Incorporating Multidisciplinary Components of Ocean and Marine Engineering in Traditional Civil Engineering Capstone Courses

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Abstract
Criterion 3 of ABET 2004-2005 Criteria for Accrediting Engineering Programs[1] requires that all engineering programs seeking accreditation manifest that their graduates have an ability to "function on multidisciplinary teams." Students should be able to serve as both a team leader and a contributing member of a design team. Although major facets of this requirement are student attitude and personality driven, a significant component involves the appropriate understanding and expectations of members representing other engineering disciplines that work on the same design project. The Citadel in Charleston, SC is a military college with traditional civil and electrical engineering programs. Traditionally, ocean and marine engineering subject content has only been introduced in a few classes as related to faculty experience. During their final semester, students select and take one of four Capstone courses that include (1) structural, (2) environmental, (3) transportation, and (4) site development. Students in these courses work together on multidisciplinary teams to design roadways, subdivisions, buildings, bridges, and a water and wastewater conveyance facility on a given tract of land. The Army Corps of Engineers, a developer, and other practicing professionals are heavily involved in the course content and evaluation process. Given Charleston's unique location, it is important to have students design basic systems in ocean and marine environments. This paper presents the development of ocean and marine engineering design projects/studies in civil engineering Capstone courses at The Citadel. Specifically, a structural engineering professor has developed the design of floating breakwater systems for wave loads and wave energy dissipation and a case study to examine damage to a breakwater following significant wave loading from a hurricane. An environmental engineering professor has a critical review of the environmental impact statement for the expansions of the Charleston, SC port facility. This paper presents the evolution of the civil engineering Capstone courses at the Citadel and provides and commentary on the importance of including fundamental ocean and marine engineering projects as part of the multidisciplinary activities.

Introduction
The number of ocean and marine engineering programs in the United States is very small relative to the number of traditional programs in civil, electrical, and mechanical engineering. However, many of these traditional engineering programs have attempted to incorporate components of

ocean and marine engineering into their curriculums as a direct result of student indicated interest in projects involving guidance and control of underwater vehicles (i.e., electrical and mechanical engineering) and protection of structures and shoreline from ocean waves (i.e., civil engineering). Niemi[11] discusses the development of an ocean engineering course for mechanical engineers that students can take as a technical elective. Students actually built a small wave tank as part of the first year offering. Dimassa[6] presents the design results for various mechanical engineering students that elected to do senior research projects related to ocean engineering. The author states that approximately one third of the students in the program typically elect ocean related projects for their senior research project. Miller[10], Hansberry et al.[8], and Consi[4] present ocean and marine engineering projects and coursework at schools that have ocean and marine engineering programs.

Evolution of Capstone Design Courses at The Citadel

ABET[1] Criterion 3d which requires students to work in multi-disciplinary teams and ABET Criterion 4 (the professional component) which requires students to participate in a major design experience utilizing knowledge obtained from previous classes has led the Civil Engineering Department at The Citadel to move away from its traditional senior research project. The traditional project was a major undertaking whereby each graduating senior, in cooperation with a research advisor, was required to spend an entire year authoring a research and/or design report on a topic in his or her area of interest. After obtaining input from the Department's Advisory Council and considering the results of a survey conducted on senior design experiences at other institutions[5], the CEE Department elected to integrate the three disciplines of environmental, structural, and site development into one unified design team on a more comprehensive and time consuming capstone design course that all graduating seniors are required to take. The transportation capstone course offered in the evening was not combined with the other capstone classes since only evening students (not cadets) can take this course. The major reason for electing to create more unified capstone classes was the lack of true "multidisciplinary activities" in the previous courses. Martin et al.[9] and Wilczynski et al.[13] discuss the importance of multidiscipline activities in capstone design projects.

The goal of the unified design project for the three capstone courses was to make the course structure for all three classes as much like the actual workplace as possible. This was accomplished using the following outside individuals as part of the design team.

- Walt Martin (Figure 1), local developer: presented a fictitious 992-acre tract of land that he had purchased and wished to have developed
- John Gardner, project architect: provided architectural drawings for all buildings and design guidelines such as buffers, open space, aesthetics, handicap access, etc.
- Jack Ellis, environmental engineering consultant: discussed topics related to the particular project such as SARA and CERCLA, Superfund sites, environmental site assessment, potential problem areas, and mitigation scenarios
- Dave Hale, geotechnical engineering consultant: discussed site exploration procedures, testing procedures, provided a "geologic and soils report" for the site, and made recommendations for the site design

- Matt Halter, Public Works Director, provided extensive guidelines concerning subdivision regulations, zoning requirements, guidelines for plans and specifications, and permitting procedures
- Tina Hadden, Chief of Regulatory Permits for the Charleston District: discussed the Clean Water Act 92-500, wetland mitigation, endangered species, NEPA (National Environmental Protection Agency), Coastal Zone Management Act, and navigable streams

Figure 1. Walt Martin presents information about 992 acre tract of land to students.

Results from the 2004 course are discussed by Black et al.[2] and both student and advisory board feedback were excellent. As a result, the spring 2005 courses will be taught in much the same way. The only new components to the course are in the area of ocean and marine engineering as described below.

New Ocean and Marine Engineering Content for the Structural Engineering Capstone Course
Students in the structural engineering capstone course at The Citadel participate in all the areas described above in relation to outside team members. However, in reality, 75% of the course work (e.g., billable time) involves developing engineering calculations, drawings, and specifications for one or two large group buildings and various small buildings that students design individually. Students are required to consider all gravity (dead, live, live roof) and environmental loads (wind, earthquake, snow, rain, flood, soil) as part of the design process. Students also consider antiterrorism standards for one of the small buildings since one is randomly indicated to be leased by the Corps of Engineers.

For the spring 2005 class, several new elements will be added. First, students will be required to design a floating breakwater system for wave loading associated with a specific location in Charleston, SC. The structural design must consider waves (sagging and hogging) associated with a certain level wind event, the placement of reinforcement in the breakwater, the stability of the floating structure under wave loads, and relevant codes not known to the student. The design should be in accordance with relevant texts such as Tsinker[12] and Fossen[7]. Guidance by a professional engineer with experience in this area and similar to that available in the workplace will be provided to the students.

In a related case study, students will also be required to write a forensic report on damage to an actual floating breakwater system caused by wave loads thought to be lower than those of the design event. In a role opposite to that of the design engineer, students will be required to examine the design of an actual structure for code compliance, adherence to performance specifications, and ethical responsibility. Catalano[3] discusses related engineering ethics problems for engineering courses.

New Ocean and Marine Engineering Content for the Environmental Engineering Capstone Course

As part of a multidisciplinary team working on the forensic engineering component of the case study of the damaged breakwaters described in the previous section, the environmental team will examine the responsibility of the original design team to consider the impact of the local marine life (i.e., local crabs) that have eaten away a significant portion of the Styrofoam used under the inverted U shaped breakwaters. Damage to the marine life and the structures' resulting stability are both considered by this team.

By the end of 2005, the Charleston Port will be expanding by constructing a new three-berth, 280-acre container terminal on the former Charleston Navy Complex. The U.S. Army Corp of engineers permit application process has been extensive and included three different proposed locations. The environmental engineering capstone class will be investigating the social and ethical considerations on the final location at the former Charleston Navy Complex. The students will be reviewing the former Environmental Impact Statements and will write a position paper of the proposed location.

Summary and Conclusions

This paper presents the development of ocean and marine engineering design projects/studies in civil engineering Capstone courses at The Citadel. Specifically, a structural engineering professor has developed a project involving the design of floating breakwater systems for wave loads and a related case study to examine damage to a breakwater following significant wave loading from a hurricane. An environmental engineering professor has included the design of a water quality study of drainage systems discharging into the local estuary systems.

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