

CEE 2602, Civil Engineering Measurements: A “Hands On” Introduction to the Profession

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Abstract

The paper describes a sophomore-level course developed by the authors to provide an introduction to the civil engineering profession. The course uses a blend on “hands on” field and laboratory work, case histories and projects to provide the students with an overview of the tasks and projects they will encounter in their professional careers.

I. Introduction

Future innovations in civil engineering will spring forth from ideas nurtured by young engineers who have been thoroughly educated in the basics of the profession. A strong and stimulating course designed to introduce first semester sophomore students to the full profession through visual and “hands on” field and laboratory experiences can provide a firm foundation for a vibrant civil engineering curriculum. Without such an introduction, a student pondering the broad range of technical and nontechnical courses in the curriculum may wonder “How does it all fit together?” A student who is well versed in the fundamentals of civil engineering will be in a position to devise creative solutions to complex problems. The Department of Civil and Environmental Engineering at Villanova University attempts to highlight these fundamentals by beginning the curriculum with CEE 2602, Civil Engineering Measurements (*Measurements*), a practical course that includes a series of linked activities designed to provide a full introduction to our interdisciplinary profession.

II. Civil Engineering Curriculum

Measurements began in the 1992-93 academic year as part of a major revision to the 136-credit civil engineering (CE) curriculum. At Villanova, all incoming engineering students share a common freshman year. The CE curriculum is actually the 2nd, 3rd and 4th years of their engineering education. The CE curriculum is designed to ensure that all CE majors will gain a basic knowledge in five disciplines: structural, environmental, geotechnical, water resources, and transportation engineering. *Measurements* serves as an introduction to the program and is

designed to stimulate the students' interest in CE by introducing them to the types of projects and tasks they will encounter during their professional careers. The course is offered in the fall semester of the sophomore year and therefore cannot address problems in structures, hydraulics or engineering geology with great technical rigor, but it does provide an overview of engineering methods by presenting some of the techniques used to model problems. One of the more important objectives of the course is to whet the students' appetites for subsequent courses where similar problems are addressed in far greater detail and sophistication. Students begin to appreciate the creative and innovative nature of engineering practice through exposure to "real world" problems wherein they must justify their choice among many feasible solutions. *Measurements* addresses professional engineering issues by presenting case studies in project management and engineering ethics to stimulate class discussion.

III. Format and Structure

Measurements is a 3-credit course that includes two 50 minute lectures and one three-hour laboratory period per week for 14 weeks. The lecture sessions have a maximum of 30 students while the laboratory sessions have a maximum of 20 students. The course is organized around three major projects of varying duration: a water resources and environmental engineering study of a local stream (8 weeks); the design, construction and testing of a model truss (4 weeks), and a route alignment project (2 weeks). All three projects involve group participation. The students work in teams of four or five on the environmental study and in pairs for both the truss and route alignment projects.

The emphasis on team activities is an important aspect of *Measurements*. It is the first course civil engineering students take together as a group. The projects allow the students to get acquainted with one another in an informal, yet professional setting. (The instructors assign the groups for the environmental study and truss.) The projects prepare the students for team activities in subsequent courses including the senior-year capstone project. The group approach to problem solving also simulates "real world" engineering practice. *Measurements* provides a somewhat controlled environment to begin to address problems associated with group dynamics. Most of the group work is conducted during the laboratory periods and these periods are deemed mandatory with a very heavy penalty for unexcused absences. At the conclusion of the environmental study, all students prepare confidential peer reviews of their teammates. The instructors use these reviews to pair recalcitrants in subsequent projects. In extreme cases, the individuals work alone in subsequent projects.

IV. Group Projects

The first half of *Measurements* is devoted to a water resources and environmental study of Valley Creek, a small tributary of the Schuylkill River, that flows through Valley Forge National Historical Park. The course begins with an outline of the project and a summary of the tasks to be completed. A series of photographic slides taken in previous years helps acquaint the students with their future activities. During the first few weeks, the students are introduced to

the drainage basin through topographic maps, geologic reports, aerial photographs and an initial field trip to the stream. All the technical tasks required in the study are discussed and explained in the lectures. The teams work with equipment such as transits, current meters and water quality testing kits in the laboratory sessions. The eight weeks of preparation culminate in a second, four-hour site visit when the teams gather the data they need for their reports. The work includes preparing topographic surveys, developing cross sections of Valley Creek and its flood plain, measuring water velocity and depth, determining latitude and longitude of their site, evaluating water quality with Hach kits and conducting surveys of aquatic organisms.

The final product from each group is a complete, detailed report which documents the tasks noted above and presents additional work on the geology of the area, stream order, discharge records and runoff computations. The instructors provide guidance on technical writing, report organization, documentation, data presentation, and the importance of report cohesion. The reports are designed to be very practical and reflective of products from engineering firms specializing in these technical fields. In order to emphasize the importance of clear and concise technical writing, each student reviews and critiques a report prepared by his or her peers. The instructors conduct a complete and intensive review of each report and set aside a substantial portion of a laboratory period to discuss the reports with the students. The total project introduces the potential civil engineer to a wide range of technical fields in a cohesive and structured manner such that basic concepts take on a “real world” rather than abstract meaning.

The second project introduces the students to structural design and analysis. The students work in pairs to design, build and test a model truss fabricated from 150 x 19 x 1.6 mm wooden craft sticks which must span a distance of 180 mm. The students must predict the maximum load the truss can support and identify the member where the failure initiates. Each team tests its own model and submits a written report that assesses the performance of the truss and discusses the accuracy of their prediction.

The truss project serves a number of useful purposes. It reinforces many of the concepts the students learn in the statics course. The team can use any truss geometry and pick the joint to be loaded, but they must submit a complete analysis that itemized all the bar forces. The students test craft sticks in the laboratory in order to develop data bases on the compressive and tensile strength of the sticks. In doing so, the students realize the variability of test data and must contend with uncertainty in making their predictions. The compressive strength of the sticks is particularly elusive because of buckling. A discussion of Euler buckling and a demonstration involving wooden dowels of varying lengths and diameters help to quantify buckling.

Most teams design Warren trusses and load their models along the bottom chord. Virtually all the teams underestimate the collapse load of their truss but do correctly predict the member where the failure initiates. The teams see that the response of the truss to the loading involves effects such as torsion and out of plane bending that the students never considered. They begin to appreciate the fact that numerical and physical models have their limitations and the need to

incorporate factors of safety and redundancy in structural design is essential.

The last project involves a highway alignment problem that serves as an introduction to transportation engineering. The project begins with lectures on highway grades, cut and fill, and horizontal curves. During the laboratory session, the students work in pairs and must select a route for a highway between two termini on a 7 ½ minute quadrangle map. All the teams have the same design criteria with respect to maximum grade, maximum cut or fill, and maximum degree of curve. Each team must submit a plan and profile of its route. The documents are not accepted until the instructors ensure that all the design criteria have been met.

V. Accuracy & Precision

One of the more subtle objectives of *Measurements* is to instill in the students an appreciation for accuracy and precision in the acquisition and processing of engineering data. In particular, the course emphasizes the appropriate use of significant figures. In many of the exercises, the students use data from a variety of sources to evaluate the parameters in an equation. For example, the teams must estimate the discharge of Valley Creek with the Manning formula. In doing so, they use their survey data for the cross section, they determine the energy grade line from contours on a quadrangle map, and they estimate the roughness coefficient from photographs of similar streams in reference publications. They learn that their discharge estimate is only as accurate as their least reliable input parameter.

The course also emphasizes the value of verifying conclusions by comparing the results of multiple independent analyses. Teams determine the latitude and longitude of their Valley Creek site by locating the position on a quadrangle map and also by using two Global Positioning System receivers in the field. Teams estimate the discharge of Valley Creek several different ways: cross sectional area and surface velocity, strip method with current meter data, Manning formula, visual reading on the gaging staff at a U.S. Geological Survey (USGS) station and USGS streamflow data at the agency's web site. They compare and contrast the values and discuss any major discrepancies among the discharges.

One of the tasks in the Valley Creek work is to use the Rational Method to estimate the 50-year discharge of Valley Creek. Some groups have the insight to calibrate their 50-year estimate by reviewing the peak flows recorded at the USGS station in its 14 years of operation.

The students learn that even simple independent checks can help the engineer to put estimates in perspective and avoid potentially egregious errors.

VI. Professional Issues

The last two *Measurements* lectures focus on professional issues. They include sessions on engineering ethics and project management. Both of these sessions are based on the actual,

practical experience of the instructors and are designed to provide a basic understanding of the CE profession to the students.

VII. Measurements Challenges

There are several administrative and pedagogical challenges associated with *Measurements*.

* The course requires an intense cooperative effort among faculty members. There are currently four lecture periods and three laboratory periods per week for a total of 13 contact hours. The two instructors must coordinate the course meetings to ensure that all students participate in the same activities.

* The laboratory sessions involve many outdoor activities such as surveying work and field trips. Some sessions require work in the structural testing laboratory or hydraulics laboratory. Scheduling can become a problem, especially in the case of inclement weather.

* There is no single text that covers all the topics in *Measurements* so the instructors must prepare and distribute all the notes and supplemental references.

* The students consume many expendable materials during the semester. These items include books, scales, topographic maps, aerial photographs and chemical supplies. These materials are purchased by the instructors who must collect a course fee from each student.

VIII. Conclusions

Measurements seems to have fulfilled its primary objective of stimulating and motivating sophomore CE students. The course provides a broad-based introduction to the CE profession by examining tasks performed and problems solved by civil engineers. The students participate in three team projects that involve real CE work. These exercises help develop the students' organizational and communication skills and prepare them for subsequent courses.

In building a strong foundation of basic knowledge, *Measurements* strives to foster innovative thinking from new civil engineering students by providing intellectual stimulation through 'hands on' experiences with a cohesive approach designed to address the common question, "How does it all fit together?"

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