

A CURRICULUM MODEL FOR PREPARING CET GRADUATES FOR POSITIONS IN STRUCTURAL DESIGN

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Abstract

This paper presents a curriculum model for preparing Civil-Engineering Technology (CET) baccalaureate degree graduates for positions in structural design. The evolution of this model was dictated in large measure by the nature of design positions that are available to civil engineering technology graduates in Virginia, and to the nature of the student that we are currently educating.

The paper discusses the changes in the curriculum that have been made necessary by the change in the student makeup coming from the traditional on-campus program and from the distance learning program known as TELETECHNET. The typical student has changed from being a full-time, recently graduated from high school or community college transfer, to being a part-time, full-time working adult. The nature of his work is often as technician, draftsman, or even junior engineer at an engineering design firm.

The authors' philosophy on the necessity for integrating the use of computers and software in the teaching of design and analysis is presented. An equally strong insistence is placed on the teaching of appropriate methods to check and verify the correctness of computer results.

An overview is provided of the content of the structural courses in the CET program at Old Dominion University, so as to give substance to the curriculum model.

Introduction – The Structural Design and Construction Management Emphasis

The Civil Engineering Technology (CET) Program at Old Dominion University (ODU) has a choice of three elective tracks that may be selected by a student in his junior and senior years. They are the general CET emphasis, the structural design and construction management emphasis, and the surveying and site development emphasis. Within the structural design and construction management emphasis, the structural courses are shown below:

Structural Courses

- Structural Analysis
- Computer Applications in Structural Design
- Reinforced Concrete Design
- Structural Steel Design
- Reinforced Masonry and Wood Design
- Building Structures Design Laboratory

This paper describes the curriculum characteristics of the structural portion of the structural design and construction management emphasis, referred to hereafter as the “SD/CM” emphasis. One of the principal positions of the graduates of this emphasis is that of structural designer. In this paper, the term, “structural designer”, refers to a college-educated civil engineering technologist working in an applied engineering design position in the structural field. A structural designer has, quite often, become qualified as an engineer-in-training, but has not yet passed the Principles and Practices of Engineering Exam. Thus it is incorrect to refer to that person as a licensed Professional Engineer or a licensed Structural Engineer.

The authors of this paper teach the courses in the SD/CM emphasis. While they have practical backgrounds in the design of a broad and diverse range of structures, their principal structural design backgrounds are in the design of low- to moderately-high high-rise buildings. Thus, based on the needs identified by input from advisory committee members, former graduates, and employers of graduates (primarily consulting engineering firms), the primary focus in the SD/CM emphasis is on the design of building structures, i.e., the structural and foundation systems of buildings.

Career Goals of CET Students in the Structural Design Curriculum

Historically, the students entering the CET Program at ODU since its inception in the middle 1970’s have indicated that their terminal goal is to obtain the Bachelor of Science in Engineering Technology (BSET) degree for use in applied positions in the field. Thus, the primary focus for the CET faculty is to prepare the CET graduates for “practice”, and not for graduate study and research.

In order to assist CET (and other engineering technology) students in realizing their long-range career goals as “applied” engineers, the Commonwealth of Virginia, along with many other states, has provided a professional track for civil engineering technology graduates to become licensed Professional Engineers. In Virginia, CET (and ET) students may apply to take the Fundamentals of Engineering (FE) examination as seniors. After graduation, those who pass this examination are allowed to take the Principles and Practices of Engineering (PPE) Examination once they have acquired six years of acceptable civil engineering experience. A number of CET graduates have acquired the requisite experience, have taken and passed the PPE examination, and have become licensed Professional Engineers.

Profiles of CET Students in the Structural Design Curriculum

Until the fall of 1994, all of the CET students were “on-campus” students. Of these, approximately fifty percent (50%) started as freshmen at ODU, taking their mathematics and basic mechanics courses here. The other fifty percent (50%) of the CET students transferred at the junior level, many with Associate Degrees in Civil Engineering Technology or Architectural Design and Drafting Technology, with most of their mathematics and all of their mechanics taken at the community college. Soon into their junior years, the typical CET student has taken moderately rigorous mathematics courses through an introduction to differential equations. Thus, they are capable of understanding and working with mathematics concepts at a high level.

In the fall of 1994, the CET program began its involvement with TELETECHNET (TTN), the distance learning outreach of ODU. TTN addresses the needs of Virginians around the state who want a bachelor's degree (or maybe just a series of higher education courses) without leaving their home area or place of employment. In this initiative, students with associate's degrees around the Commonwealth of Virginia can register and get credit for courses at ODU while attending these classes through televised instruction at their local community college. The courses are broadcast from the ODU campus in Norfolk, and are transmitted to remote community college sites at 26 Virginia locations and a few other states via telecommunication and satellite technology. Since TTN, the combined total number of CET students in the typical structural analysis and design course has increased from 25 to about 80.

The TTN students in the structural curriculum generally are non-traditional (part-time) CET students. They usually are older (from 27 to 50), and are more mature (with family responsibilities). Many are already performing entry-level structural design work for architectural /engineering, civil engineering, or structural engineering firms. The TTN students (and most on-campus students) are highly motivated, and are very demanding of the CET faculty to help them obtain the best structural design education possible.

Sequence of Courses in the Structural Curriculum

Prior to the inclusion of the distance learning student, the structural analysis and design courses in the structural curriculum followed the normal sequence of courses that is typical in CET programs. That is, the fundamental mechanics courses, statics and strength of materials, were followed by a basic structural analysis course that was, in turn, the pre- or co-requisite for reinforced concrete design, steel design, and reinforced masonry/wood design. The building structures design laboratory concluded the series as a synthesis experience.

With the beginning of the TELETECHNET program in CET, much concern was expressed about the "lock step" nature of the structural course sequencing. The first three courses offered via TELETECHNET were Structural Analysis (fall, 1994), Reinforced Concrete Design (spring, 1995), and Steel Design (fall, 1995). Since the courses are offered on a two-year cycle, there was concern that new students coming into the second year of the program would be taking design courses without the benefit of first year courses. A change in the traditional philosophy of teaching and sequencing structural analysis and design courses, to allow each course to stand alone, was necessary if the non-traditional student was to be properly served.

The revised sequence of structural analysis and design courses is described as follows. The basic mechanics courses – statics and strength of materials – again are taken first. However, the structural analysis course is uncoupled as a pre- or co-requisite from the three structural design courses. Thus, the student in the structural curriculum can now take the structural analysis, reinforced concrete design, structural steel design, and reinforced masonry/wood design courses in any sequence without penalty. The building structures design laboratory remains as the finishing course in the sequence and is taken in the student's last semester.

The uncoupling of the structural analysis course has been accomplished primarily by removing from the analysis course the instruction on material-specific approximate methods of analysis,

and adding that instruction to the appropriate design courses. As a result of these changes, more time can be spent in the basic structural analysis course on the primary and secondary methods of structural analysis that are emphasized in the curriculum, i.e., on the stiffness and moment distribution methods. The remaining portion of the structural analysis course can now include a limited but adequate coverage of approximate methods that may be used to check the results (output) of computer software.

These changes emphasize to the CET student that structural analysis is an integral part of the structural design process for every building structure design project.

Experiences Established for the Structural Curriculum

The career goals of the incoming students and the needs of employers who hire the graduates have compelled the CET faculty to establish specific experiences that stress practical curriculum elements. Some of the experiences are listed as follows:

- Basic computer literacy, using Windows 95, Windows NT4.0, spreadsheet and word processing software.
- Basic understanding and use of building codes and design specifications (BOCA, ACI Code, AISC-LRFD, etc.) in the structural analysis and design of building structures.
- Structural analysis and design in statically determinate structural elements and systems (such as beams, trusses and hung-span or cantilever systems), and statically indeterminate structures (such as continuous beams, plane trusses with continuous top- and bottom-chords, and multi-span, multi-story plane frames).
- Basic structural design in steel, reinforced concrete, reinforced masonry, and wood.
- Structural design using faculty-developed and commercially available structural analysis and design software such as STAAD III. And WoodWorks Design Office 97.
- Computer-aided drafting (CAD) for the preparation of project structural drawings including structural details.
- Structural specification writing using software such as SPECTEXT in conjunction with word processing software.

Philosophy on the Use of Computers in the Structural Curriculum

Structural design offices were among the first major users of computers. Today, structural design offices use computers and software extensively to perform structural analyses and designs of all types of structures. Thus the authors firmly believe that students should be taught how to use computers and software in the structural analysis and design process, and how to apply both theoretical and approximate methods to check the correctness of computer output.

In addition to the use of computers to assist in the design process, computer assisted instruction is also an important component to the success of this curriculum. PowerPoint [TM] presentation material has been developed to accomplish the objectives for each structural analysis and design course. This presentation material is put into course packs so that a greater number of topics can be covered in the time allotted. The need for the student to copy from blackboard or overhead transparency materials is reduced considerably, so students can concentrate on the structural analysis and design content rather than extensive writing.

All of the CET students at the junior and senior level have access to computer systems with CD-ROM drives. Thus, in the future, PowerPoint handout material may be distributed for each course to the student on a CD-ROM disk rather than on a paper medium. Structural analysis and design software may also be distributed on the CD-ROM with the permission of the developers.

Structural Analysis Course (CET 301)

This course, which is taught by the first author, is not the typical structural analysis course taught at most universities. The course emphasizes the use of three-dimensional example building structures, the assessment of design loads for example and homework building structures, and the load transfer process from the three-dimensional building structure to two-dimensional plane frames. It also emphasizes the proper use of computers and software in structural analysis and design, that is, being able to check the correctness of the computer programs that are used in structural analysis and design.

STAAD-III, and other commercial structural analysis and design programs, as well as all framed structural analysis and automated structural design computer programs developed by the first author since the late 1960s, have utilized the stiffness method as the method of structural analysis. Also, these programs make use of matrix and numerical methods to implement the tremendous amount of “bookkeeping” that is required to perform the structural analyses. Thus, the stiffness method is the most important method of structural analysis taught in the course.

“Before computers”, the moment distribution method (MDM) was the method of structural analysis used in structural design offices for the analysis of framed structures. Today, it is the most practical “approximate” method of structural analysis that may be used to verify the accuracy of computer results. Thus, the MDM is the second most important method of structural analysis taught in the course.

The students are presented detailed instructions on the stiffness and moment distribution methods, and on matrix and selected numerical methods, for a variety of structures. The types of structures range from two- to four-span continuous beams, and from one-bay, one-story to four-bay, one-story to five-bay, four-story plane frames. Some of the structures are subsequently used in the structural design courses

All of the example structures used in the course are non-trivial problems. Also, complete sets of structural calculations are provided the students in the handout material. These example structures, and the sets of calculations, provide the students with a library of problems (with

known results) that may be used to test the correctness of results from commercial computer programs.

The students in this course (and the structural design courses) are introduced to the use of MSTY_ST3. (MSTY_ST3 is an acronym derived from the underlined letters of Multi-Story Steel Plane Frames; a plane frame is the 3rd type in the hierarchy of framed structures.) It is a computer program that performs structural analyses of single and multi-story steel and reinforced concrete frames. Using the matrix stiffness method, the program performs a complete frame analysis for each load case and each load combination.

As part of the output from MSTY_ST3, it provides shear and bending moment data across all load combinations at the one-twentieth points of each span, corresponding to the envelopes of maximum shears, maximum negative moments, and maximum positive moments for each span. Also, it has a diagnostic print feature that permits students (users) to print out all member stiffness matrices, the structure stiffness matrix, and all vectors and matrices that make up the system of simultaneous linear algebraic equations that it solves. As part of the course, the students (users) are assigned problem(s) associated with “spot checking” the correctness of assigned member stiffness matrices, column vector(s) of the structure stiffness matrix corresponding to selected degree(s) of freedom, and member end-actions, using matrix methods.

When time permits, the students are provided instruction on the use of MSTY_RC3 to perform structural analyses of five-bay by four-story plane frames that are subjected to both gravity (dead and live) loads and lateral loads in various load cases and load combinations.

Computer Applications in Structural Design Course (CET 400)

Four or five computer programs are studied in this laboratory course, particularly the programs that will be used in the capstone course in the sequence, Building Structures Design Laboratory. The STAAD-III program, which is widely used in structural design offices to perform structural analyses and designs of statically indeterminate structures, is studied in depth. One or more wood design programs (e.g., Wood Works SIZER and/or the Trus-Joist design programs) and the Steel Joist Institute *Vibration Program* also are studied in the course. In addition, the *RamSteel* direct steel design program is demonstrated.

Reinforced Concrete Design, Steel Design, Wood Design Courses (CET 410, 450, 452)

The example and homework structures in the reinforced concrete design, steel design, and wood design courses have features such that all of the important structural analysis and design topics that are usually taught in a one-semester design course are covered. These include such topics as framed structural analysis, flexural design, shear design, deflection control, and column design. Torsion and footing design are included in the reinforced concrete design course.

In the reinforced concrete design course (CET 410), the ACI Code Coefficients method (Reference 1) is used to obtain structural analysis data for the four-bay, one-story framed homework structure and to check the results from computer analyses. In the steel design course (CET 450), the point-of-inflection method is used to obtain structural analysis data for the four-

bay, one-story framed homework structure and to check the results from computer analyses. Finally, in the wood design course (CET 452), structural analysis of a hung-span or cantilever system is used to obtain structural analysis data for the four-bay, one-story framed homework structure and to check the results from computer analyses.

Course Requirements Common to All Structural Design Courses

Each structural design course (CET 410, 450, and 452) has a series of (relatively) short homework problems. However, a long homework problem assignment is formulated around the homework building structure in each course. To complete this assignment, each student must perform a computer analysis of the four-bay, one-story homework framed structure. Each student also must perform a set of manual (calculator) calculations, using the approximate method of analysis assigned for the problem, so that he/she can verify the correctness of results from the computer program used in the course.

The results of the computer analyses and the set of manual calculations are included in a structural project “package” In addition, this package must include an appropriate number of structural sketches for the homework structure, showing foundation and framing plans, elevations, sections, and details as necessary. The student may use either CAD software or manual drafting to produce the sketches. Frequently, the package must include an estimate of the cost of construction for the homework structure. Each student must turn in all of his/her work in a three-ring binder that will become part of his design portfolio.

The Building Structure Design Laboratory Course (CET 455)

The Building Structures Design Laboratory is the “capstone” course for the structural curriculum. This final experience draws upon material from all of the structural analysis and design courses, as well as material from the plans and specifications and estimating courses, in a final student design project. The project is a complete structural design including plans, specifications, calculations, and cost estimates. The culmination of the class is a student presentation to practicing, local design professionals. This completes the development of the structural design portfolio, which can be a very effective document when the student begins to interview for employment.

Summary and Conclusions

The goal of a structural design office is to make a profit by designing a building structure to satisfy all structural design requirements and yet stay within the time and budget constraints set by the project engineer. The easiest way to accomplish the goal is through the use of computers and software.

The faculty who teach the courses in the structural curriculum of the Structural Design and Construction Management emphasis in the CET program at Old Dominion University have developed a curriculum model that can prepare CET graduates for positions in structural design and provide the graduates with the kind of experiences common to structural design offices.

The CET graduates have been exposed to the use of computers and structural analysis software in nearly every course. Thus, they gain training in the use of computers. They have also been exposed to the various methods of structural analysis that may be used to verify the correctness of the results of the software.

The homework, tests, and term projects in the various structural analysis and design courses can be collected and collated so to provide the CET graduates with a portfolio of their work to show prospective employers.

A number of recent graduates have been employed by Architect-Engineer, Structural Engineering, Mechanical/Electrical/Structural Engineering, and Civil Engineering firms. These graduates have provided feedback to the CET faculty, viz., that their employers have indicated to the graduates that they have been well prepared for their assignments. Only minimal additional on-the-job training has been necessary. Moreover, their employers have been pleased that they (CET graduates) have been productive from the start of their employment.

Biographical Information

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