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Civil Engineering Education in the U.S.: What Lies Ahead?

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ABSTRACT: *Civil engineering, the oldest of engineering disciplines, faces serious challenges regarding its technical content and continued relevance. While it has gone through significant changes over the past several decades, transforming from a primarily mechanics based structural engineering field to a broad discipline involving civil infrastructure systems with a spectrum of subdisciplines, there are serious concerns about civil engineering education not being able to incorporate emerging technologies and reflect new realities of socio-economic environment. The presentation will include a review of the current status of civil engineering curriculum in the U.S. and the efforts that are underway to reform it. Possible future directions in response to changing professional needs will also be discussed.*

1 INTRODUCTION

There are many challenges to the civil engineering profession today. Many of these challenges are not primarily technical in nature, but involve issues that are socio-economic. A thorough understanding of these issues and ability to solve the attendant problems are required of future civil engineers. Some people argue that the current four year bachelor's program may not be adequate to provide sufficient breadth of knowledge base necessary to launch a career in civil engineering and to continue to develop professionally. In order to expand the body of knowledge and to upgrade the current civil engineering undergraduate program several reform proposals are being made in the U.S. A major such proposal has been advanced by the American Society of Civil Engineers (ASCE 2004). It recommends making the four-year bachelor's program a five year program with bachelor's plus master's for civil engineering practice. It is felt that this change would not only provide sufficient technical knowledge but would also give opportunity to expose the student to a broad socio-economic knowledge base that is essential to cope with the demands of today's civil engineering profession. In this context, it is important to remember that in the U.S. individual engineering and technology programs are accredited by the Accreditation Board for Engineering and Technology (ABET 2002) which in recent years has been requiring civil engineering programs to reflect explicit consideration of broad societal goals of public health, safety, and welfare.

2 CE EDUCATIONAL PROGRAMS IN THE U.S.

As civil engineering (CE) is one of the oldest branches of engineering, there are numerous universities and colleges in the U.S. as well as throughout the world that have civil engineering under graduate (UG) programs. In the U.S., about 310 universities and colleges offer such a program. During the past several decades, research and development activities in civil engineering have increased in order to support and validate technologies, with increasing graduate programs. There are approximately 220 and 125 universities in US having CE M.S. and Ph.D. programs, respectively. The enrollment in undergraduate civil engineering programs in recent years is shown in Table 1, indicating a slight increasing trend. Table 2 gives a summary of the number of B.S., M.S. and Ph.D. degrees awarded in Civil Engineering during 1999-2002. An important item in engineering education in the U.S., as well as in other developed countries, is the increasing proportion of foreign students. The percentage of foreign nationals receiving civil engineering degrees is given in Table 3. It can be observed that the graduate programs have higher percentage of foreign students than the UG programs. In the U.S. the women constitute about 25% of the B.S. and M.S. degrees in civil engineering, while the percentage drops to about 17% for Ph.D.

Table 1. CE UG Enrollment in USA (1999-2002)

1999	*2000*	*2001*	*2002*
37,293	36,815	37,616	39,811

Source: (ASEE 2002)

Table 2. CE Degrees Awarded in B.S., M.S. & Ph.D. in USA (1999-2002)

	1999	*2000*	*2001*	*2002*
B.S. Civil	10,074	9,438	8,812	8,799
M.S. Civil	4,121	3,957	3,784	3,785
Ph.D. Civil	646	585	603	673

Source: (ASEE 2002)

Table 3. Percentages of Foreign Nationals Enrolled in CE Programs in USA

	1999	*2000*	*2001*
B.S. Civil	7.8 %	8.3 %	7.5 %
M.S. Civil	39.7 %	40.6 %	43.0 %
Ph.D. Civil	45.6 %	49.9 %	53.8 %

Source: (ASEE 2002)

With the increasing number of students and the continued demand for research and extension services, the number of permanent faculty has also been increasing in civil engineering. At present there are about 3,375 teaching faculty members in both graduate and undergraduate programs in the U.S. The number of permanent teaching faculty in a program is an important criterion for the accreditation of an individual university program. Most of the permanent faculty members have Ph.D., particularly in programs that give graduate degrees. In addition to the permanent faculty, many universities use adjunct faculty members from industry and governmental agencies. Adjunct faculty are an important component of a program as they bring in a rich variety of practical experience to the classroom.

3 CIVIL ENGINEERING SUBDISCIPLINES

Civil engineering, as it existed in the early period, was primarily mechanics based dealing with design and construction of facilities, such as buildings, roads, bridges, railroads, dams, pipelines, and canals. Current subdisciplines which are mechanics based are structures, geotechnical, and materials. At a later time came environmental subdiscipline with a strong emphasis on chemistry and biology. The focus shifted from the design and construction of water and wastewater treatment facilities to understanding environmental degradation processes and devising remedial and intervention measures related to air, water and noise pollution. The third and the last major group in civil engineering includes construction management and transportation. These two subdisciplines are based mainly on operations research, economics and management. Surveying, or geomatics, can also be considered a part of this group, although most U.S. civil engineering degree programs have deleted surveying from their undergraduate curriculum. Most current UG programs provide some exposure to each of the subdisciplines.

4 REFORM PROPOSED BY ASCE

Rapid advancement is taking place in technology and there are innovations in materials and construction practices. The socio-economic world in which civil engineering projects are conceived and implemented is also fast changing, affecting all the way from project planning with varied stakeholders to building with minimum environmental and community disturbance (ASCE 2004). However, most civil engineering graduates, although well versed in design principles, lack knowledge of business, economics, management, and the ability to grasp the multidimensional aspects of the project. Consequently, it is not sufficient to continue to teach the way we have done in the past several decades. Instead, we need to broaden the horizon of our students by taking advantage of information technologies, not only in the delivery of course materials but also in developing new contents of the curriculum. At the same time we need to incorporate non-technical materials such as financing and other subjects. The current four-year undergraduate program is considered by some as inadequate to prepare civil engineers with basic skills and knowledge sufficient to meet with licensure requirements of the profession. It is the position of the ASCE to add an extra year and make the M.S. as the basic degree for professional practice (ASCE 2004).

5 THE ROLE OF PRACTICE IN CURRICULUM

The medical schools in the U.S. adopted a method of teaching through practice about 150 years ago. This method revolutionized the way medical students are trained and educated. As civil engineering is a practice oriented profession, we should think about how to combine theory with practice in our curriculum. A radical change will be to learn from the medical schools and teach through practice. Faculty members will be practitioners and students will be basically apprentices taking part in real world planning, design, construction and operation of civil infrastructure facilities. Cooperative education programs currently in use allow students to go to work for civil engineering firms and government agencies at alternate semesters. Also, in many graduate programs students work on research or consulting projects as research assistants, and there is an element of practice in some of these activities. However, these programs, although they often provide excellent opportunities for practical experience, do not effectively integrate theory and practice. A radical reform can be achieved by carefully designing civil engineering curricula like the medical programs and requiring a 5-year M.S. program as the basic degree. This concept, however, is vastly different from the proposal advanced by the ASCE. I credit the late Gerald Leonards, who was a colleague of mine, for mentioning the idea to me many years ago. He also spoke of the virtue of forensic engineering in teaching our students because much can be learned from failures.

6 CIVIL ENGINEERING BODY OF KNOWLEDGE

The ASCE Body of Knowledge Committee has recently issued a report (ASCE 2004) in connection with the ASCE Policy Statement 465 supporting the proposed reform of the profession and extending the current 4-year B.S. program to a 5-year M.S. program as a prerequisite for licensure and practice. The report deals with three basic issues. What should be taught and learned? How should it be taught and learned? Who should teach and learn it?

In determining what should be taught, the committee considered the basic abilities that a civil engineer should possess. A curriculum can then be designed accordingly. For example, while a curriculum should include knowledge of mathematics, science and engineering, it should provide the knowledge to interpret data, design a system, function on multi-disciplinary teams, understand ethical responsibilities, communicate effectively, have appreciation of the impact of solutions in a global and societal context, understand project management needs, business and public policy fundamentals and leadership principles. In addition, a civil engineer must be able to apply knowledge in a specialized subdiscipline related to civil engineering and should be involved in life-long learning. These attributes encompass the current accreditation requirements (ABET 2002). The ASCE initiative broadens the ABET outcome items and introduces elements that are necessary in implementing a project as opposed to designing and analyzing a project. A basic idea is that the curriculum should provide the student with fundamental principles of civil engineering along with the knowledge and understanding of the social, political and economic world in which one practices civil engineering.

7 WHAT DOES THE FUTURE HOLD?

While basic needs of housing, transportation, water and sanitation will continue to be the main thrust of the civil engineering profession, there are increasing demands for innovation not only to make the current practice more cost-effective, but also to respond to new demands. One such demand is coming from increasing vulnerability and risk from manmade and natural disasters. One way to achieve innovation in this area is to integrate emerging communication and information technologies with civil engineering to create intelligent civil infrastructure. An intelligent infrastructure can include applications of new technologies to a host of infrastructure-related matters including the real-time monitoring of buildings, bridges, dams, tunnels, and other structures to assure their continued safety and improve design, the detection of security threats such as chemical or biological contaminants in drinking water supplies, mass transit facilities, stadiums, and airports as well as the improvement of infrastructure systems performance by reducing time losses due to traffic congestion and improving safety. Intelligent infrastructure will allow quick response and mitigation to an entire spectrum of vulnerability and risk situations arising from terrorism, earthquakes, tornadoes, floods, and hurricanes. The transformation that can take place through this type of technological innovation will take civil engineering to the next level of creativity in serving societal needs. We should not only conduct research and development for such innovations but also prepare appropriate programs to educate and train a new generation of civil engineers. At Purdue an effort is underway to introduce the concept of intelligent infrastructure in our program.

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