Undergraduate Independent Study Research Projects

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Abstract

This paper describes a senior independent study course used successful by the ABET-Accredited Civil Engineering Program at the United States Military Academy (USMA) that is believed to greatly enhance the academic program. The three general project types of independent study projects available are service-based, competition-based, and research-based. The mix of these open-ended projects usually ensures that each student can list a minimum of 3-5 project choices that meet their individual needs for a challenging, rewarding academic experience. The fact that this course is offered in addition to the program-required capstone course and taken by over 90 percent of the seniors each year testifies to the value that the cadets see in the course.

In the past decade at USMA, academic promotion criteria have increasingly looked at research and publication records of faculty members. Thus, what was once a primarily teaching-focused school has began to morph into a research-focused school. With the growing need for modest faculty research and the absence of graduate students, the development of undergraduate research opportunities quickly evolved. There have been numerous successes and failures over the last five years as we experimented with types and levels of research projects that undergraduate students could handle, how to properly manage undergraduate research, and what should be the program and student outcomes associated with the course.

Possible research projects are presented to the students early in the fall semester of their senior year. Project assignments are made by mid-semester so that initial coordination and some preparatory work can commence prior to the spring semester. With 45 to 60 CE majors graduating each year, it is easy to understand that one faculty member cannot advise the required 15-20 projects each spring. So many, if not all, of the CE program's 17 faculty must be part of this senior project program from the onset and supervise at least one project. Many of the projects entail research tied directly to the faculty member's research.

It will be shown through student assessment data that this experience both challenges and also motivates students like no other course in their academic experience. The students are providing a solution to a real world problem for a real client. It is also the case that student involvement in solving real problems stimulates client and sponsor interest; they become heavily involved in the project. Increased client participation enhances the quality of the finished product, and also enhances the experience for both students and clients. These semester-long projects are a great learning experience for all, including the faculty. The assessment will show that the students find the program demanding, but enjoyable and worthwhile, because it forces them to push the boundaries of their knowledge through initiative, self-study, perseverance, and creativity.

I. Introduction

For over 30 years, independent study projects have been offered to civil engineering students at USMA, but only to the top 2-3 students in the program. The projects focused on in-depth study in a specific civil engineering sub-discipline with the ultimate goal being greater student knowledge through self-study and occasional faculty guidance. In the mid-eighties, the ASCE steel bridge and concrete canoe competitions were added as yearly projects. It quickly became evident that the best team of students, those possessing hands-on skills, would not always come from the top tier of students. In fact, most of the students wanting to be part of these competitions were not in the top tier. Faculty were concerned whether these students would be self-starters and be able to complete the work required to design and then build the prototype for the competition -- all in one semester. By the end of the semester, most faculty advisors and students found the experience to be exhilarating, challenging, and just plain different from the normal academic experience. It was a win-win situation!

Research and scholarship activities gained greater focus in the mid-nineties with the addition of civilian faculty, and soon all faculty were spending more time on research, a trend that is occurring at many undergraduate teaching colleges. The inclusion of undergraduates in faculty research was a natural extension of faculty research and a welcome addition to the list of available student projects. At the same time, many faculty were involved heavily within their community and knew of potential service-based projects that would challenge and educate the students. It became obvious that many students would love the opportunity to put their skills to work and produce a product that met a real need.

In the fall of 1999, it was decided to expand the civil engineering independent study program to ensure that every senior CE major had the opportunity to participate in an open-ended project. Student assessment data from the handful of students who participated in previous years highlighted the value of the experience and conveyed the excitement they felt in providing a service to a real client. Therefore, an expanded project list was developed consisting of the three general project classifications: service-based (i.e., USMA, the Army, local community), competition-based (i.e., ASCE steel bridge, concrete canoe, timber bridge), and research-based. The key is that **all** of these projects are client-based projects.

II. Projects

The Department of Civil and Mechanical Engineering is extremely proud of the variety and number of projects it offers students. Consideration was given to the number of projects offered so that every student would have an opportunity. In addition, consideration was given to the complexity of each project so that the workload for each project would fall within an acceptable window. Exceptional student work provided at little to no cost to clients has opened up a ground swell of projects now constantly offered by prospective clients. A number of clients are also repeat customers.

Many projects each year are associated with some type of national competition or provide a needed service to our local community. However, many students continue/extend research being conducted by the faculty and/or at Army Labs. With an average project group size of two to four

students, each project requires each student's contribution, cooperation, and expertise, while allowing maximum student, client, and faculty advisor interaction.

Projects are presented to the students early in the fall semester of their senior year. Once the students have had a chance to conduct in-depth discussions with project faculty advisors (about two weeks time), the course coordinator requires each student to e-mail their rank order list of preferred projects. Approximately 90-98 percent of the seniors each year choose to work on one of these open-ended projects. Since this independent study course is taken concurrently with the capstone course, many have stated that it is like having two capstone experiences, but worth the experience. The goal for the course coordinator is to match the right student with the right project while trying to give students one of their top five choices. Project assignments are made by mid-fall semester so that initial coordination and some preparatory work can commence prior to the spring semester. Each student has the right of first refusal and can opt for a project slot still available or can take another course. Some advisors actively recruit students for specific skills and project success. The course coordinator ensures that every student has the opportunity to participate in a project even though it might not be his or her top choice.

Students enrolled in any independent study project must present an oral brief at the end of the project and must submit a comprehensive written report. Benefits of the oral brief are described in the "Projects day" section below. There are tremendous benefits to be gained from writing the final report, but only if both the student and the faculty member are properly educated and motivated, with proper training and resources. Technical writing references or guides[1] should be consulted to help the student organize the structure and craft the language in the report.

a. Community Service Projects

Community service projects have been extremely valuable in educating the community about engineering and building ties with local organizations/communities.[2] These local organizations / communities receive a valuable service from the students in the form of a design, professional recommendation, or a working device at minimum to no cost. Many of these organizations / communities have informed other groups of their positive experiences and these new groups have then sought assistance from our students. Students learn to interact with community sponsors, many who have little technical training, and contribute to the local area in a meaningful way. Recent project sponsors ranged from sports clubs at the academy to a local humane society. Large funding requirements must come from the client, while small amounts, if the client has limited funds, often come from our alumni organization, the Association of Graduates (AOG).

Community service projects allow students to serve the community, develop leadership skills, interact with professional civil engineers, and hone their own engineering skills on real-world projects. Students perform the role of consultant, corporate president, fund-raiser, project manager, designer, draftsperson, and construction worker. Community service gives students the opportunity to practice their civil engineering skills outside the classroom in "real life" environments. Involved students will acquire more project management experience working on these projects than can be learned in any classroom. Participants are called upon to explore his

or her abilities and talents and to communicate ideas logically. Students who can motivate volunteers from start to finish have had a rare opportunity to develop key leadership skills. [3,4]

b. Competition Projects

Competition projects are conducted at regional and national levels, such as steel bridge, concrete canoe, timber bridge).[2] Funding for these projects is primarily through our alumni organization, AOG, and donations of skills, equipment, and materials from interested sponsors/clients. These design, build, and compete projects usually involve various technologies and bring out the best effort in our students. Students become very knowledgeable about their project and they develop well structured and organized competition design teams. Competition projects are highly desirable for the students since they are competitive by nature, but traveling and winning are high on their list as well. The ability to travel and participate in the national competition is always dependent on the quality and progress of their product. Teamwork and project management skills go a long way in these major design projects.

c. Research Projects

Research projects give students an excellent opportunity to participate in existing research at an Army laboratory or with USMA faculty members. Many of these projects allow students to have access to data and computing facilities not available at USMA. Some research project sponsors are not in our local area, but an initial visit to the laboratory, constant communication, and any necessary follow up visits with the sponsor at West Point usually provides sufficient direction. Often, the client organization can easily provide the required travel funds. Many of these projects allow our students to influence new Army technology that they may use after they graduate and enter the Army.

A complete list of research projects and clients from just the past four years is shown in Table 1. A sampling of projects from the past 8 years is described briefly below to give the reader a sense of the types and complexities of these projects that students have undertaken at USMA.

Table 1: Research Projects

Research Project	Clients
Academic Year 1999-2000	
Frost/Heave	Cold Regions Lab
Strengthening RC Beams with FRP	Army Research Laboratory
Ice Jam Prediction Investigation	Cold Regions Research & Engineering Lab
Academic Year 2000-2001	
Prioritizing Repair Projects -Locks and Dams	Construction Engineering Research Lab
Carbon Fiber Reinforced Plastics	Army Research Laboratory
Modal Analysis of Blast Plates	Army Research Laboratory
Watershed and Reservoir Study	Waterways Experiment Station
Large Area Maintenance Shelter Foundation Design	Natick Labs
Mine Vehicle	Army Research Laboratory

Ice Jam Prediction Investigation	Cold Regions Research & Engineering Lab
Academic Year 2001-2002	
Reliability Analysis of Miter Gates	Construction Engineering Research Lab
Lightweight Concrete Modulus of Elasticity	Noorlite
Retrofit of Steel Structures with FRP	Army Research Laboratory
Small Arms Penetration into Geologic Materials	Army Engineering Research & Development Center
Design Charts for Laterally Restrained Slabs	Department of Civil and Mechanical Eng
Academic Year 2002-2003	
Blast Load Primer	Army Research Laboratory
Soil Constitutive Modeling to Predict Trafficability	Cold Regions Laboratory
Develop Material Properties for High Strength Low Weight Concrete	Department of Civil and Mechanical Eng
Progressive Collapse	Department of Civil and Mechanical Eng

Cone Penetration Testing—1997

This project began as an AIAD – Advanced Individual Academic Development – project, which is essentially a summer research-based project that is not graded. Students participate on the AIAD project for the experience, exotic travel locations, and the academic enrichment. Any student travel and lodging costs are paid by the project sponsor, who was in this case, the Waterways Experiment Station (ERDC) in Vicksburg, MS. Two students traveled to Vicksburg for three weeks each (at different times with a few days of overlap) during the summer of 1997. After returning from ERDC, the cadets enrolled in an independent study project to complete work started during the summer.

The project involved constructing large specimens of sand and gravel that were 6 feet tall and 5 feet in diameter, each weighing about 2000 lbs, pressurizing the specimens to simulate various depths in the ground, and then performing a series of tests. Shear wave velocities and SPT N-values were measured, and cones of various diameters were penetrated into the soil and tip resistance was recorded. This project was an attempt to predict the results of cone penetration tests performed in soils containing oversized particles in the field. Photos showing specimen setup are shown in Figures 1 and 2.

Students were involved in all phases of this project. The summer began with a big-picture brainstorming session, first briefing students on technical material that was well-established in the field, and then discussing unknowns and opportunities for the summer project. Students were involved in the brainstorming, decisions as to the project scope, and project planning and execution. Three specimens were setup and tested during the six-week summer period, a considerable feat given that planning and material procurement was started the first week, and given the large size of the specimens. At the end of the summer, the students brought all data back to USMA with them and attempted to make sense of it during their independent study. This activity would have been much more difficult and less interesting to the students if they had not been involved from the beginning. Plots were generated by the students such as shown in Figure 3 and all the data was summarized in a report to ERDC.

Figure 1. Completed sand specimen

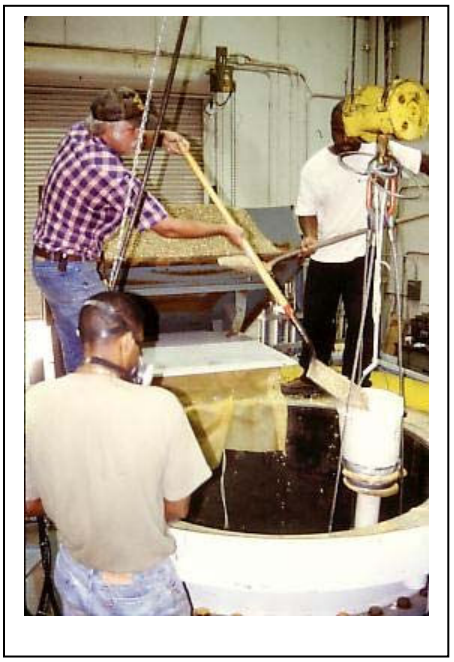

Figure 2. Setting up a gravel specimen.

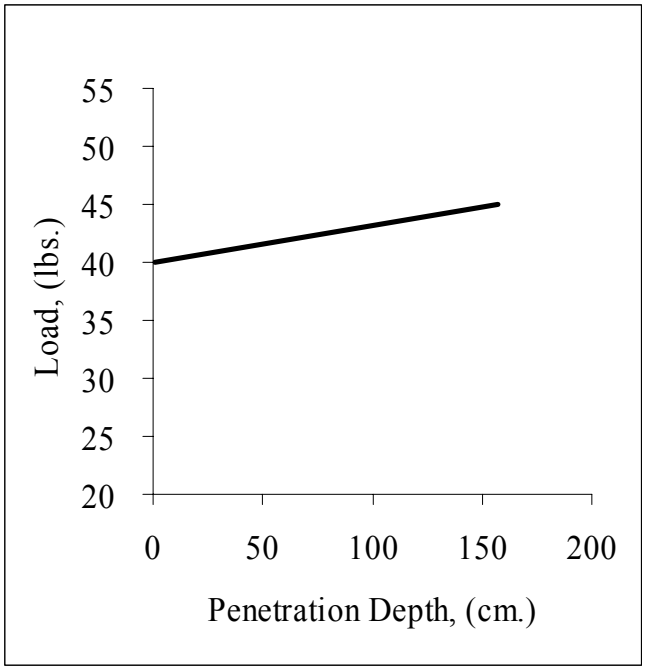

Figure 3. Tip resistance load vs penetration displacement for one specimen probe.

Large Area Maintenance Shelter Foundation Design—2000

In the Spring semester of 2000, two students undertook to write a comprehensive design report regarding foundations for LAMS – Large Area Maintenance Shelters. The LAMS are essentially very large tents that are used as Apache attack-helicopter hangers in warfare theaters of operation, such as in Bosnia, Kosovo, and Iraq. A photo of the LAMS structure is shown in Figure 4.

Figure 4. Photograph of a LAMS – Large Area Maintenance Shelter

The client for this project was the US Army, Natick Soldier Center, in Natick, MA. The students met with the client's representatives and were briefed on the system and on the issues that they wanted explored. The system was generally performing well in the field, but there were issues related to: constructability in a range of soil types, redesign of the current base plate design, the need for subgrade soils or a sub-base plate, exploration of alternate foundation support systems, etc.

The students performed a comprehensive analysis of the current system and designed alternate applications for the range of conditions requested by the client. The student-generated wiring diagram showing alternate applications depending on design conditions is shown in Figure 5. The students designed helical support anchors for a range of soil types, proposed (and designed) alternate base plate and sub-base plate design, and wrote a comprehensive report for the client. In fact, 3 years later, one of the students completed a Master's Degree and his thesis dealt with design issues of the LAMS structures.

Small Arms Penetration into Geologic Materials--2002

Two students investigated the penetration of several different rounds of common war-fighting small arms weapons in various soils for the Small Arms Project Manager at Picatinny Arsenal, NJ. The research effort was suggested and sponsored by ERDC/ Waterways Experiment Station, Vicksburg MS and it was performed to augment current Army Field Manuals addressing survivability issues and defeating small arms rounds.

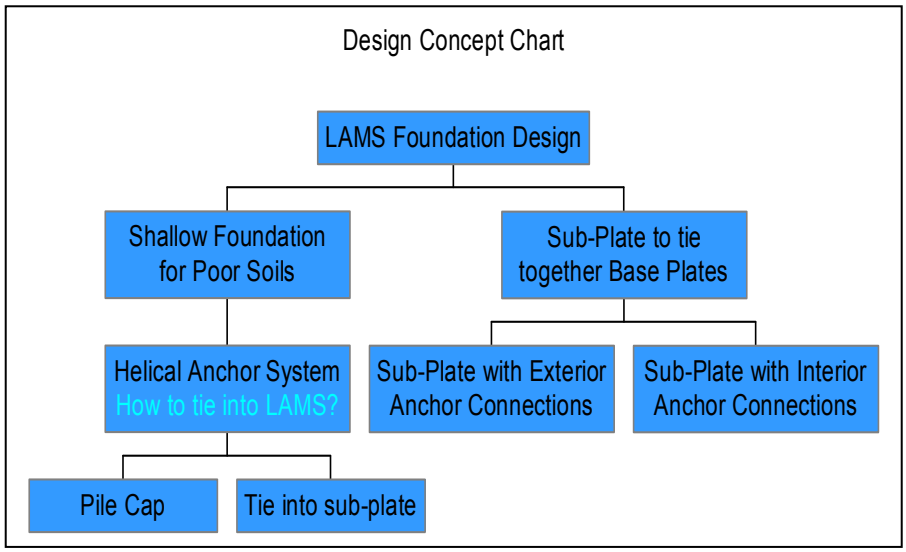

Figure 5. Student –generated Design Concept Chart for the LAMS project.

While the topic was suggested and handed off to the students, they ran with it independently. They researched current Army Field Manuals to see what was reported and recommended and defined what the problem was. Then they crafted a test program that would either validate the Army manuals or would generate data to update those manuals. Their program involved firing rounds into various test soils at the ranges at USMA and at the ranges at Picatinny Arsenal. The cadets obtained several common soils and performed standard laboratory tests to fully describe the properties of the soil. They built a box to contain the soil at the ranges (shown in Figure 6), and they selected various weapons and rounds to fire into the soils. Two sands and one gravel were tested and the rounds tested were M193 5.56mm ball, M855 5.56mm Green Tip, M118 7.62 Special Ball, x3083 Winchester .308 cal, M33 .50 cal Ball, and the M903 .50 cal SLAP round. The condition of the 0.50 caliber rounds fired into the three soils is shown in Figure 7, and plot of penetration depth for these rounds is shown in Figure 8.

Figure 6. Construction of the soil-containment box used at the firing ranges.

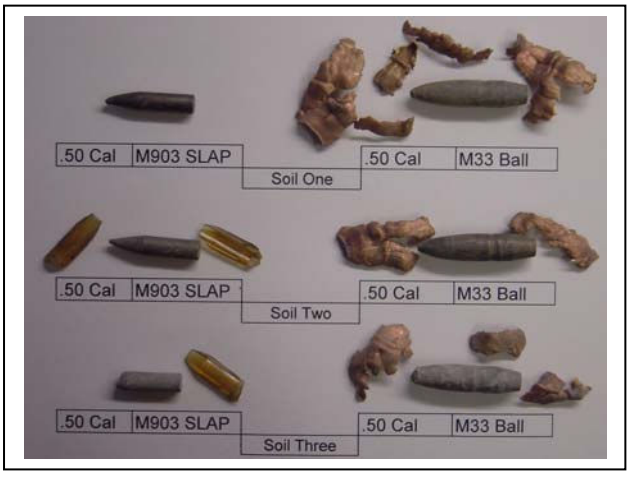

Figure 7. 0.50 caliber rounds tested.

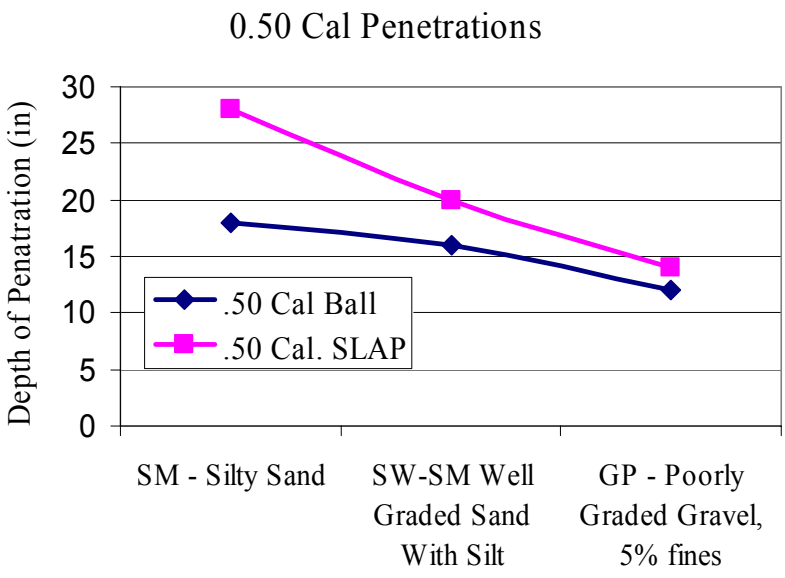

Figure 8. Plot of penetration depth vs. 0.50 cal. rounds and soils tested.

Finally, the students modeled the paths of the projectiles fired in this study using the program PENCRV3D -- Three-Dimensional Projectile Penetration Into Curvilinear Geologic/Structural Targets. This program was developed by the US Army Corps of Engineers, Waterways Experiment Station, ERDC to determine the penetration of large munitions fired into geologic media. A comprehensive report was delivered to both ERDC and Picatinny Arsenal.

Soil Constitutive Modeling to Predict Trafficability – 2003

Two students performed an independent study project in the Spring of 2003 and then continued to work on it for three weeks at the client's location during the summer of 2003. This is the opposite of the schedule described in the *Cone Penetration Testing—1997* project where students first did the AIAD in the summer followed by the independent study during the academic year. The client for this study was the Cold Regions Lab (ERDC) in Hanover, NH and the High Performance Computing Modernization Program (HPCMP) in Arlington, VA.

This study involved developing a constitutive model for the subject soil and then using those parameters to determine trafficability and rut development in the soil when traveled over by wheeled vehicles. This was part of a much larger study looking at the performance of Army wheeled vehicles traveling over soft, muddy, or thawing soils.

In this study, the students were given laboratory triaxial test data, which they reduced, and subsequently developed parameters for this soil to be used in an existing constitutive model. A finite element model of a triaxial test was run in ABAQUS (a finite element package) to test the reasonableness of the constitutive model parameters, and results such as those in Figure 9 were generated.

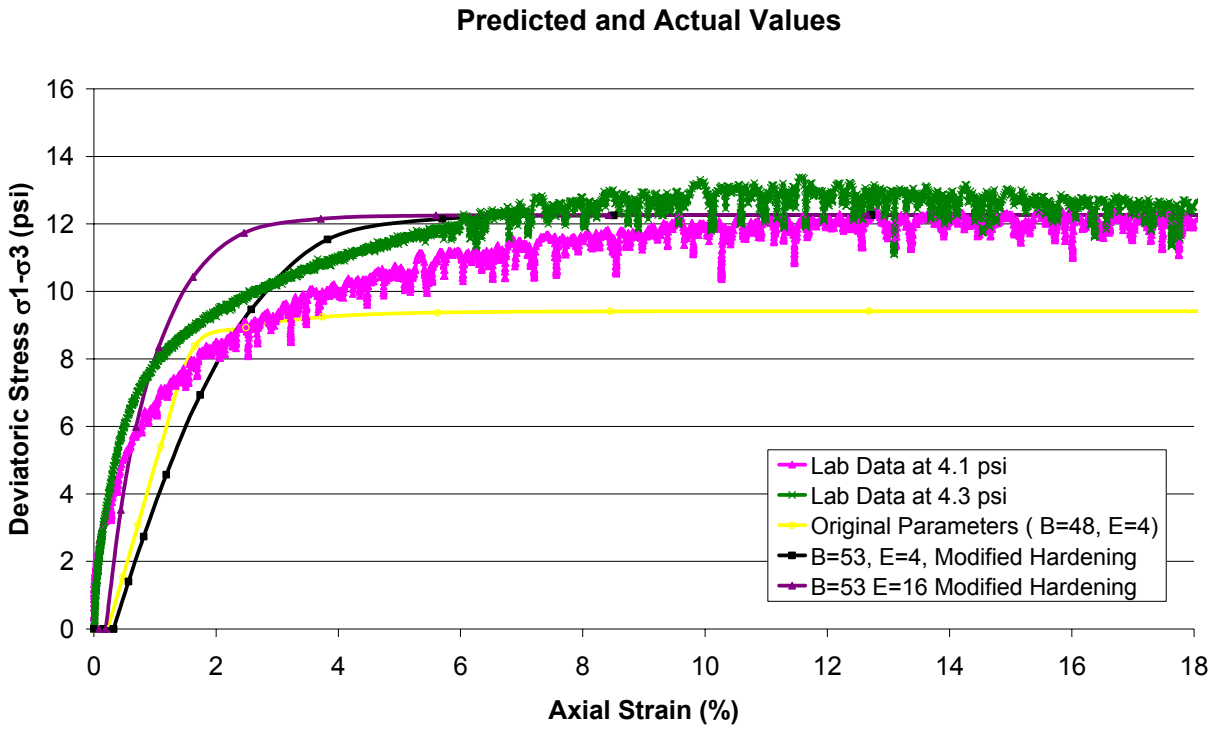

Figure 9. Comparative plots of laboratory test results and ABAQUS FEM results.

Once the constitutive model parameters were judged to provide a reasonable prediction of the soil's behavior, more sophisticated finite element models were run in ABAQUS to predict the behavior of the wheeled vehicles as described above. In that program (developed at ERDC) a 3-D model of a wheel is placed on the soil surface and then rolled (with a driving, or braking, or towed motion) across the surface of a multi-soil system. A screen capture of the 3-D model wheel and layered soil system is shown in Figure 10. A comprehensive report describing the results of this study was delivered to both ERDC and HPCMP.

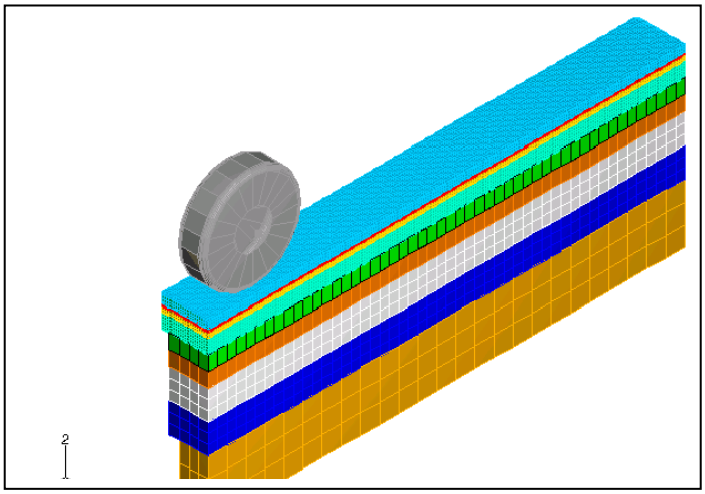

Figure 10. Screen capture of the rolling wheel FEM model developed at ERDC.

d. Research Projects Summary

We try to offer a diverse range of undergraduate research projects to appeal to a large number of cadets. Shown in the above list are projects dealing with structures (steel and concrete), blast, geotechnical, hydrology, reliability, and material properties (concrete, fiber reinforced plastics). Faculty members must understand that a number of their research-based projects will go unfilled each year due to our inability to match every project with an interested student. Properly defining and presenting the required research is also key to student selection.

Most of the projects listed above will challenge students, but cannot be counted as a CAPSTONE project since most do not include the ABET minimum-required four civil engineering sub-disciplines. So most of our students complete two challenging open-ended projects each spring: the capstone and the independent study.

III. Projects Day

Since the spring of 2000, USMA has conducted Projects Day to expose all of the academy's students and the local community to engineering design. It is unique since engineering excellence is supported and advertised by the institution rather than by one of the engineering departments. This distinction has encouraged its acceptance and promotion throughout the academy, including the non-engineering departments.

The Dean's Policy Memorandum states that Projects Day promotes academic excellence by providing senior students with a public forum to present their senior theses or design projects. [5] Projects Day is scheduled near the end of the Spring Term when most of the senior capstone projects are complete or near completion. Freshmen through seniors who have a free hour in their schedules are encouraged to attend Projects Day events, and a large number attend and actively ask questions at the end of the presentations. Additionally, the sponsoring departments try to schedule presentations over several instructional periods during the day to encourage student participation. The department of Civil and Mechanical Engineering requires its sophomore and junior CE and ME majors to attend at least one presentation and prepare a short journal entry. The individual departments also invite clients, project sponsors, community leaders, and local school children to attend the presentations as well. Considerations for future Projects Day include a non-class day three lessons before finals exams.

These independent study projects completed senior year represent the culmination of a four-year educational experience. Students begin their education as freshmen with highly structured courses and detailed requirements. Not later than the junior year, each student begins an in-depth study within one of the majors offered at West Point. The academic experience normally ends with an open-ended, challenging real-life project often providing a service to a real client. Projects Day, when used as a stimulus in conjunction with engineering classes, is a superb experience for those involved, giving students additional experience with teamwork and presentation of designs to a client with real concerns.

IV. Benefits

Project development, management, and presentation definitely require faculty buy-in and time, but the benefit to the program and the students is tremendous (Figure 11, 1-Low and 5-High). These research projects assist the program in meeting ABET criteria in a way many other courses can not and to stimulate the students to develop and apply new skills beyond the boundaries of past courses to solve an ill-defined problem. The course objectives are:

- 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.

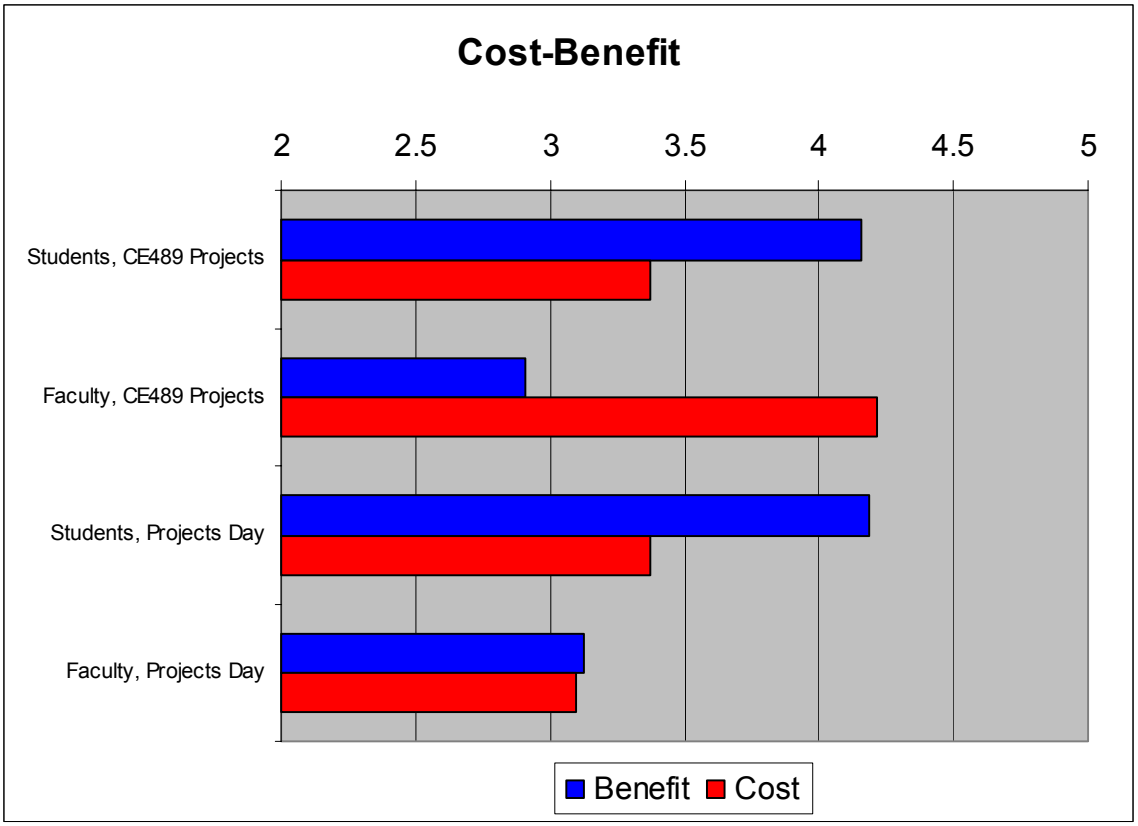

Figure 11. Cost-Benefit Comparison

The addition of Projects Day provides a single focused day for presenting these wonderful solutions and evaluating oral communication skills. One of the indirect advantages of Projects Day is the number of faculty across the campus who become more aware of other department's projects. The visual conveyance and articulation of projects have prompted many faculty members from other departments to offer solutions to an existing research problem. More importantly, they see opportunities to get their students involved in the projects and assist in

community service, competitions, and research in order to solve a stated need. These projects and the opportunities for other students to assist in multidisciplinary, engineering design help the CE program meet ABET's Criterion 3(c-e):

(c) an ability to design a system, component, or process to meet desired needs
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulate, and solve engineering problems [6]

Likewise, we allow civil and mechanical engineering students to join projects sponsored by other departments, promoting more cross-talk and coordination between all departments.

In addition to the publicity from Projects Day, the number of students attending the presentations has benefited the CE program. Some students who normally do not take engineering courses suddenly become curious and want to be part of a project in the future. Likewise, sophomore and junior civil and mechanical engineering majors who are unsure of what capstone project to pursue can see what others have done. They can read about the projects, look at static poster board displays which are required for each project, listen to the presentations, question the senior students who have worked on the projects, and query faculty advisors about the future of particular capstone projects.

Similarly, clients invited to presentations see new opportunities for projects. They have a last chance to question the service provided by the students and provide feedback to students and faculty advisors. Many clients decide to continue projects or find new ones for future students when they see that their organization and the students mutually benefit from the experience. Through active participation during the project and by attending Projects Day, their contribution and support to the senior independent study experience gains credibility and meaning.

Seniors involved in these projects, culminating with Projects Day, see it as an opportunity to "strut their stuff" and demonstrate their work products to the clients. Most students are eager to present their work and welcome questions and challenges from the general audience – part of the ABET communication program outcome. The seniors are proud of their accomplishments and have even invited family members to attend their presentations. Projects Day provides a media opportunity for the department and the institution. Since our department has the largest participation in Projects Day, the Department of Civil and Mechanical Engineering has taken the lead in publishing articles about Projects Day and capstone designs in the local newspaper as well as the alumni magazine. These opportunities help the local community understand engineering and what our students can do. In addition, the publicity helps generate local community service projects for future students. These huge benefits do come with a cost – usually on the faculty side in terms of additional time requirements on top of existing teaching loads (Figure 11). However, educational research activities are often one of the faculty benefits of many of these student projects.

V. Assessment

Client-based open-ended projects provide a wonderful opportunity for students to use all their skills to creatively solve a problem, while allowing faculty another opportunity to assess whether the students have met ABET requirements. We have assessed the effectiveness of our projects principally through the use of our institution's course-end feedback system. This system is administered entirely over the worldwide web and features a small number of USMA-standard survey questions, supplemented by department-specific and course-specific questions of our own choosing. Students respond to these questions using a scale of 1 (strongly disagree) to 5 (strongly agree). For the USMA-standard questions, this system allows us to compare our own students' survey responses to those of all other students at USMA. The inclusion of course-specific questions allows us to survey our students about their achievement of specific course objectives.

On their course-end feedback, the students have been extremely supportive of completing open-ended projects, especially for real clients. Relevant data are provided in Figures 12-14. Figure 12 shows CE489 (independent study projects course listing) student responses to USMA-standard questions that relate specifically to the quality of instruction and student learning. We also believe that these particular responses reflect student satisfaction with the course. Baseline values are averages for CE489 and USMA-wide responses. The USMA baseline responses have been extremely stable over time. Two years ago we had two projects with extremely low scores on the USMA questions for the first time. The advisors for these two projects were not able to provide the type of support the students felt was necessary. Earlier it was mentioned that there is a need for total faculty buy-in. In this case the faculty advisors attention was focused elsewhere. However, overall satisfaction appears to be quite high considering that students only meet once a week with the faculty advisor. Even though some of the students were not happy with the support from their advisor, the student's felt they accomplished the course objectives(Figure 13), the lowest value reported being 4.0 (agree). The high average response—above 4.0 for these course objectives—reflects a high level of satisfaction in the course.

Comparing 2003 feedback for the USMA questions against other senior civil engineering courses with the same general student population (Figure 14; CE404 – Design of Steel Structures; CE483 – Design of Reinforced Concrete; CE491 – Advanced Structural Analysis), we see that the independent study course (CE489) is well received by the students, even though the results for this particular year were lower than average.

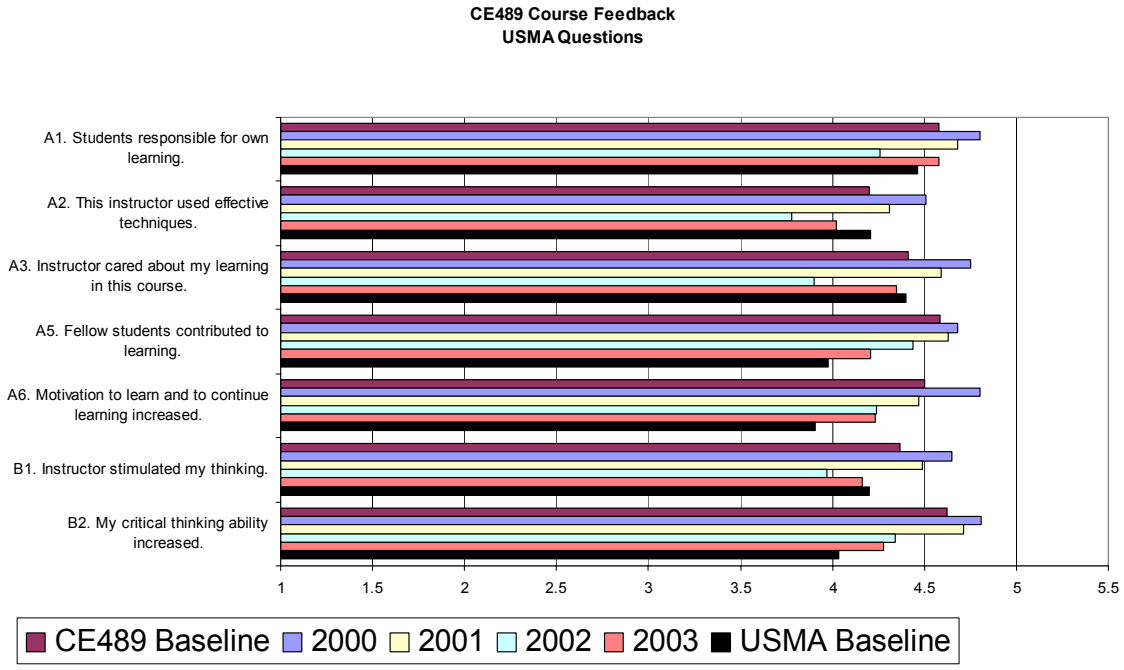

Figure 12. CE489 Course Feedback

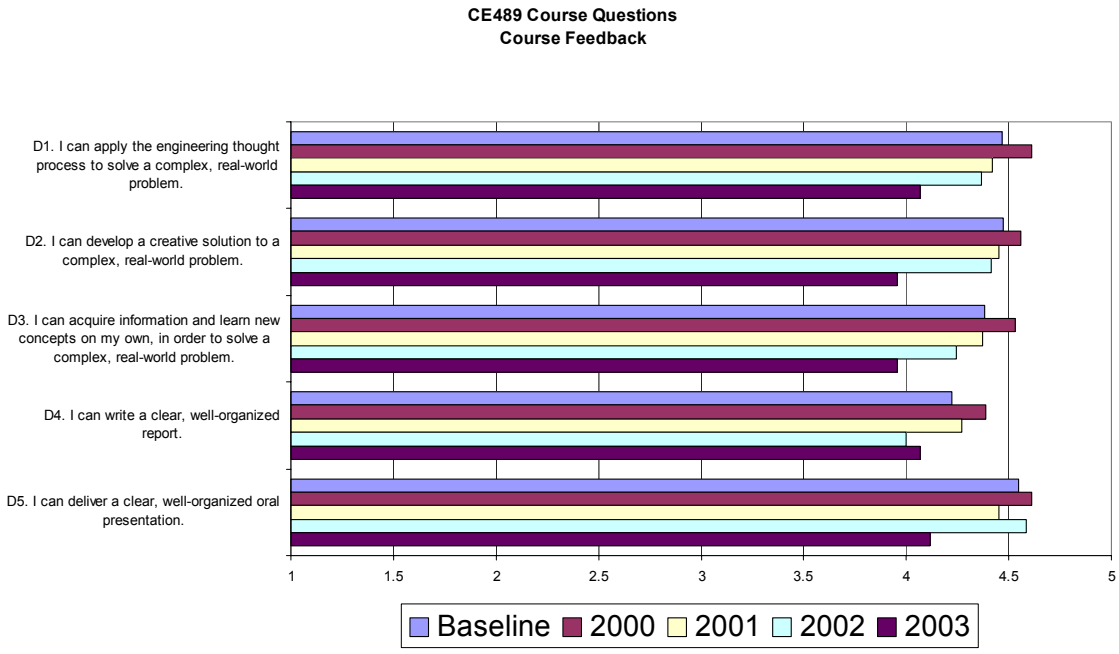

Figure 13. CE489 Course Specific Feedback

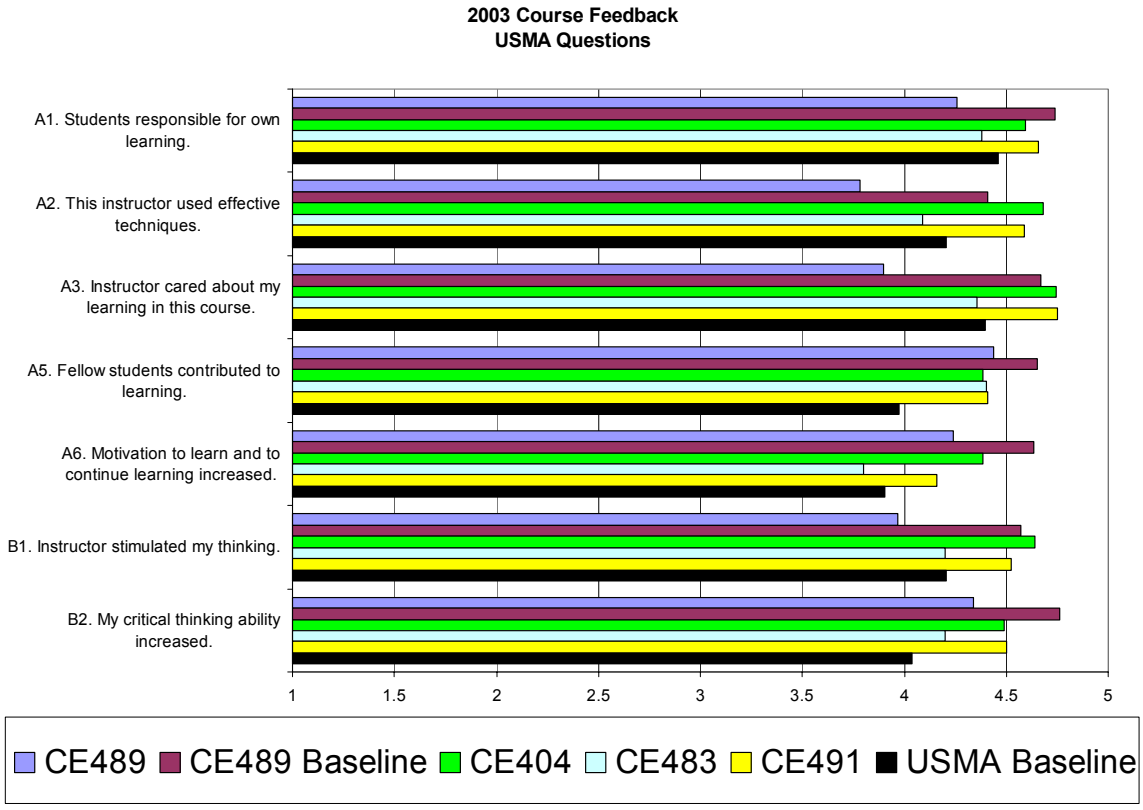

Figure 14. 2003 Course Feedback

In response to the "free text" question: "What did you learn from the course", a few of the student responses follow:

- I feel that this course was the perfect completion of my undergraduate education in civil engineering. It was perfectly tailored for what I need to learn.
- Students can make a difference.
- We have the knowledge to solve real-world problems.
- I know more than I thought I did about engineering and the problem solving methodology.
- I learned that there is much more to civil engineering than what I have learned in formal training.
- Working on an ambiguous project is more time consuming than other projects here.
- How to think outside of the box.
- That real-world problems require in-depth thinking and problem solving and that the skills I have learned earlier in my student career are actually applicable.
- There are so many points in a project to get stopped or distracted. I learned how to anticipate them and react to them.
- I enjoyed learning how to "sell" an idea.

One student summarized the learning experience as follows:

> "I learned more in this course than any other I have taken in the program."

Many other comments emphasized how much students valued being involved with real engineers, customers, and projects. Numerous students benefited from observing what other students were doing for their capstone projects and learned from them. Some students observing Projects Day decided what discipline and capstone to pursue.

Projects Day provides an opportunity for us to assess the curriculum. ABET 2000 Criterion 3(g) states that graduates must have an ability to communicate effectively.[6] Clients receive a written product and a formal brief either at Projects Day or at the clients' business. Having spent at least a semester on a project, most student design groups are very familiar with entire project. Thus, preparation for the presentation is not a burden. Figure 14, Question D5, shows an objective assessment of students' confidence to present their projects.

Faculty advisors also received informal feedback from the clients. Most clients have reported enjoying working with students and receiving a valuable product from them. Most of the sponsors volunteered again (see Table 1) and many clients solicited the students' assistance in subsequent years, which is further evidence of their satisfaction with the program.

VI. Conclusion

Students enrolled in CE489, independent study projects, are providing solutions to real world problems for real clients. Clients who observe student involvement in solving problems and/or designing/building/developing products are stimulated to become heavily involved in the process. Increased client participation enhances the quality of the final product and the experience for both student and client. These semester-long research projects are a great learning experience for all, including the faculty – they offer something for everyone! Assessment data shows that students find the research demanding but enjoyable and worthwhile because it forces them to push the boundaries of the their knowledge through initiative, self-study, perseverance, and creativity. Student-based research can be successfully conducted by undergraduates.

The Department of Civil and Mechanical Engineering's participation in USMA's Projects Day has been very positive for students, faculty, and clients. USMA promotes Projects Day as a medium to communicate student research results to peers, clients, and faculty. The Department uses Projects Day to seek multidisciplinary design/research opportunities, assess curriculum and program effectiveness, and advertise projects to prospective students. It allows engineering students to formally close out their project with the sponsors and faculty advisor. Students graduate from the program with a better understanding of customer focused engineering and are better communicators.

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