THE ROLE OF EERI SEISMIC DESIGN COMPETITION IN IMPARTING TECHNICAL COMPETENCE AND PROFESSIONAL EXPOSURE IN THE UNDERGRADUATE CIVIL ENGINEERING CURRICULUM

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EXTENDED ABSTRACT

In today's world it is extremely essential that undergraduate civil engineering students have the ability to analyze and solve engineering problems by applying basic principles. In order to do so, it is very important to integrate various fundamental fields to understand the impact of civil engineering solutions in a global and societal context consistent with the principles of fundamental mechanics. At the same time, professional exposure is needed to steer them in the right direction with regards to choosing a suitable career.

A short description of existing international framework standards for the accreditation of engineering programs is provided with reference to: EUR-ACE, (European Accredited Engineering Programmes), Civil Engineering Body of Knowledge for the 21st Century (American Society of Civil Engineers), EUCEET (European University Civil Engineering Education and Training). It is acknowledged that these institutions and frameworks recognize common outcomes for accredited engineering degree programs. Specifically, EUR-ACE specifies six types of outcomes: knowledge and understanding, engineering analysis, engineering design, investigations, engineering practice, and transferable skills.

The Seismic Design Competition (SDC) is organized by the Earthquake Engineering Research Institute (EERI) Student Leadership Council (SLC) in the United States, in conjunction with the EERI Annual Meeting. The 2011 EERI Annual Meeting, with the theme "Earthquakes without Borders," hosted the 8th SDC in La Jolla, San Diego, California between February 9 and 11. The objectives of the SDC are: (a) to promote the study of earthquake engineering amongst undergraduate students, by providing them an opportunity to work on a hands-on project by designing and constructing a cost-effective frame structure to resist earthquake excitations, and (b) to build the awareness of the versatile activities at EERI among the civil engineering students and faculty as well as the general public (national and international).

KEYWORDS
Earthquake engineering, Undergraduate curriculum, Technical competence, Professional exposure

1. INTRODUCTION

1.1 The subject matter of earthquake engineering

The subject matter of earthquake engineering has rapidly evolved over the last few decades to become a science-based engineering discipline with a well defined body of knowledge. Earthquake engineering encompasses multidisciplinary efforts from various branches of science and engineering with the goal of reducing the seismic risks to socio-economical acceptable levels [1].

1.2 Earthquake engineering at the undergraduate level: possible outcomes and goals

At the undergraduate level, the study of earthquake engineering may be limited to the knowledge and understanding of the earthquake mechanism and the territory's seismicity, seismic response of buildings, underlying criteria for earthquake resistant design and new systems for seismic protection of buildings. The EERI Seismic Design Competition (SDC) provides an opportunity for undergraduate students to gain and accumulate knowledge and skills pertinent to the seismic response evaluation of structures with simple configurations and structural systems such as moment resistant frames and shear walls at the least.

Events such as the Seismic Design Competition (SDC) provide an excellent platform in order to meet the aforementioned objectives. The competition deals with undergraduate teams designing and constructing a multi storey balsa wood building frame structure, which will eventually be tested on a shake table during the event. SDC also requires the teams to offer response predictions in terms of roof accelerations and drifts together with anticipated failure modes.

This paper presents a comprehensive summary of the SDC, by highlighting several features such as the history of the event, its basic structure, scoring and financial aspects together with insights on how the event impart technical competence and professional exposure to the participating teams.

The SDC Project gives to students the opportunity to acquire the outcomes for Earthquake Engineering at high level of cognitive achievement asked by the international standards of accreditations for the "First cycle" graduates conforming EUR-ACE [2] respectively bachelor's degree conforming the BOK [3]. The outcomes acquired are: Experiment, Design, Project management, Communications, Globalization, Leadership and Teamwork.

The "Experiment" outcome is acquired at level L4: the students are familiar with purpose, procedures, equipment, and practical applications in the field of Earthquake engineering. They are able to conduct the experiments, report results, and analyze results in accordance with the applicable standards and across more than one technical area
as architecture and socio-economical aspects. The students made reports with the results of laboratory studies, virtual experiments, and numerical simulations; they gained the ability to conduct the experiment, analyze and explain the resulting data. The outcome „experiment" is fulfilled by some participants at Master level due to the good synthesis of the results.

The outcome "Design" is accomplished at level L6 including analysis and synthesis for the activities of designing, predicting performance, building, testing and fostering creative knowledge of students. The "Project management" is accomplished at level 4: the SDC project is an undergraduate research in the frame of an extracurricular project; the students had accomplished the activities: initiate, plan, execute, monitor and control, and close the project.

The outcome “Communication” is also acquired by students at level L5, including synthesis; the students created graphics to explain the complex systems and processes of their technical solution, a documented report, and made team presentations. They wrote summaries of the work on posters and had conversations with technical audiences during the poster session. The outcomes “Leadership” and “Teamwork” are achieved by the students at L2 (comprehension) cognitive level and the “Globalization” is acquired at level 3, Application, in the context of theme “Earthquakes without Borders” and international ambiance of the event.

2. SHORT DESCRIPTION OF EXISTING INTERNATIONAL FRAMEWORK STANDARDS FOR THE ACCREDITATION OF ENGINEERING PROGRAMS

2.1 EUR-ACE Framework Standards for the Accreditation of Engineering Programs

The principal aim of the EUR-ACE [2] is to develop a framework for the accreditation of engineering degree programs in the European Higher Education Area (EHEA). The Framework Standards that have been developed, and the procedures for their implementation, are intended to be widely applicable, in order to reflect the diversity of engineering degree programs that provide the education necessary for entry to the engineering profession. The proposed framework affords a means for comparing educational qualifications in the EHEA, and thereby promoting the mobility of engineering graduates. In its current form the content of EUR-ACE is applicable to general engineering education, therefore it is not a difficult task to extend this application to Civil Engineering programs.

The six types of program outcomes of accredited engineering degree programs are: knowledge and understanding, engineering analysis, engineering design, investigations, and engineering practice.

2.2 Civil Engineering Body of Knowledge for the 21st Century

The American Society of Civil Engineers (ASCE) had produced a document titled “Civil Engineering Body of Knowledge for the 21st Century” [3]. This comprehensive document addresses the necessary educational response to the essential changes that are expected to occur in the practice of civil engineering in the 21st Century. Entry into the practice of civil engineering at the professional level requires fulfilling twenty four outcomes to the appropriate levels of achievement. The outcomes are classified into three main types and are listed below:

Foundational Outcomes: Mathematics, natural sciences, humanities, social sciences
Technical outcomes: Material sciences, mechanics, experiments, problem recognition and solving, design, sustainability, contemporary issues and historical perspectives, risk and uncertainty, project management, breadth in civil engineering areas, technical specialization;
Professional outcomes: communications, public policy, business and public administration, globalization, leadership, team work, attitudes, lifelong learning, professional and ethical responsibility.

Entry into the practice of civil engineering at the professional level requires the individual to demonstrate different levels of achievement, i.e. knowledge (L1), comprehension (L2), application (L3), analysis (4), synthesis (L5), and evaluation(L6), for the various outcomes. As an example for outcome “Design” the levels of achievement L5 is required, outcome “Materials Science” is sufficient to be at lower level L3.

2.3 Designing a curriculum

The thematic Networks EUCEET II and III have been involved in the TUNING [4] project for long. An exercise was conducted during EUCEET II to establish the generic and subject specific competences in civil engineering programs. Academic professionals and graduates were asked to express their views using a questionnaire.

To provide comprehensive guidance for the design of programs, the TUNING [4] project offers the guidance to design curricula asking questions for program design, delivery, maintenance and evaluation. The following table provides information on the items and key questions what should be considered for program delivery, maintenance and evaluation.

Table 1: Key questions what should be considered for program delivery, maintenance and evaluation

Actions	Questions
Monitoring	How is the quality of delivery of the programme and its components monitored? How is staff quality and motivation for the delivery of the programme monitored? Are there systems in place to evaluate the quality of the learning environment in work place learning/placements? Is the quality of class rooms and the equipment (including workplace environment required to deliver the programme sufficient? How is the entrance level of potential students monitored? How is student performance monitored in terms of quality of learning outcomes to be obtained / competences to be achieved and time required to complete the programme and its components? In what way is the employability of graduates monitored? How is the alumni database organized? Are data collected on the graduates' satisfaction with the programme?
Updating	How is the system for updating / revision of the degree programme organized? In what way can changes related to external developments in society be incorporated in the programme? How is staff development related to programme updating organized and guaranteed?

Sustainability and responsibility	How is the sustainability of the programme guaranteed? How is it guaranteed that the relevant bodies take responsibility for sustaining and updating of the programme?
Organisation and Information	How is the updating of information regarding the degree programme organized and guaranteed? How is the adequacy of the system of student support, advising and tutoring ensured? Is a Diploma Supplement issued to the students automatically and without charge in widely spoken European language?

3. THE EERI SEISMIC DESIGN COMPETITION (SDC)

The primary goal of the SDC is to introduce undergraduate civil engineering students, most of whom never had a course in earthquake engineering, to the principles of behavior and performance of structures during earthquakes. The SDC serves as a suitable platform to nurture a good proportion of technical objectives and professional experience in students ranging from their freshman to senior year in their undergraduate career. The main objectives of the competition are:

1. To promote the study of earthquake engineering amongst undergraduate civil engineering students,
2. To provide an opportunity to work on a hands-on project by designing and constructing a cost-effective building frame structure to resist earthquake excitations,
3. To build the awareness of the versatile activities at Earthquake Engineering Research Institute (EERI) among the civil engineering students and faculty as well as the general public and to encourage national and international participation in these activities.

3.1 Competition history

Ever since the first event in 2004, the SDC has broadened its scope and reach for eight years, with the latest event in 2011 taking place in conjunction with the 63rd EERI Annual Meeting in San Diego, California, USA [8]. The Student Leadership Council (SLC) of EERI is entrusted with the organization and conduct of the SDC every year. SLC is an umbrella organization composed of graduate students from EERI student chapters across the United States and Canada. As seen in Figure 1a, there has been a very steady increase in the number of participating teams and number of participants in general over the years, with 28 teams and over 200 participants in SDC 2011. This accounts for roughly 460% increase in the number of participating teams and is a measure of the success and commitment of the event (Figure 1).

Figure 2 shows the break-up of the year along the undergraduate career of the participants. Clearly, a very high majority of the students take part in the final year of their 4 year undergraduate career.

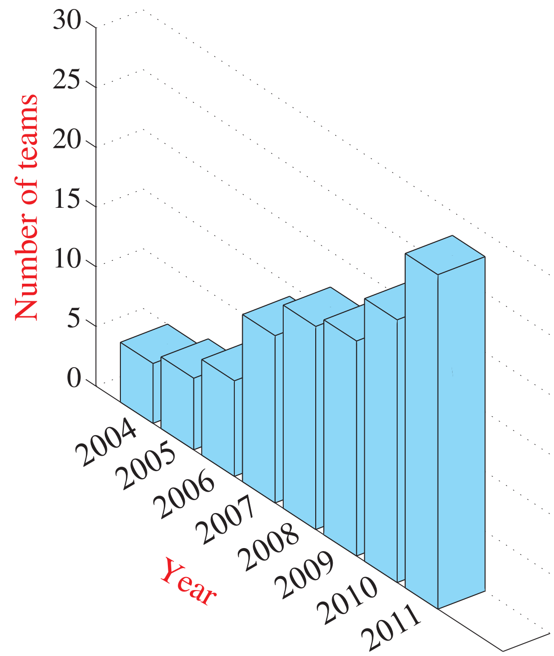


Figure 1: Evolution of the SDC – 2004 through 2011

This may be attributed to the fact that the major focus of structural engineering is inculcated in the third and fourth year in the form of analysis (static and dynamic) and design courses.

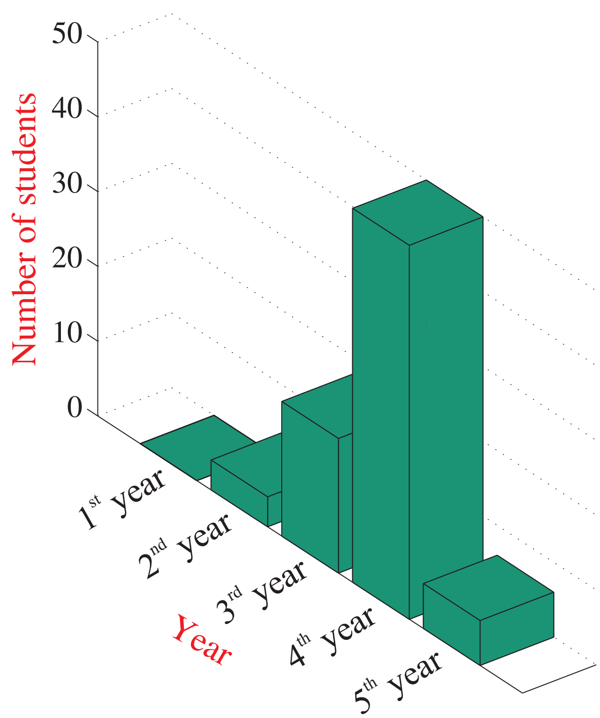


Figure 2: Demography of the participants in the SDC

3.2 SDC Structure

The fundamental premise behind the SDC is the design, analysis and conception of a multi storey balsa wood building frame that would eventually be tested on a shake table subjected to unidirectional ground motions. The SDC is a two day event comprising of several events. It begins with the teams giving short presentations about various aspects of their design, analysis predictions and unique aspects of their as-built structure including innovativeness. It continues with poster presentations highlighting yet again the significant contributions and important aspects of the structures constructed including details about the flow of forces, anticipated performance in terms of roof accelerations and drifts and some of the major constructability issues (Figure 3). The teams also come up with estimates for construction cost and revenue generated in terms of rentable space. The hallmark of the event involves testing of the structures to typically 2 or 3 ground motions, modified to push the structure to significant non-linear limits.

a) b)

Figure 3: a) Oral and b) poster presentation during SDC 2011, San Diego, California.

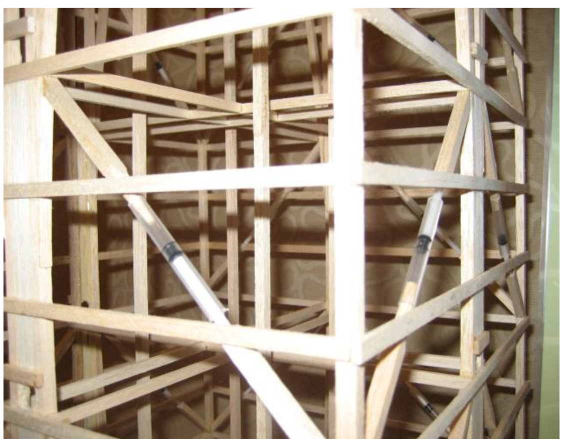
3.3 Scoring scheme

Participating teams are ranked based on their total score in the competition which is based on different components: oral and poster presentation, architectural design, seismic performance of the structure on the shake table, construction cost, and the annual revenue of the building. A panel of judges evaluates and scores the teams for oral and poster presentations as well as the architectural design. The judges are selected from the wide range of academic and industry professionals who attend the EERI Annual Meeting, which, in return, increases the interaction between the students and the professionals. The seismic performance of the building is calculated from the recorded roof acceleration and roof drift using the sensors that are attached to the structure. Each structure undergoes three historic earthquake motions simulated by the shake table, varying in severity from mild to extremely strong. The maximum acceleration and maximum drift are then converted into dollar values as seismic damage cost to the building. The other cost that is taken into account is the construction cost which is calculated based on the structure mass and the base footprint of the building. On the other hand, the annual revenue of the building is calculated using the rentable area times the average rental value of a square foot in an office building in the United States. The team that maximizes the annual revenue and minimizes the seismic and construction costs of the building is declared the winning team. Further details of the rules of the competition can be found in [6].

3.4 SDCs role in promoting technical competence and professional exposure

True to the title of the paper, this section explores the merit of the SDC in imbibing high level technical competence and professional exposure among undergraduate civil engineering students. The competition encourages the students to think about structural actions in terms of flow of forces and performance of the entire structure at the global and local member levels. The foremost of all the objectives in terms of technical competence is the exposure to the concept of structural dynamics and earthquake engineering which routinely tends to be a part of the graduate curriculum. SDC takes a leap by introducing participating students with the idea of ground motions, and response spectrum at the least. Emerging ideas of performance based earthquake engineering which involves design to meet specific performance objectives forms the forefront of the SDC. Finally, though not the least preferred, a lot of emphasis is placed on coming up with designs that are architecturally pleasing. SDC takes yet another step by encouraging the teams to come up with innovative damping systems. Figures 4a, 4b and 4c show examples of innovative damping devices adopted by select participating schools in previous SDC events.

In order to further the efforts in these lines, the SDC awards the *Egor Popov Award for Structural Innovation* and *Fazlur Rehman Khan Award for Architectural Design*. The former award is given to the team that makes the best use of technology and/or structural design to resist seismic excitations, while the latter one if conferred to the team whose building provides remarkable expression of architectural design and inherently integrates a sound structural design.


a)


b)

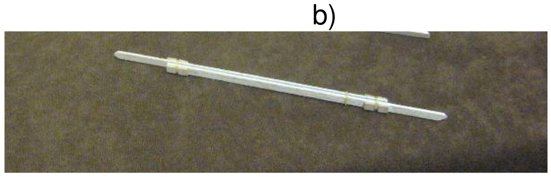

c)

Figure 4: a) A syringe viscous damper - Oregon State University, SDC 2009, Salt Lake City, Utah; b) Metallic friction damper, Technical University of Cluj-Napoca, Romania, SDC 2011, San Diego, California; and c) Friction damper, University of California Davis, SDC 2010, San Francisco, California.

SDC offers a wide range of professional exposure and benefits in addition to the sound technical competence mentioned in the initial part of this section. SDC provides tremendous exposure to the teams and the right forum to improve their oral presentation skills. It opens the doors to speak and interact with fellow undergraduate students from across United States and the world. Furthermore, the teams get a great opportunity to meet and interact with academicians and industry professionals due to its conduct in conjunction with the EERI Annual Meeting. This paves the way for their bright future, firstly in terms of molding them into full fledged professionals with the right amount of technical content and professional attitude and secondly opening their doors to graduate school or a fine industry experience that lies ahead. Above all, participation in the SDC inculcates team building exercise among peers and enhances their ability to work and interact in a competitive atmosphere. Thus, the SDC may be regarded to blend all the important aspects of structural engineering at the right stage in the undergraduate civil engineering curriculum.

3.5 Financial aspects

Costs associated with conducting the SDC include partial financial support for participating teams comprising of accommodation for teams, registration etc., and costs related to organizing the event itself. The latter comprises of costs associated with the venue and other logistics. The fiscal budget for the recently concluded SDC-2011 was about 50,000 USD for which the bulk of the funding came from the United States Federal Emergency Management Agency (FEMA) – Department of Homeland Security. Other sources of funding include sponsorships from the private sector. In addition to the partial funding provided by the competition, participating teams often tend to reach out to their respective departments in the schools they are associated with and/or local sponsors to secure funding for travel and procurement of construction material primarily. Further details about all aspects of the competition can be found at http://slc.eeri.org/seismic.htm.

4. CONCLUSIONS

The ultimate goal of an engineering program is to impart broad education and knowledge of contemporary issues necessary to understand the impact of civil engineering solutions in a global, societal, and environmental context. With tremendous boom in infrastructure around the world, it is extremely important that the current undergraduates who will shape the world in the future have the right mix of technical background and professional backing to design with minimal risk. Events such as the EERI Seismic Design Competition (SDC) provide the right platform by imparting these objectives at the right juncture in the civil engineering undergraduate program by integrating a wide array of disciplines. Apart from imparting technical knowledge in the areas of earthquake engineering and structural engineering in general, the competition offers a wide array of benefits in the form of personality development, project management and tremendous professional exposure, at the least. Several such programs must be designed and conducted at the regional and international level to steer the young minds in the right direction to build a sustainable future.

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