12th National Conference on Earthquake Engineering
Salt Lake City, Utah
27 June - 1 July 2022
Hosted by the Earthquake Engineering Research Institute

Interdisciplinary Undergraduate Research Experience for Earthquake Engineering Education

A.L. Vidot-Vega [1]

ABSTRACT

On January 7, 2020, the southwest of Puerto Rico was struck by a M6.4 earthquake that caused the collapse of several structures, including a 3-floor operational reinforced concrete school. While it is well known that the island is located on an active seismic zone, this event took by surprise and unprepared the affected communities, as the last significant earthquake dated 1918 and most attention in the island is directed towards recurrent tropical cyclones hazards. This event offers a unique opportunity to promulgate an earthquake awareness culture in the community and promote earthquake engineering within our students. This paper presents an undergraduate research case study where the students designed a vertical evacuation structure for a coastal community in Mayaguez, PR. The group was comprised of undergraduate students with different academic background: civil engineering, surveying and architecture. The objective was to foster interdisciplinary problem-solving skills and advance the knowledge of earthquake engineering principles in the students. The results from the project proved that when students from different background and perspectives work together, the solutions that arise are holistic and the knowledge acquired is deeper and better rounded.

Introduction

In 2004, the National Academy of Engineering (NAE) published a "Vision for the Future of US. Engineers" in which they make emphasis in the need to achieve integrated design solutions where interdisciplinary knowledge is required [1]. Lattuca et al. [2] summarized findings of several Engineering of 2020 projects to assess the completion of the NAE goals. They found out that engineering faculty strongly supported the idea that students should be asked to make connections across disciplines, but their reports on their courses, as well as from graduating seniors and alumni, reveal only modest emphasis on cross-disciplinary thinking and connection-making. They also indicated that faculty give only slight to moderate emphasis to applying and integrating knowledge from multiple engineering and from non-engineering fields, and graduating seniors agreed with this assessment. Their findings suggest that students who have ample opportunity to have interdisciplinary experiences and knowledge in authentic design projects are likely to develop both greater creativity and stronger engineering design skills. In this regard, Oskan and Neal Akowa [3] emphasized that real-world problems are usually incorporated in capstone or design courses that students take later in their engineering coursework. This leaves freshman students with less design or research experiences focusing on real-life problems. Another way that undergraduate students can use to connect with real-life problems is throughout research. This helps undergraduate students to learn problem-solving skills that translate to areas

[1] Professor, Dept. of Engineering Sciences and Materials, University of Puerto Rico, Mayaguez, PR 00680 (email: aidcer.vidot@upr.edu)

Vidot-Vega, A.L. Interdisciplinary Undergraduate Research Experience for Earthquake Engineering Education. *Proceedings of the 12th National Conference in Earthquake Engineering*, Earthquake Engineering Research Institute, Salt Lake City, UT. 2022.

beyond the classroom or laboratory [4].

Real-life problems for civil engineering students should be connected to natural disasters. The NAE in 2004 recognized that in a natural world scenario there are events originating beyond man's control. Therefore, the role of future engineers and new technologies become paramount to speeding a recovery from a disastrous event and to improve our ability to predict risk [1]. After a natural disaster, multiple disciplines need to come together to rebuild the damaged infrastructure using new paradigms [5]. In October 2018, the University of Puerto Rico received a Hispanic Serving Institution (HSI) collaborative award from the National Science Foundation (NSF) to develop an integrated curriculum on resilient and sustainable infrastructure. The project titled Resilient Infrastructure and Sustainability Education – Undergraduate Program (RISE-UP) aims to educate future environmental designers and engineers to design and build a more resilient and sustainable infrastructure for Puerto Rico [6]. This project aims also to provide students with opportunities for solving real-life problems focusing on natural disasters issues from an interdisciplinary perspective. Several research projects are developed during summer period for students that are part of this program. The team projects are formed from students of three different campuses of the University of Puerto Rico from different engineering majors and architecture. The idea is to foster communications and work among Architecture/ Engineering/ Construction (AEC) fields [7]. Case studies are a useful tool for research and teaching that focus on the transition between theory and practice [8]. This article presents and evaluates the experience under one of the projects in the area of earthquake engineering developed during the summer for RISE-UP.

Case Study: Vertical Evacuation Structure for Mayagüez, Puerto Rico

The case study selected was the conceptual design and evaluation of a possible structure for vertical evacuation in Guanajibo, Mayaguez, Puerto Rico. One of the goals of this research was that students acquired knowledge about earthquake risk and seismic design. It was also the perfect platform to put in practice lessons learned from the Earthquake Sequence occurred in January 2020 in Puerto Rico. Since December 28, 2019, Puerto Rico has suffered an ongoing series of over 9,400 earthquakes ranging in magnitude from 1.5-6.4. The biggest earthquake of the sequence occurred on January 7, 2020 (Mw 6.4).

Another goal was to provide the students with the experience of working on an interdisciplinary team exposed to real-life problems related to earthquake hazards. A team of 4 students was formed with students from Civil Engineering (1), Surveying (1) and Architecture (2). The research project was divided in six parts: (1) investigate current tsunami evacuation maps and seismicity in the area, (2) study the area to identify a possible location for the vertical evacuation structure, (3) study about vertical evacuation structures in other countries around the world and tsunami design considerations, (4) proposed several design ideas for the evacuation structure, (5) refine design based on a selected proposal based on earthquake and tsunami design considerations, (6) write a report and perform an oral presentation. Fig. 1 shows the evacuation maps that are currently available for one of the communities in Guanajibo, Mayagüez from the Puerto Rico Seismic Network- Tsunami Ready Program [9]. The students studied the area composed by two urbanizations, Guanajibo Homes and San Jose with a population close to 1400 persons. Most of the persons living in the area are senior citizens. The students research show that the existing evacuation routes are long, taking about one hour to reach the assembly point from the closest location. Evacuation times were estimated using the existing evacuation maps along with Goggle Earth.

Once the need for the vertical evacuation structure was recognized, the students investigate the area aiming to identify an adequate location for the vertical evacuation structure. Fig. 2 shows two possible site locations for vertical evacuation structures and the soil type maps for the Guanajibo area [10]. The soil type according to NEHRP is mostly type F and some area extending farthest from the coast are Type E. This type of soil needs special attention and present a challenge for the construction of the vertical evacuation structure. One of the proposed sites for the structure is too close to the ocean, but the options were limited as there is a river between both urbanizations and the land behind is a natural resource protected zone. In order to determine the height of the evacuation structure, expected maximum tsunami wave run-up for the area were needed. Fig. 3 presents a description of the effects of the 1918 tsunami at several locations along Puerto Rico's coast [11]. At Mayagüez, a tsunami run-up of 1.5 meters was registered which flooded the lower stories of buildings at the coastal areas. A 5.2 meters runup was reported in the town of Aguadilla (35 minutes from Mayaguez).

Figure 1. Evacuation maps for Guanajibo in Mayaguez (PR Seismic Network- Tsunami Ready Program)

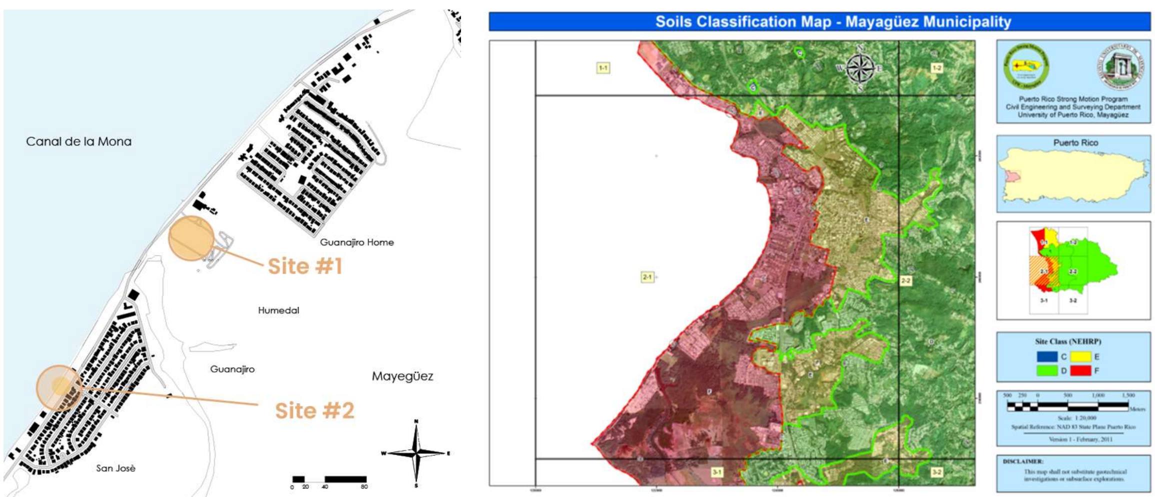

Figure 2. Site location and soil classification maps, Mayaguez [10]

Figure 3. Tsunami maximum waves and runups for west coast of Puerto Rico

According to the ASCE 7-16 [12], the required minimum elevation for a tsunami refuge area is the maximum tsunami inundation elevation anticipated at the site, plus 30% or 10 feet (3 meters) or one floor, whichever is greater. Following this recommendation, the students developed three different design proposals as shown in Fig. 4. A four-storey structure was selected and designed by the students. The last two floors are the ones used for evacuation purposes. The proposed structure corresponds to proposal design #1 with some changes (Fig.4). In this figure it is shown the structural model (without including guard rails, parapets and non-structural walls) and architectural renderings of the selected design. The idea behind this design concept was to have a multi-purpose structure. The students proposed a structure with space for small restaurants and activities taking advantage of the ocean view. None of the furniture will be static or fixed to the building. The collaboration between engineering and architecture students was evident as they made decisions based on structural earthquake design, tsunami considerations, accessibility issues, and aesthetics to create a practical design solution.

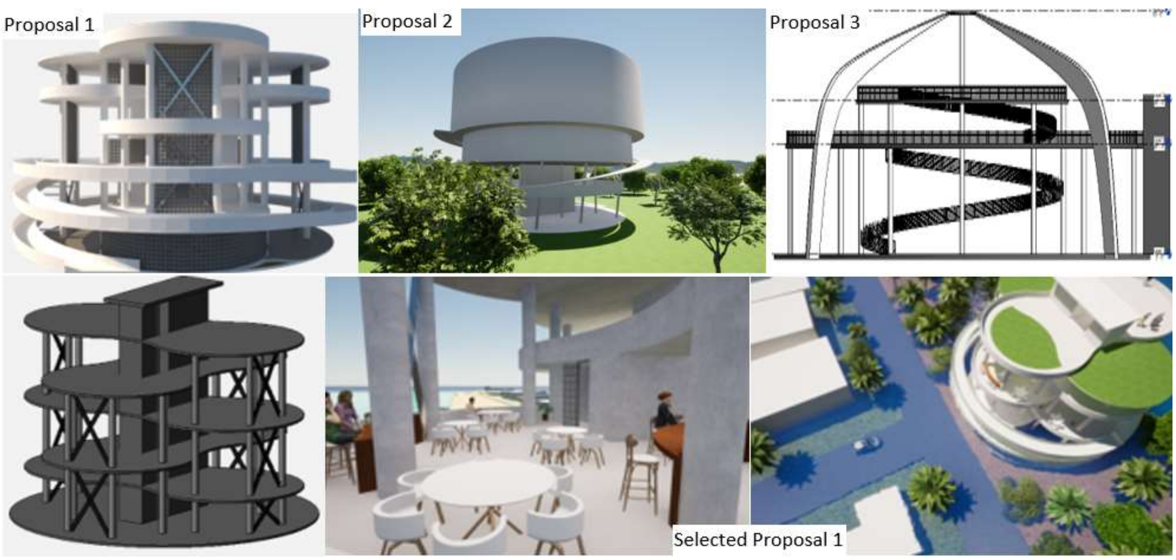

Figure 4. Proposed vertical evacuation structure for Guanajibo area, Mayaguez, PR

Conclusions

This article presented an example of a research case study for undergraduate students to learn about principles of earthquake engineering. The case study was designed to expose students to real-life problems affecting their communities and learn how can they contribute to reduce earthquake risk. The interdisciplinary student team composed of engineering, surveying and architectural students provided a sound solution for the design in which different perspectives were considered. An interdisciplinary project usually requires knowledge in areas that students have been not exposed on their courses, but the students proved that they can overcome the learning curve and be able to complete the research in a short amount of time. This case study serves as example of how similar projects can be incorporated into courses or for summer research to expose undergraduate students to earthquake engineering taking advantage from lessons learned after previous seismic events in their community. Also, it was a great example of how students can improve their writing and oral communication skills.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grants No. 1832468 and 1832427 (HSI program). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. The authors are greatly thankful to Dinorah Diaz-Rodríguez, Héctor Miranda-Sánchez, Carlos D. Pérez-Cedeño, and Jonathan J. Pérez-Rodríguez that were part of the interdisciplinary team participating in the project.

References

1. National Academy of Engineering. 2004. The Engineer of 2020: Visions of Engineering in the New Century. *The National Academies Press*. Washington, DC. https://doi.org/10.17226/10999.

2. Lattuca L. R., Terenzini P. T., Knight D. B., and Ro H. K. 2020 Vision: Progress in Preparing the Engineer of the Future, 2014. Washington, D.C.

3. Ozkan, D. S., & Neal Akowa, K. A. R. *Before Engineering: How do students consider social and technical dimensions when solving complex problems early in their academic engineering career? 2021 ASEE Virtual Annual Conference,* 2021. 10.18260/1-2—36739.

4. Petrella J.K and Jung A.P. Undergraduate Research: Importance, Benefits, and Challenges. *Int Journal Exercise Science,* 2008. 1(3): 91-95.

5. Lopez del Puerto C., Cavallin H. E., Perdomo J. L., Munoz Barreto J., Suarez O. M., and Andrade F. *Developing a Collaborative Undergraduate STEM Program in Resilient and Sustainable Infrastructure. ASEE Annual Conference & Exposition*, 2019. Tampa, Florida. 10.18260/1-2—32629.

6. Lopez del Puerto C., Cavallin H. E., Suarez O. M, Perdomo J. L., Munoz Barreto J., Vazquez, D.E., Andrade F., Guillemard L., and Troche O. Design and Assessment of Architecture/ Engineering / Construction (AEC) Curricula for Resilient and Sustainable Infrastructure. *ASEE Annual Conference & Exposition*, 2020. Tampa, Florida. #28616

7. Daza L. G., Cavallin H. E., and Lopez del Puerto C. *Developing Case Studies for a Repository for Resilient Infrastructure and Sustainability Education following a Natural Disaster.* 2 *ASEE Virtual Annual Conference Content Access*, 2021. 10.18260/1-2—36940

8. Breslin M. and Buchanan R. On the Case Study Method of Research and Teaching in Design. *Design Issues,* 2008. 24(1):36-40

9. Puerto Rico Seismic Network. Evacuation Maps. Tsunami Ready Program. http://redsismica.uprm.edu/English/tsunami/tsunamiprogram/prc/maps/west.php

10. Pando M., Ramos-Cabeza R, Lopez-Rodriguez R., Saffar A, Martinez-Cruzado J.S, Suarez L.E. Puerto Rico soils classification maps according to the 1994 National Earthquake Hazard Reduction Program. *Puerto Rico Strong Motion Program*, 2010, Civil Engineering and Surveying Department, University of Puerto Rico, Mayagüez

11. USC. Tsunamis from Puerto Rico and the Virgin Islands, 1967 Virgin Islands and 1918 Puerto Rico, University of Southern California, Tsunami Research Center website. 2005.

12. ASCE. Minimum design loads and associated criteria for buildings and other structures: ASCE/SEI 7-16. Reston, Virginia: Published by American Society of Civil Engineers, [2017]