Providing Safe Housing through Independent Study

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Abstract
The Civil and Mechanical Engineering department at the United States Military Academy has teamed up with The Center for Earthquake Resistant Housing to work toward affordable, easily constructed earthquake resistant housing in developing countries. A series of independent study projects involving design, analysis and research are being developed as courses for small teams of cadets. Each course will focus on a specific piece of the large project, helping to move it along more quickly. These projects will provide opportunities for life-long learning and community service, while allowing undergraduates to take on a complex, real-world problem with social, political and economical aspects. The goals of the first project will be discussed and recommendations for achieving the most from this type of course format will be provided.

Introduction

Research has shown that experiential project-based learning provides context for material learned in the classroom and engages students in their own learning, resulting in enhanced understanding of technical material and its application. Allowing students to work together in teams and the opportunity to work closely with faculty and other professionals has also been shown to improve learning and the desire to continue learning. [1,2,3,4,5] With this in mind, the Civil and Mechanical Engineering department at the United States Military Academy (USMA) has developed a program of individual study projects that senior cadets may select as elective courses. The Civil Engineering (CE) independent study project provides an opportunity for cadets to work in small teams to tackle real-world engineering challenges. Cadets work with one or more faculty members who guide them through the project, but the cadets work independently and are responsible for the project. The independent study provides opportunities for cadets to apply what they have learned in the classroom, do self-directed learning, do research, and begin to see how social, political and economic issues tie into engineering problems. [6,7]

"The CE independent study course objectives are to

- Apply the engineering thought process to develop a creative solution to an open-ended engineering problem.
- Produce a high-quality design/analysis/research report.
- Present a high-quality oral briefing
- Prepare for life-long intellectual growth, through self-directed learning" [6]

The skills utilized in the Safe Housing project also tie in well with several skills outlined in ABET criterion 3:

- an ability to design a system, component, or process to meet desired needs
- an ability to identify, formulate, and solve engineering problems

- an understanding of professional and ethical responsibility
- an ability to communicate effectively
- …understand the impact of engineering solutions in a global and societal context
- a recognition of the need for, and an ability to engage in, life-long learning
- a knowledge of contemporary issues
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice [8]

Service-based project learning is not always emphasized in engineering education, but has a long history at USMA where it is an integral part of the Academy's mission: " To educate, train, and inspire the Corps of Cadets so that each graduate is a commissioned leader of character committed to the values of Duty, Honor, Country; professional growth throughout a career as an officer in the United States Army; and a lifetime of selfless service to the nation." [9] Service-based projects can provide a strong sense of technical accomplishment, along with a strong sense of social accomplishment in providing a needed service to a community or organization. The project discussed here builds on the cadets' technical expertise and uses this special technical knowledge to help in the effort to provide safer housing in developing areas of the world, thus providing both a technical and social accomplishment for the cadets.

The Center for Earthquake Resistant Housing was established by Dr. Elizabeth Hausler to reduce the deaths and injuries caused by housing failures during earthquakes by creating long-term practical change in developing countries. The high death tolls in the 2001 Bhuj, India and 2003 Bam, Iran earthquakes inspired the establishment of the center, which will focus on low-cost building methods using local materials and labor in each area. [10] The initial project undertaken in 2005 will focus on housing in the northern India states of Uttaranchal and Himachal Pradesh.

Housing in Northern India

Unreinforced masonry houses using adobe, mud bricks, rubble stone and dressed stone are common in many rural areas of India [11,12] where the population is generally poor. These are usually built by local unskilled masons using local materials, resulting in poor craftsmanship (See Figures 1 and 2). This type of building has performed poorly in past earthquakes, including the 2001 Bhuj, India earthquake which killed over 13,000 people [12,13]. One proposed solution is to add reinforced concrete bands at the plinth, sill and lintel levels of burnt brick and cement mortar houses with a concrete slab roof [12]. This solution is currently being used for reconstruction efforts in India after the 2001 Bhuj earthquake and is being discussed for use in rebuilding areas in 11 countries devastated by the 2005 Tsunami in Southeast Asia. However, it is not currently clear that this solution will be effective in reducing loss of life and home. The first CE independent study had 2 senior cadets investigate the effectiveness of this proposed solution applied to two different house layouts.

Figure 1. Typical minimally reinforced masonry house, with lintel band (Killari,Maharashtra, India) provided by The Center for Earthquake Resistant Housing

Figure 2. Typical reinforced concrete slab roof (Chamoli,Uttaranchal, India) provided by The Center for Earthquake Resistant Housing

Project Plan

The cadets began the project by drafting a contract outlining the work they would accomplish over the semester and determining a timeline for completing each task. The final results of the project were presented in a written report and orally at the Academy-wide projects day. The cadets were responsible for locating the required resources, with assistance from the faculty advisor.

The contract the cadets prepared included an Introduction, Project Background, Problem Importance, Project Objectives, Investigative Approach, Time Schedule, Breakout of Grades and Anticipated References. Completing this at the beginning of the project allows the cadets to reflect on the project, its purpose and how it will be accomplished. In addition, it provides a written agreement between the cadets and faculty advisor outlining what work will be performed and when deliverables will be due. The contract is reviewed and revised as necessary by the faculty advisor and is then signed by the faculty and cadets. This then serves as the course outline for the semester.

The "Problem Importance" and "Project Objectives" sections of the contract begin to illustrate how this type of project expands the cadets' perception of engineering problems beyond the technical issues. Text from the contract written by the cadets is excerpted below:

> "Problem Importance. The importance of this project is immeasurable. If we are successful in aiding Dr. Hausler with her work, she may be able to save thousands of lives around the world with new designs and new methods to build earthquake resistant homes."
>
> "Project Objectives. We hope to provide Dr. Hausler with some research information that will help in her journey to find inexpensive and effective earthquake resistant housing. Specifically, we will be reviewing the proposed structural designs; analyzing them based on the characteristics of Uttaranchal and Himachal Pradesh, the two specific

regions of India in question, using the International Building Code and the Bureau of Indian Standards Code; and drawing conclusions about their adequacy. In addition, we will examine the possible effects of local construction practices on the given design and, if these effects render the design unsafe, suggest possible alternate designs."

Plans for two simple one-story structures were provided by Dr. Hausler for analysis. The plans represent the typical house layout for the region and are basic one-room houses with minimal windows and doors. The common construction material in the area is masonry, and the houses studied were to be constructed of clay brick, concrete brick, or rubble stone. The designs studied utilized precast reinforced concrete slabs for the roof structure. Figures 3 and 4 show photos of houses recently built using these plans.

Figure 3: Typical new brick house provided by The Center for Earthquake Resistant Housing

Figure 4: Typical new masonry house provided by The Center for Earthquake Resistant Housing

Analysis of the proposed solution could not be completed until some background research had been done. The cadets studied the 2002 Indian Building Standard and 2003 International Building Code (IBC) to determine seismic design requirements for the seismic risk associated with Uttaranchal and Himachal Pradesh, India. The 2003 IBC was used as a reference to compare with the Indian Standard requirements. The cadets were not familiar with seismic design and analysis and required some additional instruction in this area before work could begin. The cadets also researched the traditional building types, local materials, and construction methods used in the region and their performance in the 2001 Bhuj earthquake. In addition, the cadets researched the geology of the region, including soil types and seismic mechanisms. Research tools included building codes and standards, textbooks, earthquake reconnaissance reports, technical papers, the World Housing Encyclopedia, and various websites.

Once this background knowledge had been established, the cadets reviewed the plans for the proposed building solutions. They then performed seismic analyses on the as-designed buildings using the 2003 IBC and the 2002 Indian Standard. Preliminary hand-calculations using the quasi-static Equivalent Lateral Force Procedure were followed by computer analysis using the program SAP2000. SAP2000, which was developed by Computers and Structures, Inc., is a common structural analysis package used in industry and for research. This project introduced the cadets to current technology used in structural engineering and provided an opportunity for

them to learn how use it. The cadets were required to build an analysis model based on the provided plans and their knowledge of the structure and materials. The computer-generated results were compared with the hand calculations for verification. In addition to the engineering analysis, the designs were evaluated using the prescriptive criteria for residential structures in both the Indian Standard and the International Residential code. The cadets developed a table to quickly identify which criteria were not met for each code. The analysis results were then used to determine the likely failure sequence for the proposed design and determine if the as-designed building met current code requirements.

After establishing the expected performance of the buildings if built as designed, the cadets investigated the effects of several likely construction deviations from the design to assess the affect of construction quality on the overall performance of the structure. Deviations included omission of concrete bands, omission of reinforcing, poor quality masonry work, poor quality concrete, and omission of roof connections. The research and analysis results were then used to brainstorm ideas for improvements to the proposed structure to provide more uniform safety, allowing for local social and economic factors. These solutions were winnowed down and those deemed most effective were presented as recommendations for improving the proposed structure.

The cadets worked with Dr. Hausler from The Center for Earthquake Resistant Housing in developing conclusions and recommendations, requiring them to communicate effectively with a client outside the Academy and provide truly useful conclusions and recommendations. After completing the analysis, the cadets presented their work to faculty, cadets and guests during USMA's annual Projects Day. A Powerpoint slide show and project poster were developed by the cadets for this presentation.

Project Outcome

This was a challenging and rewarding project for the cadets and a supplemental capstone experience for their undergraduate education. They were able to apply and extend the knowledge they have gained through their civil engineering course work to a real-world problem with significant social and economic impact. The detailed analysis of the proposed structure helped them gain a much better understanding of structural behavior and how one element affects another. They also began to see the importance of construction quality on expected building performance.

In addition to extending their technical knowledge this project required the cadets to study economic, social and political issues in an area of the world with which they were previously unfamiliar. It taught them that engineering problems are not solved in isolation at the computer, but must take into account many "softer" issues in order to produce an effective solution. This type of project will be increasingly important in building understanding in the world community. They made large strides toward building skills for self-directed and life-long learning and seeing the benefit of venturing beyond their comfort zones.

Conclusions and Recommendations

Service based projects provide outstanding opportunities for engineering students to apply their knowledge and expand their horizons. These projects can also be very rewarding for students and faculty as they use their engineering skills to meet the needs of a community or organization.

Proper planning and supervision are essential to the success of this type of project. Students can easily be overwhelmed by this type of project so the faculty advisor must meet with them regularly to keep them on the right track and help them break the project into manageable tasks. Establishing an agreement about the scope and timing of the project up front is vital. Requiring the cadets to write a contract that is then signed by them and the faculty advisor is a very useful exercise and provides a roadmap for the semester. The amount of direction required from the advisor will vary greatly with the individual students working on the project and the advisor must be able to assess and adjust instruction as required. The students should be encouraged to accomplish as much as they can on their own, but should not be left to 'spin their wheels" when they are stuck or overwhelmed. In addition the advisor should require students to work together on at least portions of the project and not allow them to split the project and work separately since this operation mode does not encourage cooperative learning. Advisors will generally need to meet with the student team once or twice a week for a project of this scope.

The independent study project is an invaluable tool for transferring knowledge learned in the classroom to real-world engineering problems. The flexibility allowed by this type of project provides the opportunity for students to define what they want to gain from the project. Combining a public service/outreach project with the independent study gives the opportunity for maximum benefit and broader impact learning.

Bibliography

1. Wankat, Phillip C. and Oreovicz, Frank S.. Teaching Engineering. McGraw-Hill, Inc., United States, 1993.
2. Pinnell, Margaret, F., Daprano, Corrine, and Willaimson. "A Multi-Disciplinary Community Based Service-Learning Project: The Girl Scout Wall Project". *Proceedings of the 2003 American Society for Engineering Education Annual Conference and Exposition*, June 2003.
3. Eyler, J., Giles, D.E., "Where's the Learning in Service Learning", Josey-Bass Publishers, San Francisco, 1999.
4. Tsang, E. "Projects that Matter: Concepts and Models for Service Learning in Engineering", AAHE, Washington D.C., 2000.
5. Eyler, J. "What I Never Learned in Class: Lessons from Community Based Learning, Projects that Matter: Concepts and Models for Service Learning in Engineering", AAHE, e. Tsang, ed., Washington D.C., 2000.
6. Welch, Ronald W., Estes, Allen C. "Client-Based Projects for Every Senior – A Mark of Excellence for Any Program". *Proceedings of the 2003 American Society for Engineering Education Annual Conference and Exposition*, June 2003.
7. Welch, Ronald W., and Evans Mark D. "Undergraduate Independent Study Research Projects". *Proceedings of the 2004 American Society for Engineering Education Annual Conference and Exposition*, June 2004.
8. URL: http://www.abet.org/images/Criteria/E001%2005-06%20EAC%20Criteria%2011-17-04.pdf; Criteria for Accrediting Engineering Programs, 2004.
9. Cadet Leader Development System, United States Military Academy, West Point, NY, June 2002.
10. Hausler, Elizabeth. "Earthquake Resistant Houses" , The Center for Earthquake Resistant Housing, San Francisco, CA.
11. World Housing Encyclopedia summary publication 2004. Earthquake Engineering Research Institute, Oakland, CA, 2004.
12. Jain, Sudhir et al, "Bhuj, India Earthquake of January 26, 2001 Reconnaissance Report." Earthquake Spectra, Vol. 18, Supp. A., Earthquake Engineering Research Institute, Oakland, CA, 2002.
13. Hausler, Elizabeth A. "Housing Reconstruction and Retrofitting after the 2001 Kachchh, Gujarat Earthquake", Proceedings 13th World Conference on Earthquake Engineering, Vancouver, B.C., Canada August 1-6, 2004.

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