level. Cal Poly has a Civil Engineering program in the College of Engineering. Structural engineering is also a sub-discipline of civil engineering and is taught as part of that program. There is overlap at the undergraduate level but both programs are impacted and successful and there is little to be gained by combining assets. Both program offer master's level courses in structural engineering and there are compelling reasons to combine efforts since neither program is impacted. There is duplication in the areas of advanced mechanics of materials, finite elements, structural dynamics, seismic design, and matrix structural analysis. There have been obstacles to overcome. The ARCE courses are all three units while the CE courses are four units. Several of the CE masters courses are offered at the undergraduate level in ARCE. ARCE needs finite elements in the winter because it is a prerequisite for a course in the spring. CE offers it in the spring because they are collaborating with other programs in the engineering college who all want it taught in the Spring. There is a compelling need to come together on the classes which will affect both programs.

Accepting outside students – The master's program was developed primarily for those students who graduated from the ARCE undergraduate program. For the first few years, all of the enrolled students fell into that category. In the last few years, the program has accepted students from the Cal Poly civil engineering program and other undergraduate engineering programs. Because the ARCE program offers undergraduate structural engineering courses that nobody else offers, students entering from other programs need to take some undergraduate classes as part of their master's program. Because the backgrounds have been so diverse, programs for students coming from other programs need to be individually tailored. The outside students are required to stay longer, but have to date been very successful in the program.

Accreditation of the Master's program – The master's program has not sought ABET accreditation. There are currently no plans to seek accreditation. Very few master's programs in the U.S. are currently accredited and there seems to be no compelling advantage to doing so.[10] All of the enrolled students to date have come from accredited undergraduate programs. The main reason for a master's program to seek accreditation is to attract international students or domestic students who graduated from other than an ABET-accredited program.

Target audience – The master's program continues to define its target audience. The most consistent group that has benefitted so far are those ARCE undergraduates with a grade point average between 3.0 and 3.5 who would struggle to get accepted to other high quality programs. The students who attain grade point averages higher than 3.7 have often sought admission to master's programs at Stanford, Berkeley or U.C. San Diego, which is not necessarily a bad outcome. With the increased importance of the master's degree as the entrance level degree for structural engineering[1], the ARCE master's degree is serving a population that might otherwise not be getting a master's level degree. The degree to which undergraduates from other programs and those who are currently working in industry can become effective target audiences is still being assessed.

Conclusions

The Cal Poly San Luis Obispo Architectural Engineering program has developed and implemented a master's degree program that has been in effect for six years. In that short period of time, the program has encountered a variety of issues as described in this paper.

Given the brief history of the master's program, the issues faced and the current state of the program, there are some short, intermediate and long term actions and implications for the program.

- The short term or immediate actions are the implementation of the non-thesis/project option for incoming students. We expect academic senate approval in the upcoming months and intend to offer a course work only option with a comprehensive final exam to the class entering in Fall 2013. The undergraduate program is mandated to have a plan in place this year to reduce units to at least 192 quarter hours and improve some measures of efficiency. These changes will be synchronized with the master's program. The master's coursework and the degree to which the master's program remains blended (double-counted) may be affected. Some immediate coordination with the civil engineering program to improve efficiency at the master's level will pay dividends. The rules of the current budget model need to be further clarified to ensure that a larger master's program will indeed bring additional revenue to run it. Finally, the courses that were offered when the program started in 2007 have not changed significantly. A formalized assessment of those courses is currently ongoing.

- In the intermediate term, the program will continue to seek California State University approval to move from a Master's of Architecture with a specialization in Architectural Engineering to a Master's of Architectural Engineering. This is a multi-year process. The biggest challenge at this point is resolving whether administering the program through self support (continuing education) is mandatory and if so, removing the logistical obstacles and ensuring the financial benefits of this requirement. The ARCE master's program also needs to be integrated with the other master's programs in the college and university. The college is considering an interdisciplinary master's degree. The civil engineering and construction management departments are collaborating on a master's degree in construction engineering. Both of these programs are looking at certificate options where the degree is a collection of certificates plus a culminating experience. Given the master's classes taken at the undergraduate level by Architectural Engineering students, there should be opportunities to use these courses toward credit in these other degree programs. In addition, we need to market the master's program to a greater degree to students outside Cal Poly.

- In the long term, the program needs to develop on-line opportunities for some of the master's courses that will appeal to those already working in industry. A suite of courses that could be completed off-campus would attract a wider audience,

bring greater revenue to the program, and further the use of industry internships while students complete the master's degree.

The intent of this paper is to share the issues and solutions faced by this master's program with the hope that others who experience similar challenges can benefit. Hopefully, the solutions we adopted will contribute to the general body of knowledge on civil and architectural engineering master's programs.

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