STRUCTURAL ENGINEERING INSTRUCTION: FROM THE OUTSIDE IN

Susan M. Frey, Thomas H. Miller
CH2M Hill/Oregon State University

Why would an extremely busy structural design engineer, who works full time for a multi-discipline consulting firm, commit another 20 hours per week for 12 weeks a year to teaching a university level design class? Particularly, why, when normal office hours exceed 40 hours per week, and family, volunteer, and professional society obligations demand time daily? Why would an Oregon State University professor take time away from his own teaching and research to help foster classes sponsored by industry and taught by local practitioners? Why spend sabbaticals and summers, and weekly time during the academic year, working as a consultant? The answers to these questions lie within this discussion.

In 1994, The Masonry Institute of Oregon contacted Sue Frey, a structural engineer in CH2M HILL's office in Corvallis, Oregon. The Masonry Institute was sponsoring a senior/graduate level course in masonry design at Portland State University. Another class was being sponsored with industry funds at the University of Washington. The Institute hoped to foster a similar class at Oregon State University and was seeking someone to teach the class starting in 1995. Would someone at CH2M HILL be interested? After some deliberation, consultation, procrastination, and reliance upon blind faith, Ms. Frey decided to take on the challenge. And thus, for the past decade, she has taught a masonry design class for seniors and graduate students. A fair number of engineering professionals also take the class as a continuing education option.

The engineering instructor developed a strong relationship with Dr. Thomas Miller, an associate professor in civil engineering at Oregon State University, who teaches many of the structural engineering classes. Dr. Miller guided his new colleague through the rules, regulations, and culture of the university system, reducing the paperwork and procedures to a mere formality. He assisted with most of the University requirements, enabling Ms. Frey to concentrate on the students and focus on developing and improving the course.

In 2001, Dr. Miller joined CH2M HILL as a flex staff employee, starting with a sabbatical, and he has worked in that capacity to the present time during summers, and at times during the academic year. He has been involved with seismic rehabilitation of buildings, bridge projects, and anti-terrorist/force protection design of facilities for the U.S. Air Force.

Class Economics and Funding

The economics of providing this course exemplifies a true Oregon community project. Oregon State University (OSU) provides the venue, a lecture room in the Civil Engineering Building, Apperson Hall. OSU also supplies transparencies, audio equipment, computer access, projectors, and other materials. The Department of Civil, Construction, and Environmental Engineering assigns a graduate teaching assistant for grading and other assistance—typically a student who

has taken the class previously. With the instructor off campus, it is very helpful for the graduate assistant to be available to students. The first year of the course, other CH2M HILL staff also assisted with grading.

The Masonry Institute of Oregon contracts with CH2M HILL for about 50 to 60 percent of the cost of the class. CH2M HILL takes on the project, at no profit and nominal overhead costs, as a donation to the educational community. The CH2M HILL instructor, as a consulting engineer managing a project budget, uses the fees to assign copying and collating of handouts and other materials, and other weekly tasks, to administrative staff. She is able to charge about 4 hours per week to the project budget and another 4 to 6 hours per week for junior engineering staff to set up MathCad example problem templates and help with other engineering design or code research for the class.

The instructor/engineer donates about 12 hours a week in addition to the actual lecture time, except in years when the building code changes, which adds an additional 8 to 12 hours per week. She uses a day of her vacation time each week, during the workday, for course work preparation, to limit evening and weekend time away from her family. She also works on the class at the kitchen table while her children are doing their homework and her engineer husband is doing household paper work or office work.

The Masonry Institute of Oregon supplements the class textbook, which the students purchase conventionally at the bookstore. Over the course of the term, the students receive a number of supplemental books and pamphlets that are merged into the course materials. These additional materials include the current building code's masonry design chapter and commentary that has been adopted by the State of Oregon. The students leave the course with a library for masonry design, which is more complete than that for any of the other materials that they have studied.

Location, Location, Location

A major factor in making this symbiotic relationship work is the proximity of OSU to CH2M HILL's West Coast Design Center. They are less than 3 miles apart. If additional time for commuting were required, this class relationship might never have been developed or might not have lasted for the decade that it has. The community of Corvallis, Oregon, is also rich in professionals who are a resource to the university campus. The relationships, however, need to be sought out and nurtured to maintain mutual benefits.

Masonry Design Class Content

The class content is intended to provide the students not only with academic knowledge, but also with exposure to actual design experience. The practical design and construction knowledge of the consulting engineer is brought to the classroom, offering the students a window into the design office. They can begin to apply the knowledge gained in the classroom toward a building design during the 10 weeks of the term.

Element design of piers, columns, beams, and walls is taught, but always after exploration of the complete building system's flow of forces to the element. In-plane, out-of-plane, and axial load

combinations to walls are explored after the forces have been traced through the entire lateral load resisting system. A week of lecture, reading, and assignments is dedicated to exploration of code force development for both the building elements and the system for a selected masonry building. Similar force development exercises are then continued throughout the class. Students take turns explaining the flow of forces throughout a box shear wall system. Diaphragms, chords, and load distributions through connections between elements are included.

The design and material examples are geared toward the design office needs and procedures. The students undergo a "first job" design experience in many aspects. They discuss selection of materials, based on local availability, climate, and both architectural and structural needs, as well as the submittal review of materials that would occur during the construction phase of an actual masonry building project.

The design professional brings "working stories" from both the design office and the construction site to the classroom. Actual examples are used to explain design approaches and techniques. Various types of design procedures are dissected—from simplified approaches for preliminary design, or "back of the envelope" sizing techniques needed during a visit to a client's office, to more complex computer solutions.

Computer software is discussed but not used in the course; design understanding to check software is emphasized. Example problems are prepared in the design office with MathCad software that is customized to show units, unit cancellations, and current code references tied to the equations for "building official" review. In this case, the teaching assistant represents the local building department jurisdiction.

Videos of masonry construction supplement lectures. Materials study is intermixed with design examples. It is challenging to keep a 3-hour weekly technical session held in the evening after (and occasionally during) dinner paced correctly to cover all the material and hold the students' interest.

Class Evolution

The instructor did not walk through the classroom door the first time with a thorough understanding of what and how much material to convey. Although the class is still well saturated with in-depth materials, it has been simplified somewhat over the years, based upon student input and Dr. Miller's recommendations. The instructor's mentors at Purdue University, where she received her degrees, first asked the critical question, "Did you find it difficult to limit the amount of material that you want to convey?"

Student feedback has been a major resource for updating the class each year, and occasionally code-updated materials are offered to the previous group of students when their suggestions are incorporated. Handouts have replaced note taking in some cases when material is covered in slightly less depth in order to concentrate in more detail on another area. This approach still supplies the information needed in the student's near-future life as a designer.

During a code change year, much of the material has to be updated or rewritten, and course rework remains a constant challenge. However, the "design office" experience of working through a building code to perform a material design is a critical part of the course and worth the effort.

For the last several years, a mid-term survey has been conducted. Besides asking a few questions to determine if the students have an understanding of shear walls, the survey asks for suggestions for course improvements. Generally about a third of the students provide suggestions. These range from "slow down," which is then done, by dropping one proposed subject, to "pizza each week, please." Relevant comments that have been incorporated into the course include:

- Eliminating student homework on distribution of lateral forces through flexible and rigid diaphragms into masonry walls and piers. Instead, the last 2 hours of lecture for the term are devoted to a short seminar on the subject. Concepts only are tested on the final exam.
- Eliminating overhead and board work of design examples with the students copying each step. Instead, handouts are prepared presenting the most important information. Each year, the time spent drawing and discussing clarifying examples has increased.
- Reading assignments have been reduced or listed as "skim for future reference" on each topic. Instead, class notes summarize the most important information.
- A design notebook is built over the course of the class. Each week, common formulas, section tables, and material properties are added as needed for that week's assignments. By the end of the class, each student has a fully functional masonry design notebook, which, along with the current masonry code, will allow them to design most masonry buildings without additional materials. The notebook will also be helpful for the Structural Engineering Exam. Students are allowed to use the notebook with the approved materials as open book for all quizzes and tests.

Overall, the course is a living entity that has better tools and more organized materials each year. The instructor and the course have improved each year in the last decade, thanks to the OSU students and faculty.

Scheduling

One major decision revisited each year is when to schedule the 3-credit class, both time of year and time of day. This might seem to be a simple scheduling issue, but it is often the most difficult determination for the instructor each year. CH2M HILL project deadlines are generally indeterminate as a result of workload leveling, project schedule slip, construction delays, and other non-schedulable parameters. Other outside instructor commitments become major factors for class term selection, as substantial weekend and evening time is needed for course work preparation.

The masonry class is intended to provide continuing education and professional development for the working professional, as well as university education for the typical upper division and graduate student. Most consulting engineers find it more convenient to attend a class requiring a personal commitment in the evening, rather than during the work day. The class instructor, also

serving as staffing manager for the structural engineering group at CH2M HILL, needs to be in the office during working hours to perform ongoing workload leveling, as well as to monitor project deadlines. These variables led to the decision for an evening class time.

Another major decision is how to schedule the weekly 3 hours of class time. The working professional instructors who teach three OSU structures classes (Masonry Design, Prestressed Concrete Design, and Building Design Forces), have each elected to spend one evening a week at the university for a long, single period rather than take multiple evenings away from family and other commitments. The masonry class is separated into three segments, with a break after the first and second hours. Therefore, the material could also be taught as three single hour lectures.

Student Participation

The three types of students who take the course each significantly influence the course content. Undergraduates, graduate students, and working professional engineers each lend a texture to the course flow.

If the class is heavily populated with seniors, the pace is slowed a bit and more thorough explanations are given, because these students have taken fewer related design courses. The senior students, who are one term away from graduation, often are less focused. They request a more repetitive approach, with review of problems; they often want to back up to look over code and theory applications; and they have a "slow down" attitude. However, several seniors each term are highly interested in the construction as well as the design aspects, and the class usually works through a series of questions, including: Why is masonry construction allowed in high seismic zones? Do design engineers visit the field? What do junior engineers do in a building design in a typical design office? How could 10-inch slump possibly be allowed for masonry grout? Why do I need to know how to determine forces on a masonry wall? Won't someone provide that? …and so on. These exchanges occur throughout each lecture, and the class is provided with a mini-workshop each week on accessing a design professional in many areas outside the class topics. In addition, the instructor shares life experiences, including combining family and career needs.

The graduate students are assigned more theory, as well as additional design problems most weeks. They are highly motivated and have a more in-depth interest in both the theory and the design components. They frequently stay after class to discuss the course content informally, and to seek advice on finding employment, continuing in academia, or working abroad.

The working professional engineers (PEs) make up the most interesting set of students. This class allows the PEs to receive close to 30 professional development hours, stay current in building codes, have access to the opinion of another professional engineer on code interpretations, and learn a material in which they may not have great depth of experience. They also share their design work and field experiences with the university students. However, there is a draw back. These students frequently monopolize the instructor's time at breaks and after class to receive opinions on their current work issues. This situation occurs with at least one

continuing education student each term, and new ground rules have to be set. Once that occurs, such students cease to be an annoyance and become a resource.

The working professionals are very positive about the class and usually generate a flow of future students from the same firm. They bring more in-depth questions to the classroom, although they occasionally jump ahead of the materials. Based on these questions, the university students get a feel for what the working professional wants and needs to have in his/her toolbox. The PE questions frequently lead to a short side bar on an expanded topic with several participants. These vary from code minutia on masonry 'E' values and half stresses to how to select the building materials: concrete masonry units versus hollow clay brick versus face brick. The sidebars on field inspection by the special inspector and structural observation by the design engineer lead to some amusing field stories.

Consulting Engineer: Professional Benefits

The consulting engineer receives many personal and professional benefits from the university instruction experience. Although a major personal time commitment is required, the rewards are more than enough to justify the hours. By delving deeply into the current building code on a weekly basis, the instructor develops a more in-depth understanding, which is needed to teach the subject. The students' in-class questions broaden the level of detail, focus, and interest and challenge the instructor. Answers often are postponed to allow time to research code interpretations or to bring in real world examples of drawings or specifications to answer the question in more detail.

The instructor has become a company-wide resource for masonry design and construction. Questions come from all over CH2M HILL's many design offices across the United States and Canada. She has spent a series of evenings working with New Delhi staff on the design of masonry buildings, including connections, diaphragms, and transfer of forces to and through elements. Current detailed code knowledge and interpretations are shared immediately with other design staff, mainly through quality assurance reviews of their work.

CH2M HILL also benefits in other ways from the overall firm-university relationship developed and maintained by the instructor. Sue Frey is able to evaluate students in the graduate program on a weekly basis and make recommendations for hiring for the firm's various West Coast offices. New structural engineering graduates from other universities hired into the Corvallis office have all attended the evening class, as many of them were not able to attend a masonry design class at their own universities.

There are also more esoteric benefits. Relationships developed with students over the decade have networked CH2M HILL with many of the structural engineering firms throughout the west coast, particularly in Portland, Oregon, which has more structural engineering firms than any other city in the state. Relationships with these firms are further cemented through participation in the Structural Engineer's Association of Oregon (SEAO). OSU students are encouraged to join SEAO and to attend monthly meetings. These firms also contact faculty and the instructor for hiring recommendations.

In 2001 and 2004, the Northwest Concrete Masonry Association contracted the OSU masonry instructor, the instructor from Portland State University, a faculty member from Washington State University, and a private consultant, to author and present day-long seminars for practicing design engineers. These seminars focused on new code updates and changes in masonry design practice. The seminars were presented in major cities throughout the Pacific Northwest. Without the ongoing university work, this opportunity would not have been available.

Finally, various experiences have presented themselves. Participating in the development of graduate students' theses, interacting with OSU faculty in other course work, and preparing materials for and understanding the ABET accreditation process have provided personal enrichment.

Oregon State University Faculty: Professional Benefits

Interaction with industry also has tremendous benefits for university faculty. The exposure to current state-of-the-practice and a practitioner's outlook is invaluable, in terms of both teaching and research. For example, structural design teaching in many places tends towards member design, but Sue Frey has helped bring a building system orientation to OSU.

Oregon State University's structural engineering faculty, currently at four full-time staff, has been as small as two members. The relationship with CH2M HILL and industry has enabled the Department to add three vital courses to the structural engineering curriculum, at very little cost to the university. CH2M HILL also has supported OSU in a number of other ways, for example, building the CH2M HILL Alumni Center on campus, and helping with the American Society of Civil Engineers student chapter (finances, speakers, hosting of a balsa wood bridge contest for high school students, etc.).

Faculty experience in professional practice at CH2M HILL has been very rewarding. Helping to integrate new seismic code developments into the firm's practice, while at the same time learning daily about consulting methods, is a great example of give and take. Work on anti-terrorism/force protection projects provided a means to contribute in a unique way, based on previous experience in Air Force research on blast effects, and is also a very fulfilling job as part of the CH2M HILL team working on important current needs.

Finally, personal relationships established with practicing professionals have served the faculty and our students in many ways over the years. Technical advice, references, and valuable professional direction and personal encouragement have all sprung from these ties.

Conclusion

The relationship that has developed among industry, practicing design engineers, and university faculty has been very positive for all parties. Industry is able to educate students and professional engineers on design and application of their materials. Practicing engineers can keep their skills current, meet graduating students, and take advantage of tremendous opportunities to share their experience in meaningful ways. University faculty members learn ways to better orient their

classes to meet the needs of current practice. Industry and practicing design engineers have helped to strengthen structural engineering teaching at OSU, from the outside in.

Biographical Information

SUSAN M. FREY, P.E., S.E., is a senior structural engineer in CH2M HILL's Corvallis, Oregon, Design Center. She has B.S. and M.S. degrees in Civil Engineering from Purdue University. Her specific design and construction interests include masonry, wood and concrete buildings, prestressed concrete potable water tanks, and various hydraulic structures.

THOMAS H. MILLER, Ph.D., P.E., is an Associate Professor in the Civil, Construction and Environmental Engineering Department at Oregon State University, Corvallis, Oregon. He has B.S., M.E., and Ph.D. degrees in Civil Engineering from Cornell University. His research and teaching interests include structural analysis and design, wood and cold-formed steel buildings, and earthquake engineering.