2006-13: EFFECTIVE USE OF TECHNOLOGY TEACHING STRUCTURAL ANALYSIS AND DESIGN

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POSSIBLE SESSIONS:

- 10. Innovative Curriculum in Engineering Technology
- 1. Curriculum Development in Civil Engineering Tech.
- 20. The Future/Direction of Engineering Technology

Effective use of Technology Teaching Structural Analysis and Design

Abstract

This paper describes the history of successful implementation of technology over the past 10 years in which enrollment in a Structural Analysis and Design Engineering Technology program has increased several-fold. The program has received high marks by external evaluators and at presentations at conferences on engineering technology education. It should be noted that most of the existing testing equipment used in the laboratories was built by students in the program.

The technology described in the paper can be divided into the following groups: Computers used for analysis and data acquisition in structural testing; transducers such as load cells, accelerometers and strain gages used in structural testing; loading apparatus built for structural testing; structural elements including reinforced and prestressed concrete beams and frames; and steel beams and frames. The paper also describes the steps leading to modernization of the program, including transformation of the curriculum, implementation of computer methods, and the addition of realistic laboratory experimentation and report writing.

Success of the program is evidenced by accomplishments of its former students. Graduates of the program are successfully employed in federal and state government agencies, consulting engineering firms, construction companies, utility services, and a few have established their own engineering companies. Many have been successful in passing the Fundamentals of Engineering Exam, the first step toward professional engineering registration in the State of Texas.

Introduction

The Structural Analysis and Design program suffered from low enrollment in the early 1990's due to instructional use of manual methods of structural analysis and lack of hands-on experience in structural testing. In order to increase enrollments, a new program coordinator was asked to join the program. The professor had many years of industrial experience related to the application of modern technology in structural engineering in two distinct aspects: Finite element analysis and structural testing.

As a first step in changing the program, he applied for a Laboratory Improvement Grant from the National Science Foundation and was awarded a grant upon first application. The NSF grant was funded and focused on effective application of modern technology using computers and testing equipment to teach structural analysis and design. Two additional faculty members with

many years of industrial and research experience also joined the department in the late 1990's and early 2000's.

The Teaching Philosophy of the Department is focused on the idea that the best learning method of engineering technology is "hands-on". In this way, the laboratories were conceived as part of the teaching activities. The intensive use of computers models, designed by the Faculty or obtained from industry, are used as complements of the experimental tests and of the theory covered in class.

Laboratory Equipment

The equipment of the Structural Analysis and Design laboratories is used to perform experiments with different setups, according to the problem to be studied. The equipment consists principally of jacks, electronic and mechanical dial gages, data acquisition, load cells with different applications, devices for soil mechanic tests, electronic thermometers, and reaction frames.

The Department decided to purchase industrial jacks, as shown in Figure 1, instead of those available for academic use. The advantages of the industrial equipment are their versatility for different setups, a broad range of load capacity, and economy. Other important decision is the manufacture of the reaction frames by in-house students and tailored to the specific required setup. In this way, two reaction frames to test cylinders and a reaction frame to test small beams were made by students of the Department. Also, the structure of the building is used as a reaction frame to test medium size beams and frames.



Figure 1. Different Type of Jacks Used: Hollow for Postensioning, High Capacity Low-Running, and 5-in Running

Equipment for the Laboratory of Soil Mechanics is the standard used by the industry in order to provide experience in an industrial environment. The exception is that the equipment used in the unconfined compression test, uses a frame built by students, an industrial jack, a load-cell to read the acting force, and a dial gage to measure the deformation, as shown in Figure 2. This laboratory is used by soil mechanics and foundation design classes, during tests for soil grain

distribution, Atterberg limits, soil classification, weight-volume relationships, permeability, shear strength, and compressibility. The students gain valuable experiences using different type of soils, industrial equipment, and writing of the report. The calculations to obtain results are done using spreadsheets prepared for the experiments and provided in the textbook⁽¹⁾.



Figure 2. Unconfined Compression Test in Soil Mechanics

In the Modern Concrete Technology lab, the main equipment are the jacks with useful ability to apply forces of the order of 150-kips. The frame was designed to house a concrete cylinder of 3 in. by 6 in. and to permit the loading for compression and splitting tests, as shown in Figure 3.



Figure 3 Compression and Splitting Test

Engineering Software

In the of Structural Analysis and Design courses, the software used may be commercial or inhouse (developed by the faculty and students during class). The advantage of the in-house software is the flexibility to adapt to different experimental and teaching needs.

Students of Engineering Technology have programming experience obtained in their freshman year. In the Freshman-year course, the students learn computer languages widely used in engineering, such as Excel and Visual Basic. The advantage of teaching the course by the department is that students can visualize and apply the computer in real engineering applications, developing two projects during the semester. One of them is selected by the professor and the other one is proposed by the student according to his/her interest and experience. This approach requires an extra effort by the faculty because the students generally select a project from other courses or work experience, often requiring instructor support to develop the program.

During the sophomore year, a course in analysis of engineering networks is required. This class emphasizes the application of linear algebra and computer methods for the solution of piping, electrical, or structural networks. Therefore, the students have a global idea of the application of the computer technology in the solution of different problems of engineering.

In the analysis and design courses, students are required to develop or use existing commercial software. For instance, in the class Structural Analysis, students learn the matrix analysis approach to analyze structures, complementing their learning with software developed by the faculty that follows a step by step formation of local matrices, the global matrix, the solution for displacements, and the computation of internal forces in the structural elements. Finally, students are exposed to finite elements commercial software in order to be familiarized with the tools used in the industry.

Spreadsheets are constantly designed, or used, by students in Design courses to make calculations, as occurs in the classes of Modern Concrete Technology, Steel Design, Reinforced Concrete Design, Pretensioned Concrete Design, and Foundations. The spreadsheet is formatted according to the engineering practice, and different features of Excel and Visual Basic for Applications are used, such as automatic selection, subroutines in Visual Basic to perform calculations with conditionals, elaboration of sketches, goal-seek, etc. Typical spreadsheets are shown in Figures 4 and 5. Commercial software also is introduced to students, principally programs able to design and verify the design of steel or concrete structures.

Another successful use of technology is the incorporation of an online assistant in the design classes. The University of Houston Downtown is using the WebCT² software to help professors and students. WebCT permits the dissemination of information to the students; principally displaying the partial results of laboratories, software and lecture notes. WebCT is also able to offer quizzes in multiple choice formats, discussions about specific topics, and deliver reports using e-mail which is also part of WebCT.

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BENDING AND SHEAR CAPACITY OF w14x90

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Figure 4. Spreadsheet Used to Teach Steel Design at UHD

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Figure 5. Spreadsheet Developed to Teach Reinforced Concrete Design at UHD

Incorporation of Laboratories in Design Courses

The Design Courses consist of: Foundation Design, Steel Design, Senior Steel Design, Reinforced Concrete Design, Pretensioned Concrete Design, Senior Concrete Design, and Structural Dynamics and Control. Eventually, according to the interest of the students, other subjects are studied under the umbrella of the Directed Study course; this is the case for Bridge Design, Hydraulics, or any other topic.

Throughout these years, some original experiments were developed by the students during the Design Courses, and these projects are currently used to help the learning process.

For example, during one session of Senior Steel Design, a slender beam was constructed to show the elastic lateral buckling of slender beams. Students use the theoretical equations to compute the load that produces lateral buckling and thus, compare the theoretical results with the results obtained during the experiment. Figure 6 shows the slender steel beam during lateral buckling.



Figure 6. Lateral Buckling of a Slender Beam Constructed by Former Students

A two-span beam was designed and constructed during a session of Senior Concrete Design. This beam is currently used during the course Pretensioned Concrete Design to show the effect of the postensioning on the deflections of a continuous beam. The 3 in. by 6 in. beam has a 3/8 in. cable inside, with a shape conforming to 3-parabolic curves in each span, in order to apply an upward force at the center of the span and downward forces over the center support. Figure 7 show this two-span postensioned beam.

Students of Pretensioned Concrete Design also constructed a simple supported post-tensioned beam, which was tested under ultimate loads, as shown in Figure 8. This combination of theory and laboratory practice facilitates understanding of the behavior of a post-tensioned beam, the effect of the cable, and the ductility of the beam under ultimate loads.



Figure 7. Two-span postensioning beam used for Prestressed Concrete Design



Figure 8. Postensioned T-Beam Under Loading Test.

In Reinforced Concrete Design, the classical theory to design beams and columns is covered, but in addition to that, students complement their study constructing and testing a simple supported beam, as shown in Figure 9. Different beams were constructed helping to understand the theory. Furthermore, it is important for students to understand the assumptions used by the theory and its implication on the real behavior of the beam. Thus, students need to interpret the results using commercial computer software available or a spreadsheet prepared by the professor. Software using Finite Elements is also useful to explain actual beam behavior.



Figure 9. Construction of the Reinforced Concrete T-Beam

During the Structural Dynamics class, students were exposed to the use of electronic sensors to acquire data related to deflections, accelerations and strains of a steel frame, concrete beams, and a pedestrian bridge. The strain gage reading is used to find the elastic properties of the material using a static test, as shown in Figure 10. The data acquisition is performed using different software, such as LabView or software used by the oscilloscope or strain gage reader equipment.



Figure 10. Static Test of the Frame Showing the Strain Gage and Strain Gage Meter

In Structural Dynamics the students learn the theoretical methods to find the natural frequencies of a structure using Finite Elements methods. In the laboratory, thanks to a device designed by the faculty combining a signal processor and an electromagnetic field, students have the opportunity to find the natural frequencies using resonance. Another method, utilizing Fast Fourier Transformations is shown in Figure 11. The structure is excited the using a tap and the acceleration is recorded during free vibration of the structure. The first and second natural frequencies are found using this non-destructive method. Finally, the students compare the experimental and the theoretical results obtained using a Finite Element model.



Figure 11. Accelerometer and Oscilloscope Used to Find Natural Frequencies of Structures

After completing the experiments, the students need to prepare and submit a technical report. This report follows the scheme of a typical paper, and students use the necessary software, such as a word processor, spreadsheets, CAD software, and the interaction between them. Coordination with English professors is encouraged in order to produce good written reports.

Assessment of Program Success

Program enrollment increased several fold while receiving high marks by external evaluators and also by presentations at conferences on engineering technology education. The Structural Analysis and Design program was in decline before these changes. The enrollment was very low, and the classes were focused on preparation of drafters instead of developing well-prepared Engineering Technology graduates.

The department chair conducts a detailed exit interview with each one of the graduates after completion of all requirements for graduation. The results of the interviews are evaluated and used to change curriculum, to acquire new equipment, and to get feedback on the overall satisfaction of students with the programs. Graduates of the Structural Analysis and Design

Engineering Technology program uniformly praise the hands-on educational approach and describe their lab experience as an important factor in maintaining their interest in the program.

The program coordinator and department chair keep close contact with the graduates to find how soon after graduation they receive employment offers. It is important to observe that 90% of the students in the department already work in activities related to their field of study. Many become employed through networking with classmates. Faculties keep close contact with industry and orient new students in the direction of programs with good employment opportunities. This activity is critical because of current outsourcing of technological employment to other countries.

At the end of each course, a survey is conducted to evaluate the satisfaction of students with faculty performance and course content. The results are used for faculty promotion and for curriculum and physical facilities improvements.

The Structural Analysis and Design program is accredited by Technology Accreditation Commission of the Accreditation Board for Engineering and Technology (TAC-ABET). Engineering Technology students are allowed to take the Fundamental Engineering (FE) examination as the first step to become a Professional Engineer in Texas. The Department encourages students to apply for the FE exam and offers a tutoring class, free of charge, for interested students.

Conclusions

The Structural Analysis and Design program offers a modern and effective method of teaching engineering technology courses, reflecting current wishes of engineering and construction firms. Moreover, it combines theory, computer software, and laboratory work to maximize student understanding of theory and integrate theory with real-life practical applications. This approach increases enrollment in the program, reinforces the understanding of engineering principles, and improves job opportunities for the graduates.

Employers are highly satisfied with program graduates, many of which are already employed in related industries. In fact, important program strengths are the valuable contribution of such students to class discussion and students' description of real life engineering technology problems and their relationship to text and class material.

In order for practice-oriented programs to be successful, faculty require ample industrial experience to be able to successfully integrate practical knowledge with theory. Program success is determined, in large part, by the ability of faculty to continuously bring relevant real-life technology experiences into the classroom, and thus motivate students to become interested and excited about their studies.

References

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