INTEGRATION OF DESIGN IN CIVIL ENGINEERING CURRICULUM

Michel Ghosn

Department of Civil Engineering
The City College of New York
The City University of New York
New York, NY 10031
USA

ABSTRACT - *Over the last few years a concerted effort has been placed in the Civil Engineering (CE) Department of The City College of New York (CCNY) to introduce engineering design throughout the CE curriculum. Two entry level courses were developed to familiarize first year students with concepts of design in the various engineering disciplines including Civil Engineering. In addition, second year courses in Statics and Strength of Materials follow up on this introduction by including "design" type assignments in these traditional "analysis" courses. This paper focuses on the experience of the author in integrating design in the two courses: "Freshman Design" and "Mechanics of Deformable Bodies" that he helped develop.*

DESIGN FOR ENGINEERING FRESHMEN

The first year of a traditional Civil Engineering curriculum consists of courses in the basic sciences (mathematics, physics and chemistry) and a set of liberal art courses (English composition and humanities) with practically no engineering courses. This type of curriculum may often lead freshmen to loose interest in engineering as many students are unable to see the link between the courses they are taking and their stated career goals. To help alleviate this problem, many first-year curricula have included Freshmen seminar courses that often consist of featured speakers and slide and video shows describing the great achievements of well-known engineers and grandiose engineering projects. The approach taken at CCNY consists of developing a sequence of two "Freshmen Design" courses giving students a hands-on experience in engineering design. These courses include modules in various engineering disciplines requiring students to develop expertise in a particular subject matter and apply this expertise to "solve" a simplified engineering problem.

In the Spring of 1996, a module on structural engineering was developed and implemented as part of the course ENGR 101- Freshman Design. The objectives of the module were set as follows:

1. Introduce students to the basic concepts of structural analysis and the behavior of engineering materials.
2. Demonstrate the significance of math and science to civil engineering practice.
3. Stress the relevance of understanding the physical phenomena associated with a given engineering problem in order to find an appropriate solution.
4. Show the importance of computers as tools to be extensively and intelligently used to complement the engineer's analytical skills and judgment.
5. Emphasize the multi-disciplinary nature of civil engineering.
6. Describe the interaction between economy and safety in engineering decision making.
7. Illustrate how engineering design is an open-ended iterative process.
8. Help students develop good writing and oral communication skills.

The module developed to meet the above-stated objectives consists of a seven-week sequence of simple experimental and computer investigations that illustrate fundamental concepts of the behavior of engineering materials and structures. The experimental investigations were designed to use everyday material (wooden planks, rubber tubes, plastic rulers, steel wires) and measuring devices (rulers, kitchen scales). The investigations culminated in a design project and the construction of a model of a truss bridge. Specifically the module covers the following topics:

1. Behavior of Materials. The behavior of materials in tension, compression and bending is illustrated through simple experiments on rubber tubes, plastic columns and wooden beams. For example, students are required to measure the elongation due to the application of known weights at the end of rubber tubes of different lengths and thicknesses. By dividing the weights by the cross sectional area and dividing the elongation by the original length, the students can draw a stress-strain diagram and notice how the area and the tube's lengths are not important to describe the behavior of the material. Pushing rulers of different lengths against a kitchen scale, the students observe the effect of column length on the buckling load. The importance of the cross sectional shape (moment of inertia) on the bending stiffness is studied by bending the same wooden plank around its different axes. Fatigue failure is introduced through a simple experiment with paper clips.

2. Equilibrium of Bodies. The concept of equilibrium of bodies is introduced through experiments illustrating the calculation of reactions, effects of moments, and calculating the forces in tension members. For example, a weight is placed at different points of a wooden plank supported on its ends by kitchen scales. The students observe how by moving the weight to different positions on the beam, the readings (reactions) on the end scales change although the sum remains constant. The effect of the moment arm on bending is illustrated by requiring the students to balance a wooden plank supported at one point by placing one weight on one side of the support and finding the position where three or more weights need to be placed to keep the balance. The analysis of trusses (and joint equilibrium) is introduced by pulling a weight with two wires and observing how the force carried in each wire changes as the angle of inclination of the wire changes

3. Structural Analysis. A simple exercise illustrates how to calculate forces in truss members using the joint equilibrium approach. This exercise builds on the physical intuition that the students gain from the experiment with the equilibrium of a weight pulled by two wires as described above. The concept of structural safety and the use of safety factors are also introduced.

4. Computer Usage. The use of a commercial computer package for structural analysis is demonstrated and the steps required to perform a structural engineering design using the computer package are introduced. As a first step, the students are required to perform the analysis of a simple structure and check the computer results by verifying the accuracy of the reactions obtained. The output data from the structural analysis are entered into a spread-sheet data file for subsequent processing.

5. Design Process. The students perform the analysis of a truss bridge subjected to truck loads. Based on the results of the structural analysis the students choose appropriate truss member sizes to satisfy pre-set safety criteria. Re-analyses may be required until all the safety criteria are satisfied.

6. Engineering Decision. The importance of economics in engineering design is illustrated by requiring the students to compare the costs of materials for their different design options.

7. Constructibility and Testing. The module requires the students to build a model of the bridge they design. The bridge is then tested to failure and the students observe the different possible failure mechanisms. Simultaneously, this exercise illustrates the importance of quality control and careful detailing on structural safety.

8. Engineering Communications. The module is concluded by requiring the students to submit an engineering report and an oral presentation describing their final design and the design process they followed.

DESIGN FOR CIVIL ENGINEERING SOPHOMORES

To build on the experience that the students acquire during their freshman year, subsequent courses have also incorporated concepts of design at early stages of the CE curriculum. For example, elements of learning-by-design have been introduced into the course CE 332 - Mechanics of Deformable Bodies. This course is designed to teach undergraduate students of the Civil Engineering Department the basics of mechanics and strength of materials. The author who has been teaching this course for the last three years realized that most of the objectives set for the structural module described above could be addressed in Mechanics of Deformable Bodies with very minor modifications to the original course content. Hence, with these objectives in mind, the course has been modified to include the following topics:

1. Testing of Material. Experimental investigations of the behavior of structural materials (primarily steel) are introduced. Simple laboratory experiments are performed on bars in uniaxial tension and compression, beams in bending, cylindrical shafts in torsion, and steel bars under critical buckling. The students use the data obtained to draw stress-strain diagrams and compare the experimental results to those predicted analytically from the theories developed in the classroom.

2. Computer Usage. Computer usage takes several aspects in this course. For example, students are required to write their own programs to analyze simple beams (to find the moment distribution due to a given loading) and to calculate structural member properties (such as finding the moments of inertia of composite sections). The results of the laboratory experiments are processed and plotted using spreadsheet packages. In addition, the students are required to use a structural analysis package to verify the results they obtain for a set of problems using analytical calculations.

3. Design Process. The students are required to use the results of their experimental observations along with the computer programs they develop and the packages available to them to perform the preliminary design of a simple span composite steel-concrete bridge. The bridge design must satisfy the specifications set by the American Association of State Highway and Transportation Officials (AASHTO). This exercise is believed to be the first major experience that CE students have in combining several concepts developed in the classroom to solve a realistic engineering problem.

4. Engineering Communications. The students are required to summarize the findings from their laboratory experiments using formal engineering reports. Also, they must describe the process they followed in their design project in a complete report.

CONCLUSION

The Department of Civil Engineering at the City College of New York is strongly committed to the integration of engineering design throughout the CE curriculum. This commitment is demonstrated by: a) Developing design courses for engineering freshmen; b) requiring CE students to complete design projects in their sophomore level coursework (statics and strength of materials); c) and by introducing design assignments in courses traditionally classified as "analysis" courses (structural analysis and dynamics). The experience gained in recent years showed that the addition of at least one simple but meaningful design experience in every CE course does not lead to the "weakening" of the analytical and engineering science part of the curriculum. On the contrary, experience has shown that the introduction of design assignments resulted in a better appreciation by the students of the importance of the analytical tools that they are required to master.