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Bringing Lifeline Research to Vertically Integrated Classrooms via a Four-Point Bending Test of a Pipe

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Life Line Research to Vertically Integrated Classrooms via a Four- Point Bending Test of a Pipe

Abstract

Research dealing with earthquake response of lifelines was brought to classrooms at a predominantly undergraduate urban university as part of an education, outreach, and training activity centered on a simple four-point laboratory-bending test of a ductile iron pipe. A Freshman Civil Engineering Design class, a Junior Structures Laboratory class, and a Graduate Structures class participated by integrating the subject matter amongst these classes. The experiment simply represented the pipeline behavior subject to fault displacement by simple four- point static bending tests. In addition, the ductile iron pipe was analyzed with Nonlinear Finite Element Analysis software to validate experimental results. This simplification is much needed to bring these concepts to undergraduate classrooms. The freshman students were also required to perform a preliminary design of a new water conveyance system, which includes a pipeline that crosses an active earthquake fault. The junior structures laboratory class concentrated on four-point pipe experiments as well as simple structural modeling. The graduate structures students used more sophisticated analysis techniques. Using a pipe experiment as a common theme it was possible to take various applications of the same experiment to different courses.

Introduction

For the design of underground structures and lifelines[1] in seismically active zones, structural performance can be determined by assessing the anticipated ground strains and fault ruptures. In particular, lifelines crossing active faults are vulnerable to breakage as large displacement induces rupture at fault locations. The probability, magnitude, and direction of fault rupture during a major earthquake event are of primary concern, since this can result in pipeline damage or failure. In order to mitigate pipeline damage, water utilities[2] in United States and Japan have introduced designs that will allow pipelines to deform[3] with the ground while maintaining the structural integrity for continuous service after an earthquake.

This paper presents an educational component surrounding simplified laboratory tests conducted to evaluate pipeline behavior subject to fault displacement. The laboratory tests provide stress-strain deformation data for ductile iron steel pipe that were subjected to progressive loading until failure. Laboratory data obtained through these tests will explore the correlation between field installed pipelines and laboratory test cases.

This work addresses the Dee Fink's Taxonomy[4] of significant learning category Integration. An ongoing large scale pipe testing research program was utilized to enhance student learning for three different levels of student groups by jointly working on a lab experiment and then performing analysis at their class level. The pipe experiment was related to the freshman class's preliminary design of a pipeline crossing an earthquake fault. The junior computer aided design students modeled the experiment with simple structural computer simulation and predicted experimental results. The graduate class used more sophisticated finite element models to analyze the experiment. The purpose of the vertical integration of three levels of students at freshman, junior, and graduate was to provide an environment that is similar to a design office practice where staff of varied technical expertise work collaboratively. Another reason is to allow undergraduate students to meet with graduate students so graduate students could act as project mentors. This project was conducted in close contact with several civil engineering practitioners who shared a professional perspective with the students. This integration and exposure to practitioners will help the students in their career planning process as well as later in their professional life.

Classroom Organization

Students from a Freshman Civil Engineering Design course (CE195 – Freshman Design), a Junior Structures Laboratory class (CE 382 – Computer Aided Structural Analysis/Design and Experimentation), and a Graduate Structures class (CE 564 - Numerical Methods in Structural Analysis) participated by vertically integrating the subject matter among these classes.

Following are the highlights of the way the program was implemented:

- Three classes worked on four-point laboratory-bending tests (Figures 1 and 2) of a ductile iron pipe.
- The freshman design course (CE 195) with 50 students (about eight groups of six) addressed a preliminary design of a pipeline network (Figure 3 and 4) that crossed an active fault line. They studied the impact of a rupture of this fault on the pipeline. They participated in the preparation and testing of a four-point pipe bending tests.
- The junior structural laboratory course (CE 382) with eighteen students (about four in a group) analyzed the laboratory pipe test arrangement (Figure 5) using SAP2000 software with the pipe element as a structural element. They also participate in the four-point pipe-bending tests.
- The graduate finite element course (CE 564) students (four groups of four students) used shell elements to analyze the pipe-bending test (Figure 6). They also participated in the four-point pipe-bending tests.
- Graduate research students (four students) used more sophisticated non-linear finite element analysis including material nonlinearity with Nastran program for the pipe experiment (Figures 7 and 8).
- Students at different level classes successfully worked together around a common experimental program thereby vertically integrating classrooms. Lab meetings among the students were orchestrated at experiment preparation site with practitioners present to answer questions. The experiment led to different aspects of course content of pipeline safety issues to three courses.
- Other interested students in the Civil Engineering program were also invited to join the experimental effort.

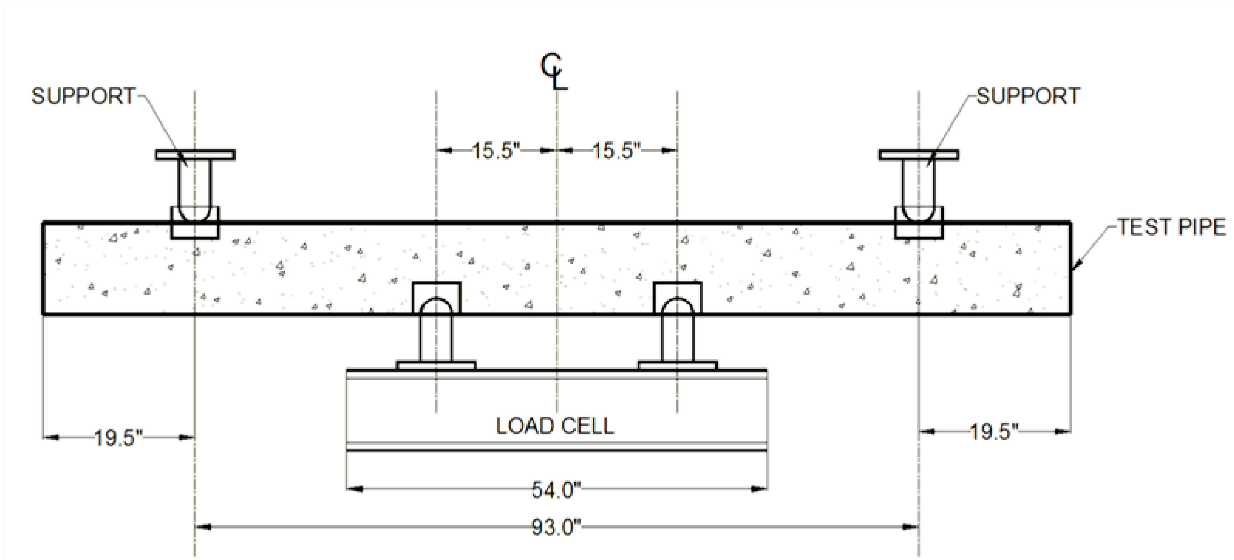


Figure 1 – Details of Experiment Setup


Figure 2 – Four-Point Bending Test of a Pipe

Course Applications

The project was organized to provide the students with an experiment that can involve the participation of students at different levels of engineering discipline. The experiment was also designed to act as a bridge between lab work and computer applications frequently taught in the various engineering classes[5]. The implementation of this experiment required three classes at different levels to weave this experiment within their classroom structure, while allowing time for students at the different levels to interact amongst each other at the experimental program for the purpose of sharing information and knowledge.

In the Freshman Design class, students learned about pipeline alignments and earthquake faults. They also were directly responsible for the preperation of the materials and the experiment set up. Students in the junior level Structural Analysis/Design & Experimentation Lab created a virtual simulaton of the experiment using finite element modeling. Graduate students used more sophisticated analysis to correlate the results of the physical experiment to digital models. Group discussion of the results were encouraged which included practitioners in the field of civil engineering. A sample of the work done by various student groups is included below.

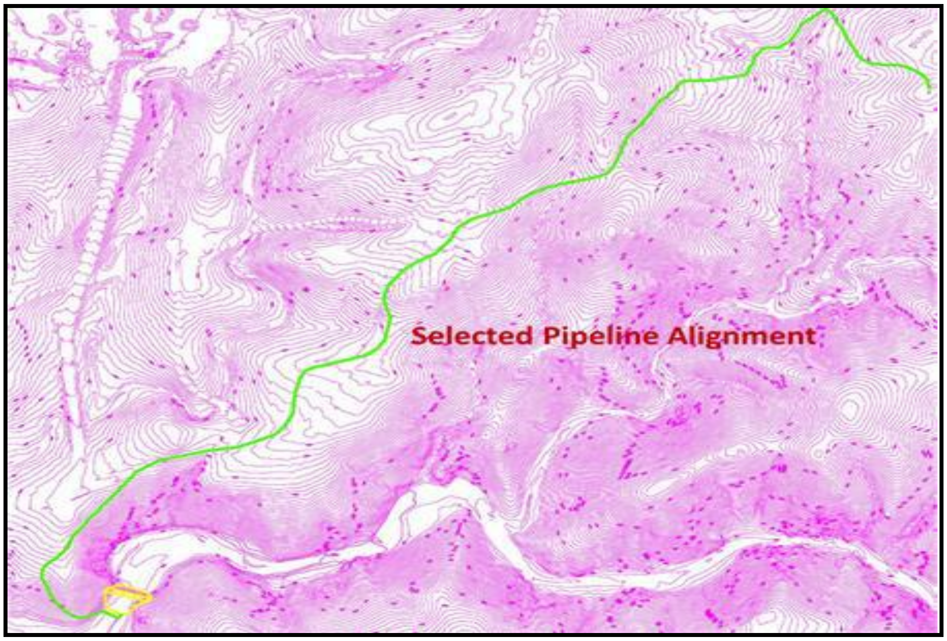


Figure 3: Profile of a pipeline alignment crossing a fault zone
CE 195 – Freshman Level: Civil Engineering Design Course

Figure 3 depicts the preferred pipeline alignment selected among many alternatives considered in the Freshman Design class. Figure 4 is a typical cross section of a buried pipe line developed by students in the same class.

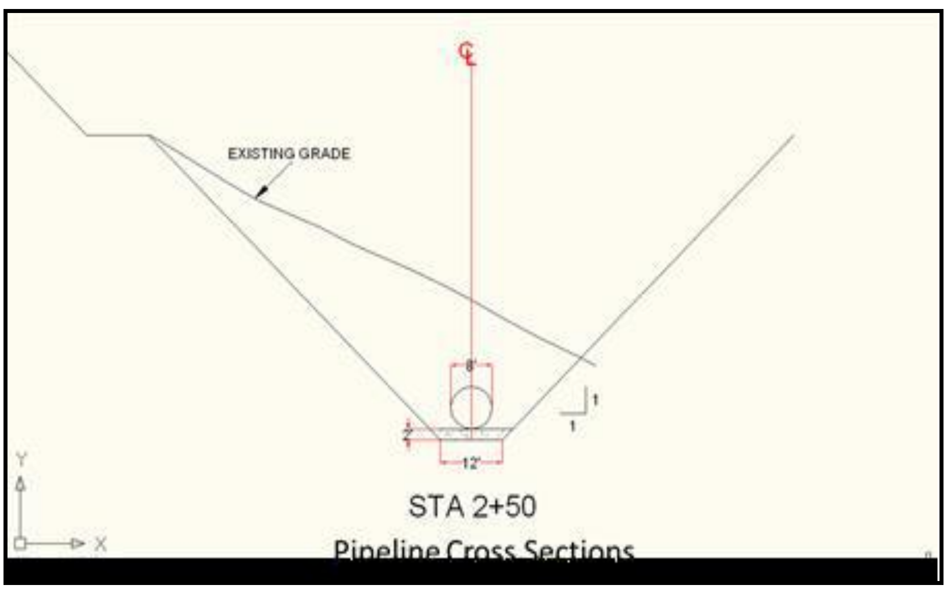


Figure 4: Student developed pipeline cross-section
CE 195 – Freshman Level: Civil Engineering Design Course

Figure 5 depicts a student developed simple computer aided structural simulation model of the experiment in the Junior level Structures lab.

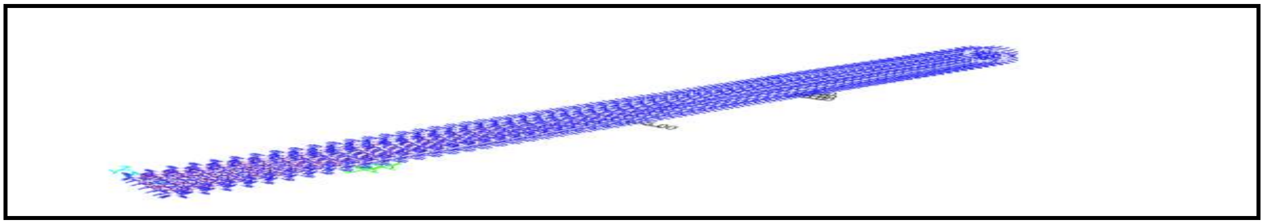


Figure 5 – Loading of Ductile Iron Pipeline Simplified finite element model of the pipe
CE 382 –Junior level: Structural Analysis/Design & Experimentation Lab

Figure 6 is a more detailed 3-dimensional finite element model of the experiment created by the graduate class students. Figure 7 shows the sophisticated nonlinear finite element analysis model created and tested (Figure 8) by graduate research students.

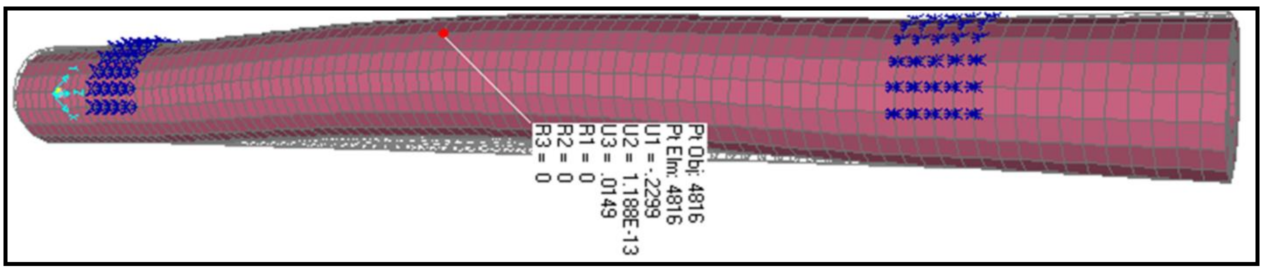


Figure 6 – FEA model with detailed support and load application modeling
CE 564 – Graduate level - Finite Element Analysis Course

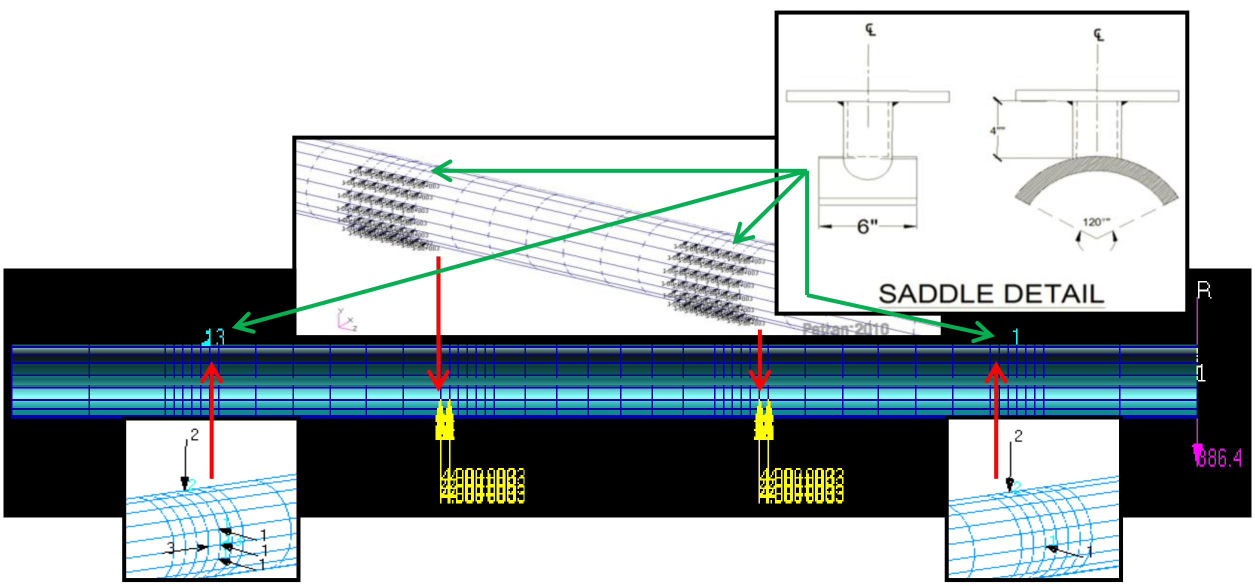


Figure 7 – Nastran Model with Support Conditions and Applied Loads
Graduate level – Non Linear Finite Element Analysis by Research Students

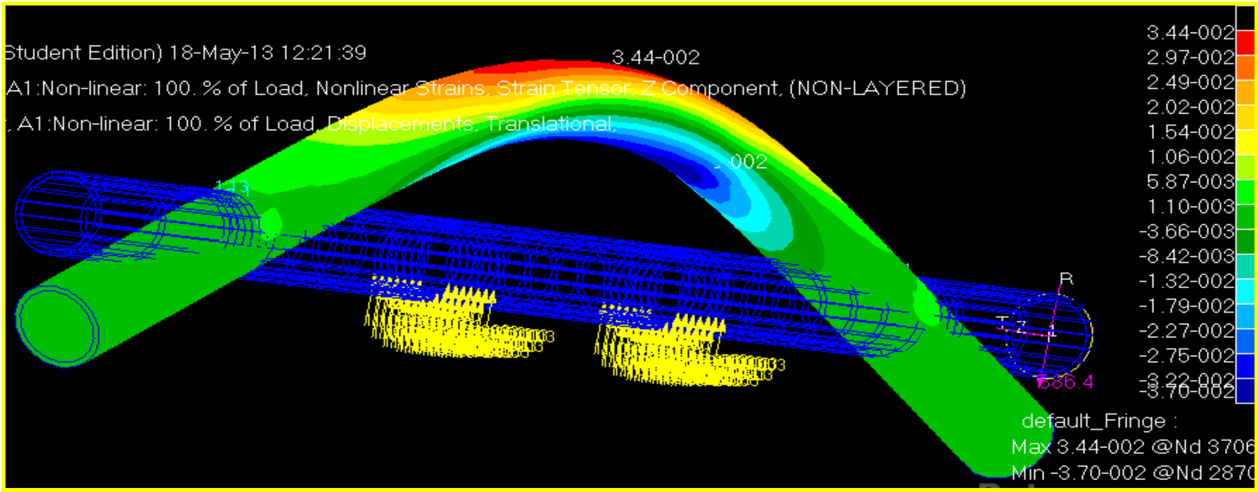


Figure 8 – Strain Contours from Nastran Nonlinear Analysis
Graduate level – Non Linear Finite Element Analysis by Research Students

Figure 9 is a plot of comparison of analytical and experimental results of the pipe experiment.

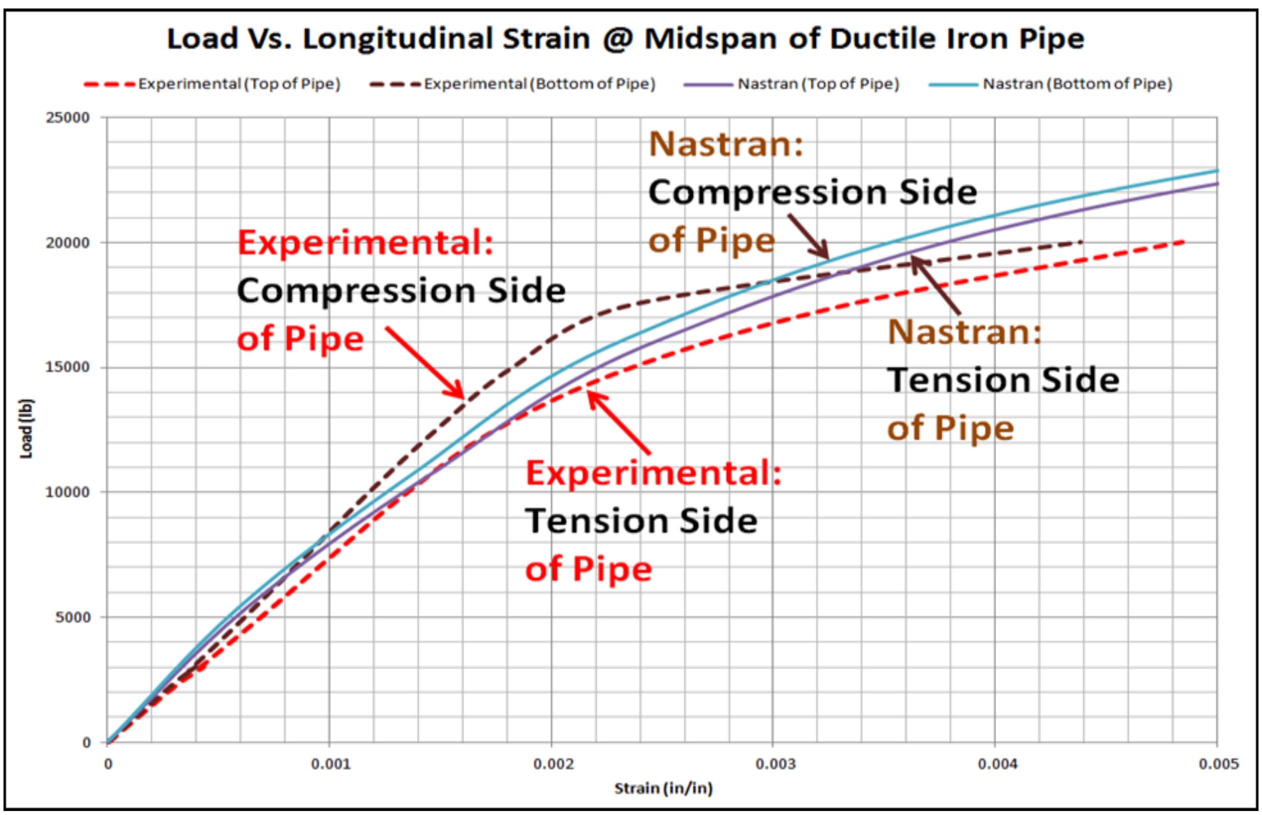


Figure 9 – Experimental vs. Analytical Results of the Lab Experiment
CE 564 – Graduate level, CE 382 –Junior level, and Graduate Research Students

Course Evaluation

Industrial Representatives evaluated the course outcomes, in the areas of knowledge, and skill after listening to oral presentations prepared by the students followed by a question and answer period. At the conclusion of the presentations, they provided scoring in the following areas:

Knowledge Outcomes

- Knowledge of structural simulation program for analysis
- Knowledge of structural simulation program for design
- Ability to perform structural engineering experiments
- Knowledge of engineering principles
- Knowledge of current design specifications
- Knowledge of computer aided structural analysis
- Knowledge of computer aided structural design

Skills Outcomes:

- Ability to identify, formulate and solve structural engineering problems
- Ability to plan and design a component or process that meets desired needs
- Ability to use techniques, skills and modern engineering tools
- Ability to design and conduct experiments as well as to analyze and interpret data
- Ability to validate results of experiments
- Ability to communicate effectively by oral reports

The results of these evaluations by industry representatives are shown below. The ratings are on a four point GPA scale (4 being high and 1 being poor).

i. Junior level CE 382 - Computer Aided Structural Analysis, Design and Experimentation:

Results of evaluation of four student groups by two industrial representatives for thirteen course outcomes are shown below (Figures 10, 11 and 12) on a four-point scale on a four point GPA scale (4 being high and 1 being poor).

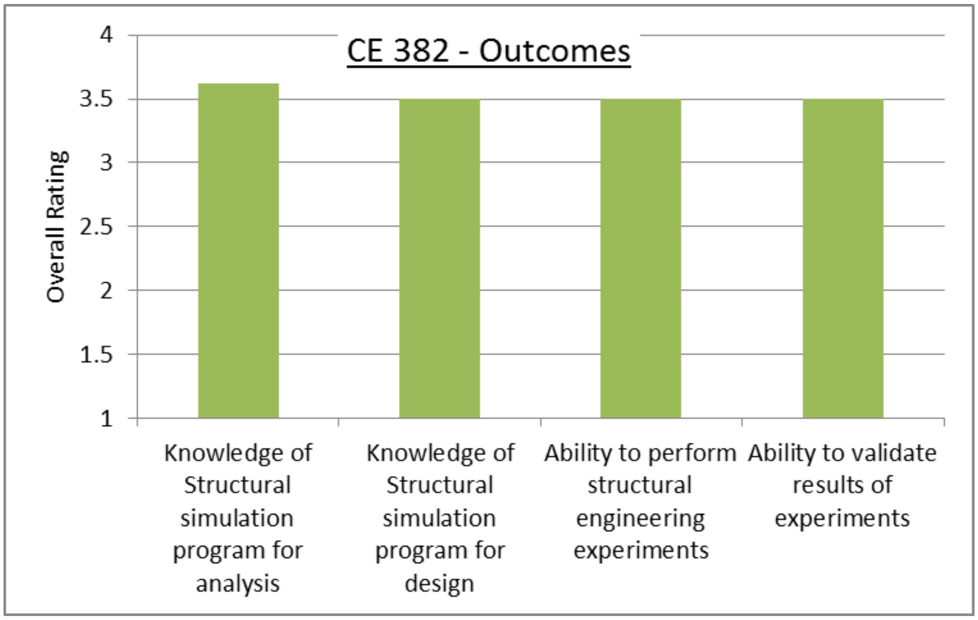


Figure 10: CE 382 –Student presentation assessment results

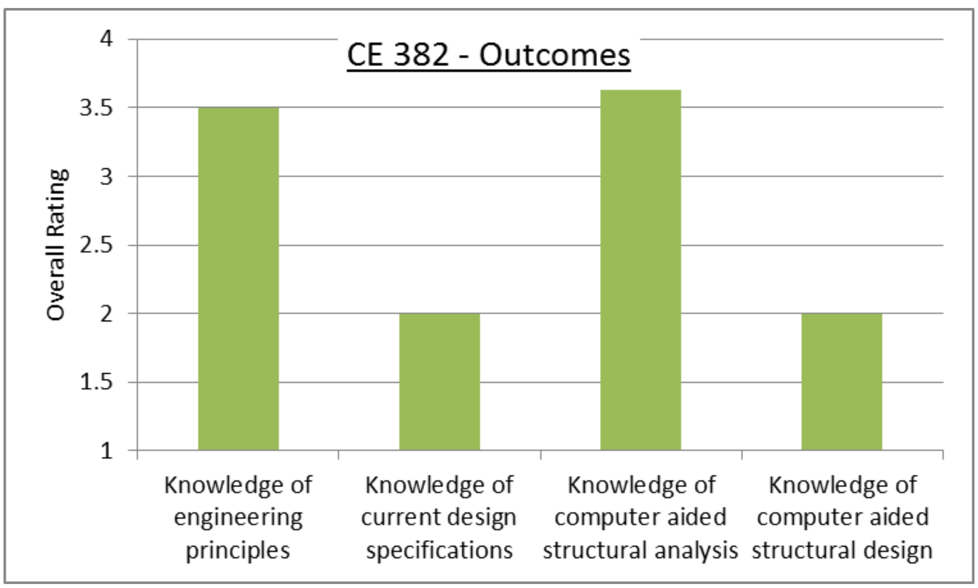


Figure 11: CE 382 –Student presentation assessment results continued

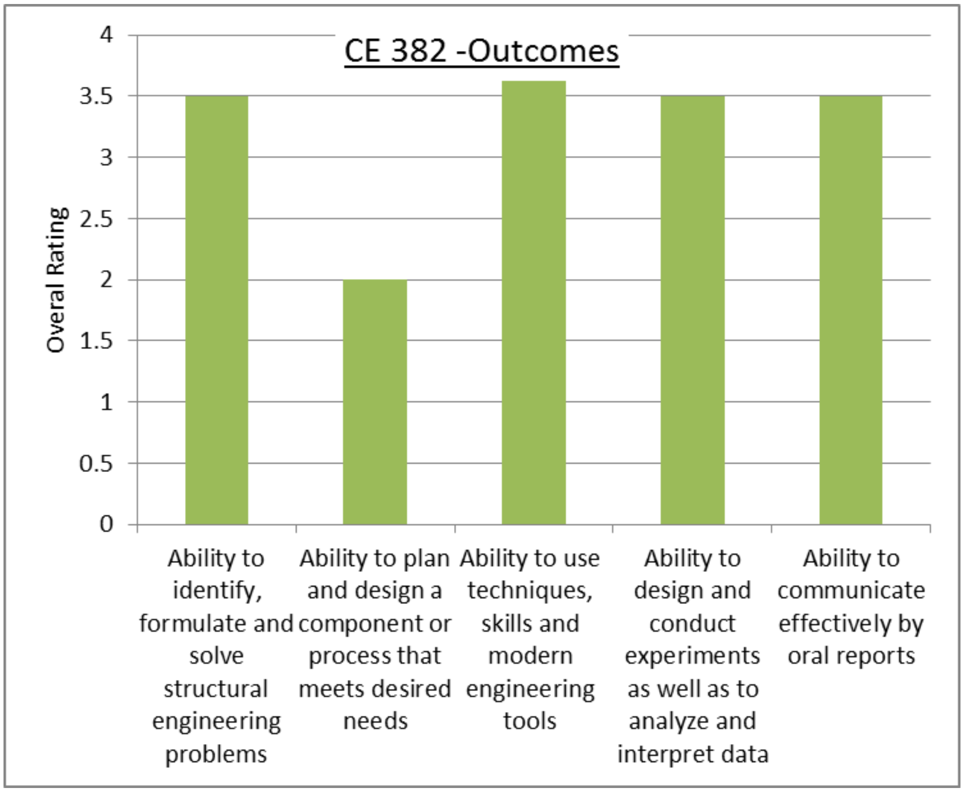


Figure 12: CE 382 –Student presentation assessment results (continued)

It is noted that all outcomes were rated high except for Design Specifications, Computer Aided Structural Design, and the Ability to Plan and Design Components. Both of these are in the areas of Design. The CE 382 course is a one-quarter unit lab, and perhaps not sufficient to bring detailed design issues that a practicing engineer expects. However, this course will prepare students for additional design courses that will allow the said outcomes to be met.

ii. Graduate level CE 564- Numerical Methods in Structural Analysis:

Results of evaluation of student groups by two industrial representatives for thirteen course outcomes are shown below (Figures 13, 14 and 15) on a four-point scale on a four point GPA scale (4 being high and 1 being poor).

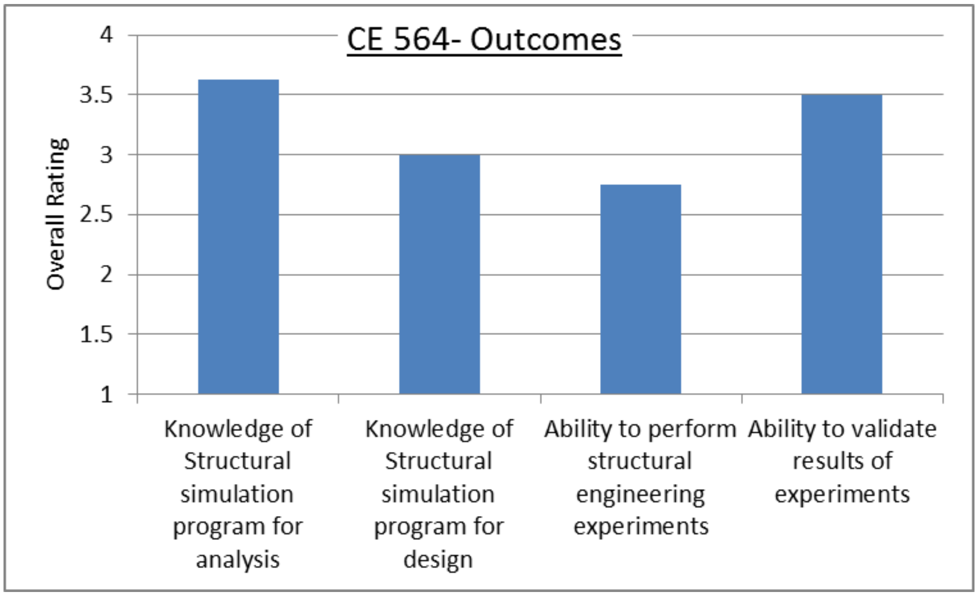


Figure 13: CE 564 - Student presentation assessment results

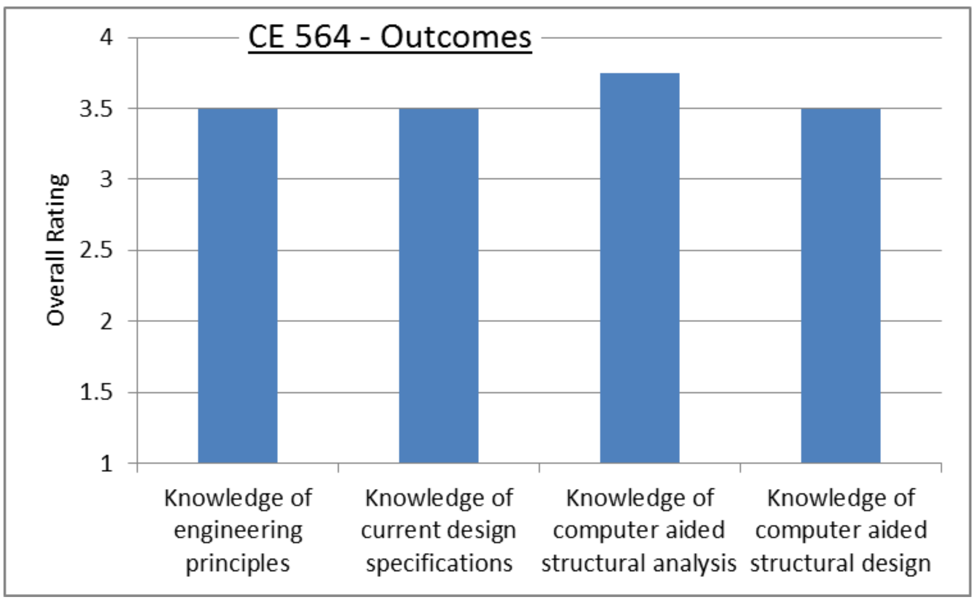


Figure 14: CE 564 - Student Presentation Assessment results

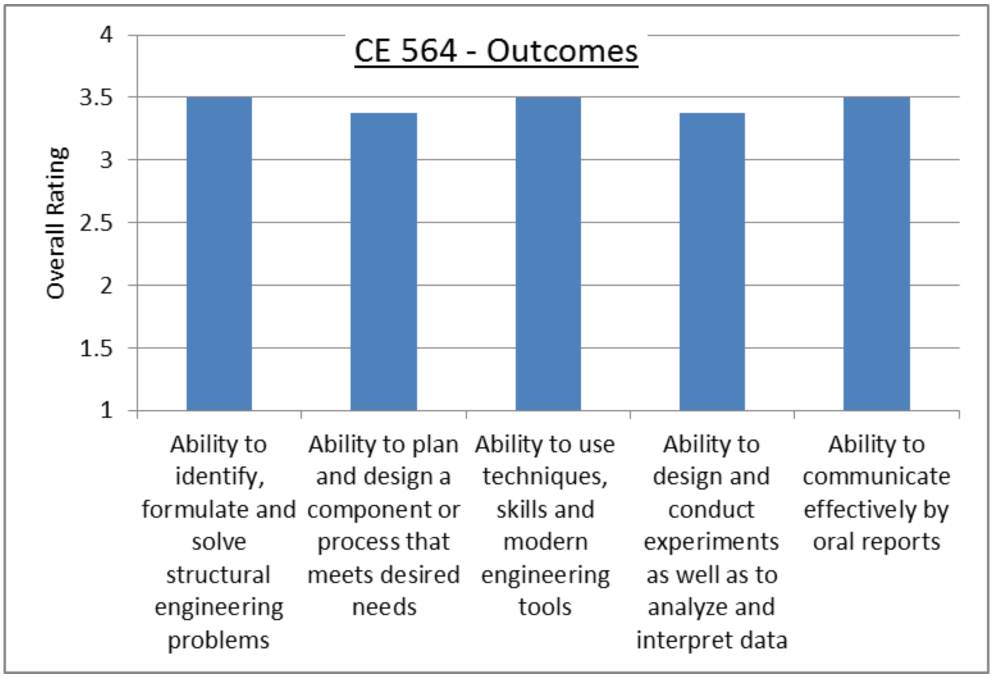


Figure 15: CE 564 - Student Presentation Assessment Results

All outcomes were rated high except for Knowledge of Structural Simulation Programs for Design and Ability to perform structural experiments. The CE 564 course is essentially an analysis course and we have extended the applications of design and validation through experiments as an extension. The students may not be comfortable with this additional extension, even though it justifiably adds value to student learning.

iii. For design and ability to perform structural experiments.

Industrial representatives with Civil Engineering P.E. license were also asked their opionion regarding the interaction amongst the different participants including the practitioners who helped with the experiments. Following is the result of these evaluations shown in Figure 16.

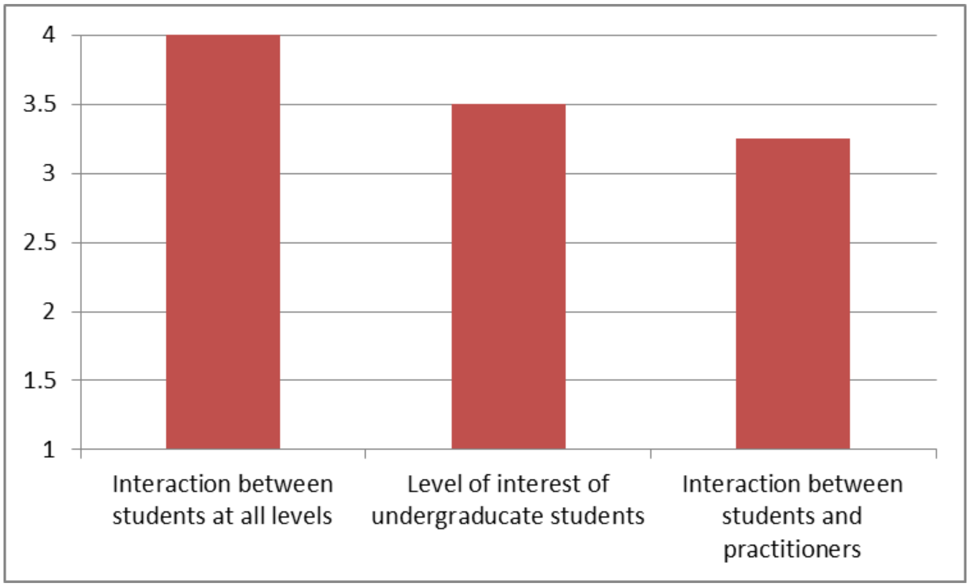
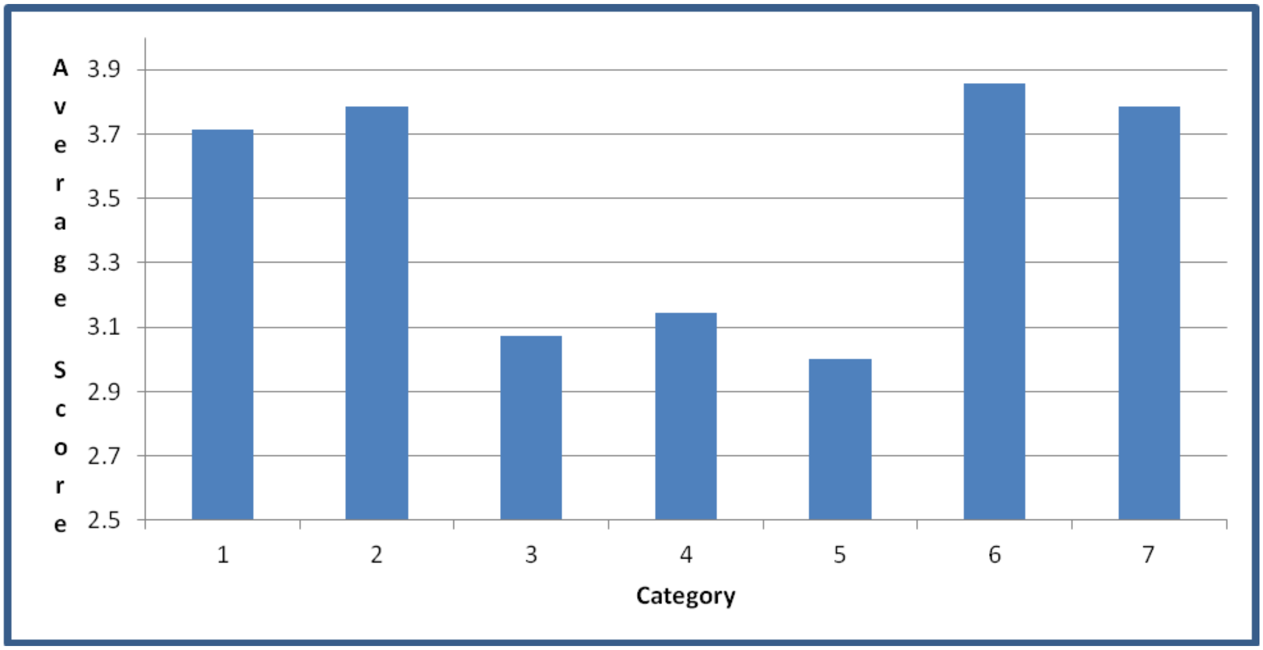


Figure 16: Industrial Representatives' Opinion Survey

The industrial representatives reacted very possitively to the interaction among students, but beleived that the interaction between students and practitioners was not optimal and can be improved.

iv) Freshman class students' perception three years later



Category	Survey Question:
1	How well the incorparation of the pipe experiment help you to think "out of the box" ?
2	How well the pipe experiment, help u to get the big picture about your class project ?
3	How useful were the interaction with the upper class students (such as grad students) in the pipe experiments for you to expand your knowledge?
4	How do you rate the mentorship of the graduate students in the experiment ?
5	Did the interaction of the graduate students in the experiment help you to think of grad school ?
6	How do you rate the mentorship of the industrial representatives in the experiment ?
7	Do you think the industrial representatives provided the "big picture" behind the experiment for applications in professional practice ?

Figure 17: Freshman Class perception three years later

Freshman students were surveyed (fourteen out of the fifty students participating) three years after they completed the course and the results are shown in Figure 17. Four outcomes were rated high, except the three relating to interaction with upper class students and their mentorships. Also it appears from the survey that at the Freshman level students do not think seriously about the graduate school.

Conclusions

The experiment brought research concepts to classrooms at the freshman, junior and graduate levels centered on a simple four-point bending test program of ductile iron pipes. This allowed students at different levels to work on a common theme. The experiment allowed undergraduates students to work with graduate students in an educational environment with common objectives. This gave the undergraduates a valuable resource of mentorship. This vertical integration also encouraged undergraduate students to prepare for professional practice.

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