Multidisciplinary Research using Nondestructive Evaluation

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Abstract

A major objective of the Junior/Senior Engineering Clinics at Rowan University is to introduce students to open-ended engineering projects. All engineering students from the four engineering disciplines, namely Civil, Chemical, Electrical and Mechanical share a common engineering *clinic* class. The Junior/Senior Engineering Clinics, part of the innovative 8-semester Engineering Clinic sequence, provides the venue for multidisciplinary student teams to engage in semester-long design and development projects. These projects are typically funded by local industry, faculty research grants or departmental budgets. The clinic projects are crucial in developing the design, problem solving and project management skills that are often absent in the traditional engineering coursework. They further reinforce communication skills both oral and written. This paper focuses on the details of successful multidisciplinary research on non-destructive evaluation using engineering undergraduates.

Introduction

Rowan University is a regional state university committed to teaching and community service. The enrolment is approximately 9,000 students. The College of Engineering at Rowan University was initiated in 1996 as a result of a $100 million donation in 1992 from the Rowan Foundation. The engineering faculty use innovative methods of teaching and learning to better prepare students for entry into a rapidly changing and highly competitive marketplace[1-4]. Key program features include: (a) creating inter- and multi-disciplinary experiences through collaborative laboratories and coursework; (b) stressing total quality management (TQM) as the necessary framework for solving complex problems; (c) incorporating state-of-the-art technologies throughout the curricula; (d) and creating continuous opportunities for technical writing and communication. To best meet these objectives, the four engineering programs of Chemical, Civil, Electrical, and Mechanical Engineering have common engineering clinic classes throughout their programs of study, in which undergraduates work in teams on hands-on open-ended projects.

The Engineering Clinics

The purpose of the clinic classes is to provide engineering students with a hands-on, multidisciplinary experience throughout their college education. The freshman clinic focuses on primary principles, measurements, and competitive assessment. In the second semester, student teams take on semester long projects involving reverse engineering and/or engineering process exploration. The sophomore clinic focuses on design taught from the viewpoint of the four engineering disciplines represented at Rowan University: chemical, civil and environmental, electrical & computer, and mechanical. In the second semester, students work in teams on well-defined semester long design projects. The junior and senior clinics emphasize multidisciplinary

design on projects of progressive complexity. Professors work with teams of 3 – 5 students on open-ended design, planning, or research projects[5-6].

The Junior and Senior Clinic are project-based courses. Each provides a venue for multidisciplinary student teams to engage in semester or multi-semester projects. Local industry, faculty research grants, or departmental budgets are expected to provide ideas for and fund the majority of these projects[5-6]. Clearly, projects such as these are central to developing design, problem solving and project management skills that are often lacking in traditional engineering coursework.

At the conclusion of four semesters of Junior and Senior clinic activities, students are expected to:

- Demonstrate expanded knowledge of the general practices and the profession of engineering through immersion in engineering project environments of moderate complexity.
- Demonstrate an ability to work effectively in a multidisciplinary team.
- Demonstrate acquisition of new technology skills through use or development of appropriate computer hardware, software, and/or instrumentation.
- Demonstrate understanding of business and entrepreneurial skills by developing a business plan, market plan, venture plan, or other approved instrument.
- Demonstrate effective use of project and personnel management techniques.
- Be better able to meet customer needs.
- Integrate engineering professionalism and ethics in their work and as it relates to the context of engineering in society.
- Demonstrate improved communication skills including written, oral, and multimedia.
- Utilize information obtained from sources that cross geopolitical and language barriers.

Project Goals

Research funding for developing a nondestructive evaluation (NDE) test procedure (system + algorithm) to characterize defects in concrete sewer pipelines, using ultrasonic inspection was obtained from the Water Environment Research Foundation in April 1999. Drs. Mandayam, Jahan and Cleary formed a dynamic multidisciplinary team for this proposal each lending their individual strengths in three areas closely related to this research namely: NDE, wastewater and reinforced concrete.

This paper focuses on the development of junior/senior engineering clinics for investigating an innovative Nondestructive Evaluation (NDE) method using the ultrasonic technique for investigating the structural integrity of existing concrete sewer pipelines in the wastewater industry. The wastewater industry is approaching a critical juncture where concrete pipeline renovation must be initiated to extend service life. Maintenance of existing sewer collection

systems is a priority for all wastewater treatment plants. While concrete is known for its durability, it is susceptible to a range of environmental degradation factors, which can limit its service life. Therefore there is an imminent need for test methods to measure in-place properties of concrete for quality assurance and for evaluation of existing conditions. Ideally these methods should be nondestructive so that they do not impair the function of the structure and permit retesting at the same locations to evaluate changes in properties with time.

Nondestructive Testing (NDT) for concrete has progressed at a slower pace compared to other materials, because concrete is inherently more difficult to test due to its heterogeneous nature. There are two techniques that are predominant in the nondestructive inspection of concrete infrastructure – ultrasonic inspection and ground penetrating radar. Ultrasonic inspection has long been the mainstay of the industry – it involves propagating acoustic energy inside a medium and observing its interaction with the specimen. The presence of discontinuities (cracks) can be determined by processing the received ultrasonic signal. Operating signal frequencies typically lie in the 50 kHz to 50 MHz range. Ultrasonic methods require the presence of a couplant (usually water) to convey energy from the acoustic source to the specimen under test. Mobile autonomous ultrasonic inspection vehicles have been employed for in-line pipe inspection, especially in the gas pipeline industry. In recent years, microwave techniques using Ground Penetrating Radar (GPR) have made some headway– this is a non-contact method; however, it is expensive and requires very precise sensor-specimen positioning. The principle is similar to the ultrasonic method; microwave signals in the 1 – 50 G Hz range are used.

Student Activities

The NDE junior/senior clinic project was held from the fall of 1999 through the fall of 2000. A team of 4 students (3 from Electrical & Computer engineering and 1 from Civil & Environmental engineering) was chosen to participate in the project. Weekly meetings were organized for planning research and development activity and reporting periodic progress. Students were also required to write a final technical report on their findings and orally present their work to faculty. The students also conducted peer evaluations assessing each other's performance. This helped identify problems in team dynamics and evaluate individual student efforts.

The goal of the clinic project was to develop a nondestructive test procedure (system + algorithm) using the ultrasonic technique that can be used to inspect wastewater concrete pipelines for defects. The specific research objectives were:

- To consistently identify ultrasonic C-scan signatures of degradation inside a concrete specimen immersed inside a fluid medium.
- To develop signal-processing algorithms that isolate defect-related signatures irrespective of variations in the concrete properties and composition of the fluid medium.

The following work plan was established for a successful completion of project objectives and meeting all requirements of the project deliverables:

- Ultrasonic Test-Station Set-up.
- Specimen Preparation.
- Wastewater Preparation.
- Data Acquisition.

- Data Fusion Algorithm Design.
- Verification and Testing.

Project deliverables included:

- Copies of all research results obtained and software developed during the project.
- Quarterly progress reports and final report summarizing findings.
- Recommendations for a complete system design for a field prototype.

Discussion

The discussion covers three topics: The hands-on nature of this clinic, problems coordinating with the funding agency, and effective incorporation of out-of discipline students.

Hands-on

Many Junior and Senior clinic projects result in either the generation of primary data or the construction of some sort of prototype. This project resulted in students assembling an ultrasonic test station, preparing concrete specimens and synthetic wastewater.

Coordinating with funding agency

Whenever possible, clinic projects at Rowan University are to be funded[5]. Not only does that bring in needed money, it also means that projects have interested industrial clients. However, the more "real" the project, the more likely that it has time constraints. Timing is extremely important for externally funded research grants. The Water Environment Research Foundation had stringent deliverable dates for submission of work progress in the form of quarterly reports. The NDE project was successfully completed in the time frames set by the funding agency. The research also led to publication of technical papers[7-8]. Some students from the clinic projects worked on the project as their summer internship. This helped faculty maintain continuity of the project with previously trained students.

Out-of-Discipline Students

A hallmark of the Rowan University Engineering program is the involvement of students in multidisciplinary activities. Thus, students are expected to work on at least one out-of-discipline clinic project during their junior and senior years[5]. This experience can demand extra attention of the project leader (professor). In the NDE project, the out-of-discipline student was from Civil and Environmental Engineering. This student had the opportunity to apply both structural (casting of concrete specimens) and environmental (preparation of synthetic wastewater) skills to the project. It was also possible, to provide this student an opportunity to acquire knowledge on NDE that might prove useful in his/her career.

Conclusions

The four-year clinic program at Rowan University provides engineering students with a number of positive experiences, including: working in teams; participation in multidisciplinary problem solving; and the solution of open-ended problems. The NDE clinic successfully provided all three experiences. Issues concerning project funding and appropriate involvement of out-of-

discipline students were successfully addressed in this clinic. This research activity has also laid the foundation for developing a prototype inspection vehicle that exercises these NDE and signal processing algorithms for in-line inspection of wastewater concrete pipelines.

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