STRUCTURAL ANALYSIS DESIGN: A DISTINCTIVE ENGINEERING TECHNOLOGY PROGRAM

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Abstract

Graduates of the Structural Analysis and Design Engineering Technology program, University of Houston-Downtown, are successful in reaching responsible positions in industry and government. The strong emphasis on computer technology provides an advantage to graduates of the program because they are highly productive.

The Structural Analysis Design (SAD) Engineering Technology program, University of Houston-Downtown, is focused on the design of bridges, buildings, towers, offshore platforms and other structures. It is not traditional civil engineering but includes all aspects of structural design, including soil mechanics, foundation design, and construction surveying by GIS-GPS.

Students take an intensive course in applications of computers, a visualization course, and two courses in computer-aided design, followed by a course in 3-D modeling including the most common CADD software packages: MicroStation, AutoCAD, and 3D Studio. Structural Analysis deals with application of finite element theory to beams and frames. A second course, Finite Element Analysis, utilizes ANSYS and ROBOT.

Since the program focuses on structural analysis and design, students are exposed to several techniques and practices that are taught in schools of civil engineering at the graduate level. Examples include instruction on finite element analysis and use of structural software packages used in industry.

Structural Analysis Design – Program Description

This program covers the design of structures, bridges, buildings, towers, and offshore platforms and in general what is called civil structures. However, the program is not civil engineering because that field is considered broader. All aspects related to structural design are part of the program, including soil mechanics, foundation design, and GIS-GPS surveying.

All courses in structural design combine theory, testing and applications. Typically, the problem is presented as a specific application. For example, in the design of a bridge, a 3-D computer model of the bridge is created according to specified geometry; then loads are applied to the structure to evaluate its strength. Finally, theoretical results are reviewed using computer results and appropriate modifications are applied to the design. Figure 1 show the Structural Analysis Design curriculum.

Freshman

			HRS	SEM				HRS	SEM
ENG	1302	Composition II	3	ALL	ENGR	1400	PC Applications in Engineering	4	F,S
ENGR	1401	Engineering Graphics	4	F,S	PHYS	1307	General Physics I	3	ALL
HIST	1305	US History to 1877	3	ALL	PHYS	1107	General Physics Lab I	1	ALL
PSY	1303	General Psychology	3	ALL	HIST	1306	US History after 1877	3	ALL
MATH	2401	Calculus I	4	ALL	EET	1411	Circuits	4	F
			17					15	

Sophomore

			HRS	SEM				HRS	SEM
ET	3321	Soil Mechanics	3	F	ENGR	2409	Engineering Mechanics	4	F,S
ENGR	2407	Surveying with GIS-GPS	4	SU	ENGR	2410	Analysis of Engineering Networks	4	F,S
POLS	2303	US Government I	3	ALL	CHEM	1307	General Chemistry	3	ALL
PHYS	1308	General Physics II	3	ALL	CHEM	1107	General Chemistry Lab I	1	ALL
PHYS	1108	General Physics Lab II	1	ALL	ENG	23XX	Sophomore English Literature	3	ALL
SPCH	1304	Introduction to Speech	3	ALL	POLS	2304	US Government II	3	ALL
			17					18	

Junior

			HRS	SEM				HRS	SEM
		Writing Proficiency Exam							
ENGR	3311	Structural Analysis	3	F	ET	3322	Finite Element Analysis of Struct.	3	S
ENGR	3312	Reinforced Concrete Design	3	F	ET	4321	Structural Steel Design	3	S
MATH	2307	Linear Algebra	3	ALL	ENG	3302	Business and Technical Writing	3	ALL
ET	3320	Modern Concrete Technology	3	F,S	ET	3325	3D Computer Modeling, Rend. & Anim.	3	F
ET	3308	Materials Science	3	F,S	ART		Fine Arts Course	3	ALL
			15					15	

Senior

			HRS	SEM				HRS	SEM
ET	4323	Technology Seminar	3	F,S	ET	4320	Prestressed Concrete	3	S
ET	4324	Senior Concrete Project	3	F,S	ET	4325	Senior Steel Project	3	S
ENGR	3302	Engineering Economics	3	S	ET	4322	Foundation Design	3	S
ENGR	3409	PC Facilities Management	4	ALL	ET		Elective	3	ALL
ET		Elective	3	ALL	ET		Elective	3	ALL
			16					15	

F= fall; S = spring; SU= summer

Figure 1 - Structural Analysis Design Curriculum

Students start by taking an intensive course in applications of computers to engineering. In this course they learn how to use the computer to solve engineering problems. The course involves a project selected by the student, combining computer languages, databases, data acquisition, and spreadsheets.

Computer modeling is an integral part of the program. Students start with a visualization course and two courses in computer-aided design, followed by a course in 3-D modeling. These courses include the most common CADD software packages: MicroStation, AutoCAD, and 3D Studio[1]. The latest version of software is always used in these courses.

There are two courses in structural analysis, the first one deals with application of finite element theory to beams and frames. Students write their own computer programs and validate the results, measuring loads and deflections in actual structures. The second course, Finite Element Analysis, utilizes ANSYS, the best-known "industrial-strength" FEA program for the analysis of members, connections and other structural details ROBOT is also used for finite element analysis of shells and plates. The course includes linear and nonlinear behavior.

Field measurement of vibration of bridges and other structures are also performed in structural courses. Once students realize that structures vibrate, they are exposed to computer programs that predict the frequency of vibration and present the theoretical basis for dynamic analysis of structures.

Design of steel structures is based on the ultimate design approach known as LRFD (Load and Resistance Factor Design) common in American engineering practice. This course uses the manual of the American Institute of Steel Construction as a textbook, and extensive examples are presented to illustrate practical design applications[2].

There are three courses in concrete structures: Modern Concrete Technology presents the principles, practice and testing of high performance and lightweight concrete. Students perform extensive tests of mixes every semester. Reinforced Concrete Design is a course where students design and build actual beams, columns and slabs that are tested to failure. The principles of reinforced concrete design are presented based on the results of these tests[3].

Self-compacting concrete is one of the newest technologies developed in Japan to reduce the labor cost of cast in place concrete. The design involves careful selection of the mix proportions and requires additives such as superplastisizers. The water-cement ratio has to be controlled with great precision to obtain the required results. In the fall of 2001 students and faculty of the structural program designed and built a self-compacting concrete beam.

Prestressed concrete is an important subject in structural engineering. Students build statically indeterminate complex structures in this course, apply stressing forces, and test structures. Fiber reinforcements are included in the course.

Foundation design is a critical aspect of structural engineering. Students are exposed to the principles of foundation design. Foundations of different sizes on several different soils are tested during this course. Once the results of the test are available, students develop programs based on classical theories such as Terzaghi's to predict the capacity of foundations. This foundation course is preceded by a course in soil mechanics where students go to the field, take samples, and perform all tests necessary for soil classification and computation of typical Houston, Texas, soil strength.

During the fourth and last year of training, students work on their senior concrete and steel design projects. Students are encouraged to apply their creativity to the conception and design of a real structure. Some of the projects are also engineering design problems that students are assigned at their place of employment.

Creativity is the main characteristic of an engineer. In the past, technologists were employed to perform manual routine computations as "checkers" for structures that were created by engineers. Today, with the advent of the computer and proper training, the engineering technologist may be assigned the responsibility for creation and design of structures[4].

Construction surveying is perhaps the best example of an application of modern technology in the Structural Analysis Design program. With sponsorship of industry, students are exposed every summer to the latest technologies in total stations, global positioning systems (GPS), and global information systems (GIS). GPS and GIS have revolutionized surveying, because of the ability to determine a position with high precision and obtain its corresponding information[5].

Hands-on laboratory testing on a variety of structures is conducted in the laboratory (located in the same room as the classroom). Figures 2 through 4 show students at work in the laboratory.

Figure 2 - Structural Analysis and Design students preparing truss for testing

Figure 3 – Structural Analysis and Design student reading ultrasonic cover measurement

Figure 4 – Students applying fiberglass-reinforcing mesh to beam

Description and Origin of the Structural Laboratory

The Structural Analysis Laboratory is first of all a place where students feel themselves at home. They take care of the equipment and computers and on many occasions build new pieces of testing equipment on their own initiative. The lab is also their favorite place to study and work on projects. The lab becomes a second home where students share life experiences with each other and network about work opportunities.

The history of the laboratory starts when one of the authors assumed the position of program coordinator and professor structural analysis. He had worked for many years at the Balcones Research Center, University of Texas, Austin, building testing equipment with components taken from WWII surplus tanks, jeeps and boats.

He considered that actual testing was a must in his courses. He started building testing rigs with the students and later wrote a proposal to NSF to finish development of the laboratory using off-the-shelf components. The proposal was accepted and the required funds provided. For three years all student projects were related to design and construction of the laboratory.

Some anecdotes during development of the laboratory are interesting. After investigating how to develop a testing rig for concrete beams, it was found that the building itself was a strong testing facility because of its construction involving 17-inch reinforced concrete floor slabs and very strong columns. Because of safety considerations, it was not possible to weld components in the laboratory. To solve this problem, the welded components were contracted out to companies where students worked. The pleasant surprise was that the contractor decided not to charge for the work as a contribution to the education of the student employees. To wisely spend the funds allocated for the grant on time became a difficult task. At the end of the project, a laboratory beyond all initial expectations had been developed and the project became an NSF model for laboratory improvement.

Computer programs to predict results and monitor the progress of testing have been developed for all tests performed in the laboratory. The standard testing procedure involves the following steps:

Presentation of the theory
Computer simulation of the test
Testing with continuous monitoring of results

The laboratory includes the following facilities:

- Soil Mechanics and Foundations: All necessary equipment for soil testing including a triaxial testing apparatus and consolidometers were built by students. Also, a rig to test foundations to failure was built be students. This device allows students to visualize failure of soils under structural loads.
- Testing Bed for Concrete Beams: This device is use to test beams that students design and cast. After failure, the beams are repaired using fiber composites and tested again to failure. Following this procedure, students learn reinforced concrete design and structural repair using composites using a single beam. Description of this approach has received great attention at international conferences where faculty and students described the methodology[6]. Figure 5 shows a concrete beam reinforced with composites after failure.

Figure 5 - Testing of concrete beam reinforced with fiber composites

- Testing Bed for Steel Elements: This facility is used to test trusses, beams and girders. The elements are not tested to failure because the educational goal is to show deflections, flange buckling, web bucking and other behavior typical of steel structures. Figure 6 shows a steel joist ready for testing.

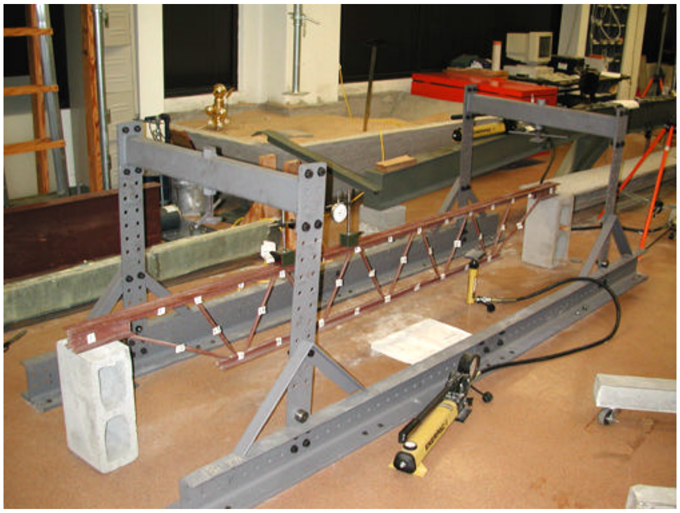

Figure 6 - New rig for testing of steel elements with truss in preparation for testing.

- Post-tensioned Concrete Beam. Figure 7 shows a two-span continuous beam used to train students in the procedures required to design and apply the required tension to the strands of prestressed concrete beams. The trajectory of strands is delineated on the surface of the sides of the beam for easier visualization of their position inside of the beam.

Figure 7 - Two span continuous beam used to teach post-tensioning techniques

- Post-tensioned Crane: Figure 8 shows a crane designed and built to handle heavy loads in the laboratory. Details of its design and construction were presented at the ACI annual conference in Montreal gaining great compliments from fellow educators.

Figure 8 - Post-tensioned concrete crane used to lift heavy equipment in the lab.

Success Story of a program graduate

Figure 9 - José Maldonado, BSET (Structural Analysis Design)

José Maldonado's story is an example on how an individual can overcome the hardships of a life that seemed destined to enter poverty's entrails working at odd jobs for the rest of his life. He proved that by studying hard one could beat the odds. Born in Rio Bravo, Tamaulipas, México, Maldonado began his education at public schools in México. For his junior and high school years he was able to transfer to private schools.

As many of his fellow-citizens, when Maldonado was eighteen, he moved to Houston with his mother and sisters in search of opportunities and a better life. He enrolled himself in 11th grade in order to improve his English and graduated Valedictorian in his class. Because of his outstanding performance in high school he received a state scholarship, which he used to attend the University of Houston-Downtown.

Maldonado's dream was to study structural engineering. Buildings and bridges fascinated the young man. He chose the University of Houston Downtown since it offered a more specialized program in analysis and design--his field of interest--than in any other university in the area. Most area universities offer degrees in civil engineering, which he considered too general for a structural engineer. He chose structural analysis design, and also applied mathematics, as his majors at the university. He took courses in computer applications to engineering, soil mechanics, foundations, structural analysis, finite element analysis, reinforced concrete design, prestressed concrete design, steel design, and senior projects in structural design.

According to members of the faculty Maldonado was an active student as well as a good friend who always tried to help those who needed assistance. He became a leader, absorbing what he was taught, and in turn shared his new knowledge with his classmates. He graduated Magna Cum Laude with a grade-point-average of 3.5.

Maldonado's main goal was to overcome every possible difficulty, to take advantage of every opportunity that came his way, doing the best he knew how. He wanted to gain experience in structural engineering and later obtain an advanced degree in the field. With help of his classmates he was given the opportunity he was looking for, and was hired at Global Marine to do structural detailing. His supervisors detected an unusual ability and moved him up to other positions with increasing responsibility. Maldonado has worked in challenging applications of structural engineering for offshore platforms; among these are the Celtic Sea and the Drill Ship. Maldonado also had the opportunity to work in Houston and Brownsville. He did extensive work in North Ireland on one of the offshore platforms projects.

Maldonado considers linear algebra to be the most important mathematical technique for structural engineering. Furthermore, he recommends that engineering students take courses in linear algebra and statistics. He took many courses in applied mathematics: calculus, differential equations, applied statistics, discrete mathematics, and linear algebra. At the present time he is planning to work on his Master's Degree.

Maldonado believes that working in teams, the development of projects, and working with other students, is a vital experience at the University of Houston-Downtown. Perhaps the most important statement he can make to help new students is: *"The computer is the main tool of modern structural engineering."*

Maldonado is a glowing example of how a person can overcome barriers, achieve his dreams, and become an outstanding professional in his field. He attributes his success to perseverance and to the use of the computer, both of which helped him become a successful professional and role model.

Conclusions

- The Engineering Technology Department at the University of Houston-Downtown focuses on unique programs relevant to the Houston, Texas area. Structural Analysis Design was designed to meet the needs of the community at-large.
- Faculty interacts continuously with industry in order to provide feedback to the department about employers' expectations and the performance of the graduates.
- The strong emphasis on computer technology provides comparative advantage to graduates of the program because they are immediately productive after employment. The program trains students to fit the specific needs of the Houston area and equips the graduates with a bundle of advance technology training and tools that makes them immediately productive.
- Use of advanced technology is necessary and advantageous to the department for the following reasons. Faculty is more productive in the delivery of educational material when up-to-date educational technology is applied. Furthermore, faculty becomes highly motivated when exposed and trained in the newest technologies in their fields of expertise.
- Students become more efficient in the learning process since computer simulations and laboratory testing are more attractive to students than abstract numerical computations and as a result, they spend more time studying the material.
- Since most students in the department work, they have very busy schedules. Distance learning provides very flexible opportunities to receive educational input and also to reduce time wasted in transportation to and from the campus.
- Concentration in structural analysis and design rather than on the broad field of civil engineering allows for student learning of subjects that are typically covered at the graduate level in schools of engineering.
- Graduates of the Structural Analysis Design option, Engineering Technology program, University of Houston-Downtown (UHD), are successful in reaching responsible positions in industry and government. An example is described in this paper.
- Graduates' accomplishments are due to a variety of factors, for example: motivation, a teaching staff that is dedicated and knowledgeable of new developments in their fields of expertise, remediation of deficiencies, design of the program, educational experiences built into the curricula, and a strong orientation of the courses towards current professional practice.

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Biographical Information

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Alberto Gomez-Rivas is Professor of Structural Analysis and Chair of Engineering Technology. Dr. Gomez-Rivas received Ph.D. degrees from the University of Texas, Austin, Texas, in Civil Engineering and from Rice University, Houston, Texas, in Economics. He received the Ingeniero Civil degree, with Honors, from the Universidad Javeriana in Bogotá, Colombia. He also served as Chief of Colombia's Department of Transportation Highway Bridge Division.

GEORGE PINCUS

George Pincus is Dean of the College of Sciences and Technology, and Professor at the University of Houston-Downtown (1986-date). Prior service includes Dean of the Newark College of Engineering and Professor, New Jersey Institute of Technology (1986-1994). Dean Pincus received the Ph.D. degree from Cornell University and the M.B.A degree from the University of Houston. Dr. Pincus has published over 40 journal articles, 2 books and is a Registered Professional Engineer in 5 states.