

Promoting Intra-Disciplinary Design in Civil Engineering Technology: An Approach to Comprehensive Capstone Design Through Faculty and Practitioner Mentorship

John W. Duggan, Ph.D., P.E.⁽¹⁾, Michael Davidson, P.E.⁽²⁾, Leonard Anderson, Ph.D., C.P.C.⁽³⁾

Abstract - Working in teams, civil engineering technology students develop an open-ended design on a project of their choosing. The design integrates several design and engineering concepts including design alternatives, design assumptions, value engineering, cost, safety, construction feasibility, construction scheduling, engineering ethics and engineering economy. All projects include elements of civil engineering sub-disciplines, including structural, hydraulic, site-civil, environmental and geotechnical engineering into the design. To facilitate teams, the course is team-taught by a group of faculty with expertise in specific sub-disciplines of civil engineering. In addition, other practicing professionals, faculty and/or alumni are available to students to provide expertise, advise and mentor in other topic areas relevant to the particular design. Access to multiple faculty and practicing professionals allows students to develop design concepts to project-specific challenges that often have more than one civil engineering area of specialty. The course format promotes student development in both integrated design as well as project-based teamwork and has been recognized as a program strength as an outcome of a recent accreditation review.

Keywords: Capstone Design; Civil Engineering Technology; Intra-Disciplinary; Design

Background

Wentworth Institute of Technology has been an institution in Boston, MA for over 100 years. For generations, students have attended Wentworth with the intention of working in design and construction professions. All students have 2 separate cooperative education semesters (CO-OP) as part of their experiential learning experience. During these CO-OPs, civil engineering technology students are exposed to current engineering projects and, often, the latest design and construction means and methods utilized by some of the leading architectural, engineering and construction firms in the construction industry. As a result, students in the civil capstone course have a strong interest in selecting their own capstone projects and many if not all projects are related to student coop experiences. Student project selection gives the students a sense of ownership in the project. The capstone course is structured to provide support for student-led design concepts.

¹ John W. Duggan, Ph.D., P.E., Wentworth Institute of Technology, Department of Civil Engineering and Technology, 550 Huntington Ave., Boston, MA 02115, dugganj@wit.edu

² Michael Davidson, P.E., Wentworth Institute of Technology, Department of Civil Engineering and Technology, 550 Huntington Ave., Boston, MA 02115, dugganj@wit.edu

³ Leonard Anderson, Ph.D., C.P.C., Wentworth Institute of Technology, Department of Civil Engineering and Technology, 550 Huntington Ave., Boston, MA 02115, dugganj@wit.edu

Introduction

Most, if not all, engineering and engineering technology programs have capstone design courses to meet criteria for accreditation. For engineering technology, capstone courses are typically created to meet the general *Integration of Content* and program-specific requirements in TAC of ABET (ABET, 2011). At Wentworth, the capstone course is a project-based comprehensive civil design that starts with a parcel of developable land and culminates with a comprehensive conceptual design. All course-work taken by the students in their undergraduate experience is incorporated into the project and evidence of this must be demonstrated in the student work. Team-work, project management, scheduling, principles of economics, etc. must also be incorporated into the project and demonstrated to meet course requirements.

As a result of a 2010 TAC of ABET accreditation review, the civil capstone course was identified as a program strength.

Course Description

Course Structure

The course is structured to maximize meeting times between individual design teams and faculty. Three faculty are assigned to the course, including a structural engineer, a site civil/hydraulic engineer and an environmental engineer. One of the faculty also assumes the role of course administrator. This faculty member also instructs design teams in meeting other course requirements, including other sub-discipline topics (safety, ethics, scheduling, economics, etc.), project management and communication methods (written reports, oral presentations, CAD, etc.).

Design teams are generally comprised of 5 students. Each student has more than one area of specialty for the project. Areas of specialties vary from team to team based on the nature of the project. All projects must have a significant emphasis on structural design and site-civil design and this emphasis varies from group to group. For example, one project might have 60% of the project focused on structural design (such as a highway bridge) while another project might be 60% site-civil (such as a subdivision design). All team members are responsible for understanding all aspects of the design, forcing students to exchange individual work with the other members of the group.

Each design team meets in 2-hour blocks, 3 times per week, during which time the three faculty meet with each team separately. During these meetings, research (code requirements, design options, review of construction materials, etc.), engineering calculations and design renditions (CAD) are reviewed and commented on by faculty. New assignments/tasks for the next meeting time are also given at these times.

In addition to the above described meeting times, all design teams meet together once a week in a one hour block for a lecture. This time is used by the course administrator to introduce concepts common to all design projects as well as review overall course requirements. This time is also available for guest lectures and general issues that may arise from individual students.

Practicing professionals and other civil faculty meet with project teams at an in-class event early in the semester when teams have initially developed a project scope of work. This event includes informal student presentations on feedback from these external professionals to each group. The event provides an opportunity for teams to get critiques and advice early in the design process from a wide range of professional views and expertise. In many cases, these visiting professionals (and faculty) continue to provide advice and mentorship to one or more design teams throughout the semester. These professionals also make up the project reviewers that evaluate final design presentations at the end of the course.

Scope and Schedule

The course is run in the last semester of the senior year. Prior to that semester, eligible students meet 3 times with the course administrator to review course requirements and assist students in the development of their scope of work and

design topic. These pre-course meetings help prepare students for creating a Design Services Report, which is due within the first 2 weeks of the semester. Since all designs must incorporate a wide range of civil engineering topic areas (in addition to the major topic areas of structural and site-civil) every week a different topic, such as geotechnical, environmental and safety, is presented to each design team. Sub-topic areas are listed as follows:

- Geotechnical
- Value Engineering
- Engineering Budgets and Scheduling
- Engineering Ethics
- Safety
- Sustainable Design
- Environmental Engineering and Permitting

For each of these sub-topic areas, an interim report is required. Each of these sub-topic area reports are eventually incorporated into the Final Design Report, which is due at the end of the semester. The Final Report also includes details of project management, project scheduling and other relevant projects details and data. Each group is also required to give a Final Presentation of their design, which is presented to Department faculty, external practicing professional reviewers, other students and the greater Wentworth campus community. Students are evaluated based on several modes of communication, including oral (the Final Presentation), written (text of Final Report), design calculations and design drawings (also part of Final Report).

Examples of Student Work

Range of Student Projects

The types of design projects selected by student teams for a recent graduating class are summarized in the following Table. As can be seen, the design projects represent the spectrum of projects civil engineers routinely encounter in the real world. The range is a testament to the diverse interest of students and a reflection of the types of project they had encountered during their coop experiences.

Table 1 Summary of Recent Capstone Design Projects	
Project Title	Major Design Elements
Marston Mills Airport	Site-Civil (pavement design, site layout, drainage); Structural (tower design); Environmental, Airport Runway Design
Canton Driving Range and Condominium Development	Site-Civil (grading and layout, road design, utility design) Structural (building design); Municipal Planning
Wentworth Parker Street Graduate Housing	Structural (building design, foundation design); Site-Civil (site layout, drainage); Green Building
Rehabilitation of Bloomfield, NJ Stadium	Site-Civil (site-layout, utility design); Structural (stadium stands); Environmental (hazardous waste, wetlands)
Parker Street Recreation Center and Parking Garage	Structural (parking garage design); Site-Civil; Recreational Field Design
Blue Hills Ski Slope Expansion	Site-Civil (drainage, utilities); Structural (lift tower design); Environmental (MEPA, erosion control); Hydraulic Design (water supply, snow-making)
Solar Energy Field, Kingston, MA	Site-Civil (site development, septic design); Structural (solar array supports, building design); Energy (solar array design)
Sudbury Commercial Office Development	Structural (building design); Site Civil (road design, drainage/stormwater management, parking lot design); Environmental
Central Maine Residential Development & Chirimoto, Peru Infrastructure Improvements	Site-Civil (subdivision design, septic design); Structural (water treatment structure) Water Supply (water treatment design); Sustainable Design
North Reading Recreation Facility	Site-Civil (drainage and grading, road design); Structural (building design); Field Design

From the Table, it can also be seen that each group placed a different emphasis on the type of civil design for their project. Some projects focused more on structural design, others more on Site-Civil design. In either case, faculty assigned to the course were able to guide the teams to develop designs in these areas. Also, based on the nature of the specific projects, some designs incorporated “other” design elements, such as solar power design, green building design and airport runway design. In some cases, course faculty did not possess expertise in these other design areas. However, because of the course structure, design teams were able to get valuable guidance and mentoring from external practicing professionals familiar with their projects from early semester meetings and in some cases other faculty, not formerly affiliated with the course. As a result design teams were able in most cases to perform comprehensive civil engineering designs.

Intra-Disciplinary Nature of Design Projects

The following summarizes some aspects of the intra-disciplinary nature of one of the recent design projects. For this project, a team of 5 students designed a graduate housing facility on an empty lot adjacent to the Wentworth campus. The design included a “green” building (suitable for LEED certification), structural design of the building and multiple site-layout plans that incorporated stormwater management, roadway, parkland and utility plans. Figure 1 is the cover sheet to the plan packet submitted in the Final Report and lists the different design plans that were developed by the team. For this project it was unavoidable to perform one design without consideration for other design elements. For example, Figure 2 shows the Site Plan. In order to determine building placement, consideration for utilities (existing and proposed), site drainage, roadway design and zoning requirements were required. Elements of green design included plans and specifications for a green roof and a rainwater collection and recycling system. For the green roof, structural design of the building was necessarily dependent upon the loads created by the green roof materials. Similarly, the water recycling system design was linked to the building design and fluid mechanics/hydraulic design, since the designed water reuse at differing building elevations.

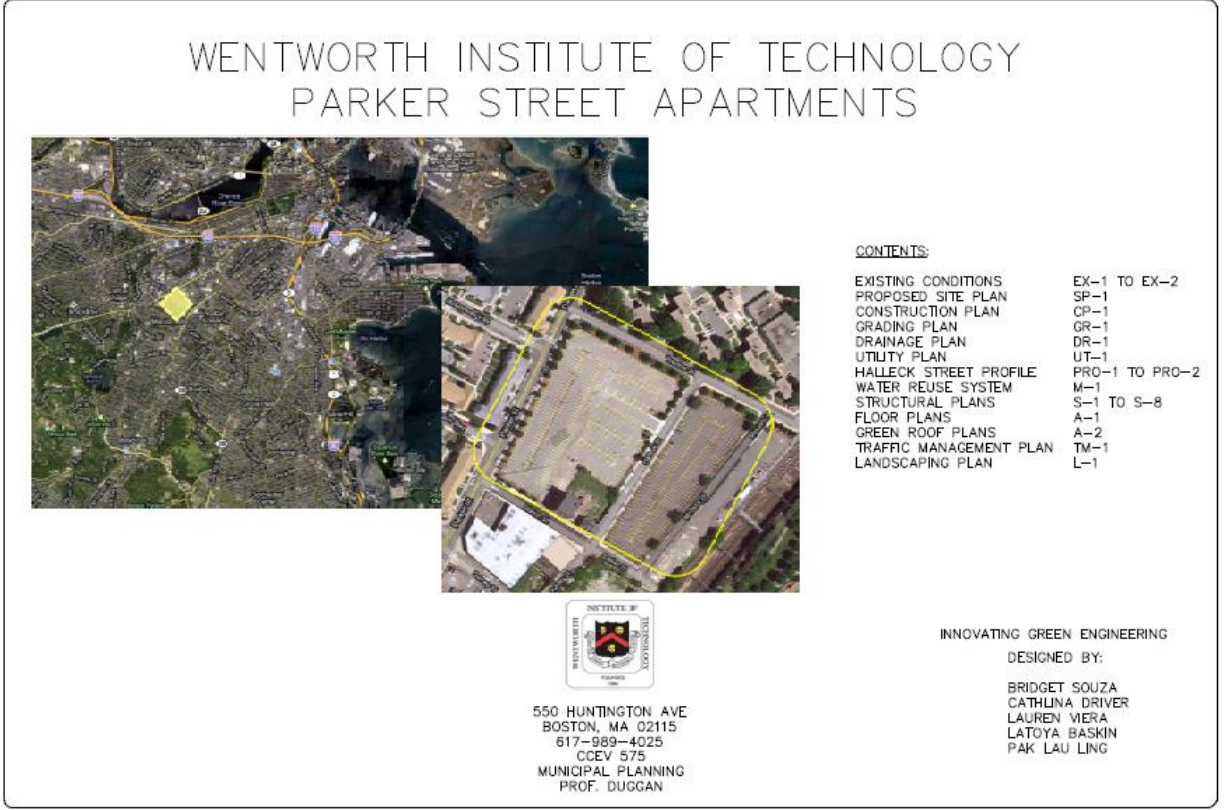
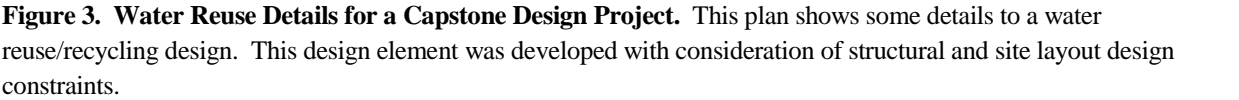


Figure 1. Title Sheet for the Plan Set of a Capstone Design Project. For this project, students chose to develop a design for a graduate housing facility on under-utilized land on Wentworth’s urban campus. The project incorporated several civil engineering design elements, with a major emphasis on structural design.



Wentworth's civil engineering technology capstone course provides students with faculty and external practicing professionals that guide and mentor design teams to develop designs that incorporate a wide range of intra-disciplinary concepts in civil engineering. Student conceived design projects also enhance to projects in terms of enhancing student ownership. The CO-OP experiences students receive prior to the capstone course help students develop design projects and in many cases coop serves to provide design teams with valuable mentorship from external practicing professionals. The outcome of the structure and implementation of the capstone course has resulted in a wide range of comprehensive design projects, meeting course objectives.

John W. Duggan

John Duggan is a Professor in Wentworth's Department of Civil Engineering and Technology. He has a B.S. in Chemical Engineering (Clarkson), M.S. in Civil Engineering (UMASS Lowell) and Ph.D. in Chemistry (UMASS Lowell). He is a registered environmental engineer.

Michael Anderson

Michael Davidson is an Assistant Professor in Wentworth's Department of Civil Engineering and Technology. He has a B.S. in civil engineering (URI) and M.S. in civil engineering (URI). He is a registered structural engineer.

Leonard Anderson

Leonard Anderson is an Associate Professor in Wentworth's Department of Civil Engineering and Technology. He has a B.S. in civil engineering (UMASS Amherst), an M.S. in civil engineering (WPI) and a Ph.D. in civil engineering (WPI). He is a certified professional constructor and licensed construction supervisor.