Adopting an ACI/ASCE Competition as a Learning Tool in Civil Engineering Materials Class

Dr. Daniel Hochstein, Manhattan College

Dr. Daniel Hochstein is an Assistant Professor at Manhattan College and he received his PhD from Columbia University in 2013. He teaches civil engineering courses in the areas of engineering mechanics and materials, probability and statistics, and structural design. His research interests include studying the mechanical and thermal properties of lightweight concrete and performing accelerated weathering, durability, and aging tests on civil engineering materials.

Dr. Goli Nossoni, Manhattan College

Dr. Goli Nossoni is currently an Assistant Professor in the Department of Civil and Environmental Engineering at Manhattan College. She received her M.S. and Ph.D. from Michigan State University in Structural Engineering and Materials Science. In addition to her interest in engineering education, Dr. Nossoni specializes in the research area of materials especially concrete and corrosion of steel inside concrete.

Dr. Mohab El-Hakim, Manhattan College

Dr. El-Hakim is an assistant professor in Manhattan College - New York City campus. He is a licensed professional engineer in Ontario with nine years of industrial and academic experience. He is a sessional instructor in University of Waterloo and EPIC since 2011.

During his industrial experience, he worked on several infrastructure projects, some of which included airports, highways, and municipal roads. His technical background and project experience in infrastructure projects includes in-depth knowledge of the nondestructive and destructive testing of pavements, infrastructure condition surveys, and pavement investigations related to airports, highways, and municipal roads.

He worked on infrastructure evaluation, analysis, and design projects for the Ontario Ministry of Transportation; the Alberta Ministry of Transportation; the Saskatchewan Ministry of Transportation; and the cities of Hamilton, Calgary, Ottawa, and Wood Buffalo. These projects entailed the development of design and rehabilitation strategies for new and existing infrastructures, nondestructive testing, and the analysis of infrastructure conditions.

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Abstract

Knowledge in technical courses is enhanced through high-level active learning, which includes activities that integrate learned theory. Student-centered strategies, active participation of all parties – students and faculty– and clearly defined outcomes are promising approaches in teaching technical material. Students need critical thinking skills and creativity to develop effective solutions to complex technical problems and an active learning environment is useful for students to learn practical skills. This includes problem-based learning and student designed laboratory experiments.

The Civil Engineering Materials course at Manhattan College is a core course taken by all civil engineering students in the spring semester of the sophomore year or fall semester of the junior year. Traditionally this course covers a variety of civil engineering materials, their sources, manufacturing processes, and behavior under different loading conditions. The content of this course is flexible and includes a laboratory component. This is one of the core classes in which active learning techniques can be implemented successfully.

A term project competition inspired by the "Concrete Frisbee" competition held by colleges and universities across the country and world was introduced to four sections of the Fall 2016 and three sections of the Fall 2015 Civil Engineering Materials course. In alignment with Constructivist Learning Theory, students work in groups, and engage in group discussion and hands-on activities. Each group is asked to design their green concrete using recycled materials and construct a concrete Frisbee. Students are graded based on many factors such as aesthetics, weight, distance traveled, creativity and their written report.

The success of the project is evaluated using a post in-class survey instrument. The assessment is based on student feedback evaluating their knowledge of sustainable concrete materials. The project was first incorporated in the fall semester of 2015 and it was again used with slight modifications in the fall semester of 2016. Along with these slight modifications, a student survey was introduced in the Fall 2016 semester to assess the success of the project. The results of the survey indicate that the project was effective. Additionally the course instructors have decided to reuse the project in future semesters with several additional modifications.

Introduction

Various types of concrete Frisbee competitions have been used at colleges and universities across the country and world such as ACI Malaysia chapter [1] and PSWE/ASCE [2] as a fun and creative way for students to learn about concrete design. These competitions have been both incorporated into existing civil engineering courses and run as extracurricular activities through student groups.

Recently several faculty members at Manhattan College have introduced a similar project with a twist to incorporate sustainability concepts in concrete technology into a course named Civil Engineering Materials. The motivation behind the decision to add this project was to assign a course project that: 1) provided the students with a hands-on way to learn about concrete mix design and the sustainable aspects of concrete, 2) required the students to work in teams and 3) allowed the students to be creative and think outside the box. These were set as three goals of the term project and their success was evaluated through the final in class survey.

Students learn best through active learning and high-level learning includes hands-on activities that integrate learned theory into meaningful experiments. Student-centered strategies, active participation of all parties – students, faculty and administrators – and clearly defined outcomes are promising approaches in teaching new materials [3] [4] [5] [6] [7] [8]. Research has also shown that competitions can be used as effective student-centered learning method [1]. The competition promotes innovation and group unity, while teaching students important lessons on expected standards of professional courtesy and the role of the peer review process in practice.

Thinking outside the "technical" box, ability to work in multi-disciplinary teams, leadership and understanding the different scopes of sustainability across their discipline are the skills that should be incorporated in the Civil Engineering core courses to prepare the students to work on interdisciplinary teams to solve the complex problems of the future [9].

Civil Engineering Materials Course

The purpose of a course in civil engineering materials is to expose the students to the various materials that are used in civil engineering including aggregates, steel, concrete, wood, and asphalt. The course format at Manhattan College is a hybrid lab/lecture course in which the students split their time between lecture and laboratory sessions. For the laboratory experiments, the class is divided into groups of approximately four students and each group is required to perform each experiment as a team and to prepare a group lab report summarizing the testing procedure, theory, and equipment as well as simple analysis of the collected data. All junior level students are required to take this three credit course and it is generally the first course in which the students are exposed to concrete mix design. As indicated from the survey results, only one of the students had previously taken a course involving concrete mix design and 47% of the students had not previously mixed or placed fresh concrete.

Project Description

A requirement of the Civil Engineering Materials course at Manhattan College has been for students to participate in a group project at the end of the semester. Students submit a final report and present their project to the class in a 10-minute oral presentation. Over the past several years, a variety of topics have been used, including a research project in which the students present on a civil engineering laboratory testing procedure or material that has not been covered in the course

and a project focused on sustainability where the groups design a green concrete and evaluate its mechanical properties [10]. The decision was made in the Fall 2015 semester to introduce a lightweight concrete Frisbee project.

The stated project requirement was for each group to construct a circular Frisbee using lightweight concrete that incorporates at least one recycled material. Additionally, the Frisbees were required to have a diameter of 8 – 10" and they were allowed to contain reinforcement either in the form of mesh or discrete fibers. The students were given the project description around the midterm of the semester. This is the time when the students are learning about the concrete mix design procedure in the lecture portion of the course and mixing/testing concrete in the laboratory portion. The students were then given several weeks to develop their target Frisbee specifications (thickness, density, and diameter) and concrete mix design. The groups cast their concrete Frisbees and allowed them to cure for 2-3 weeks before the competition.

In the fall semester of 2016 a total of 59 students were enrolled in four sections of the Civil Engineering Materials course that were taught by two different instructors (each instructor taught two sections). The competition consisted of the 59 students being divided into 16 groups and it was held at an athletic park with an artificial turf field. This provided an open space with no obstructions and a relatively soft landing surface for the Frisbees. The groups were each allowed an initial throw with their Frisbee and only allowed to throw that Frisbee a second time if the Frisbee did not receive any significant damage on the first throw. Additionally several groups had casted two Frisbees and those groups were allowed to throw this Frisbee for their second throw. The competition was judged based on the farthest distance thrown, not including any distance that the Frisbee rolls or bounces once it initially hits the ground.

The final grading criteria for the term project was: design and construction - 10%, competition results - 15%, oral presentation - 25%, and final report - 50%. Design and construction evaluated the creativity that each group demonstrated in the selection of their recycled material as a replacement for coarse and fine aggregate or reinforcing mesh and the degree of difficulty of their construction method. The competition results included the aesthetics of the final concrete Frisbee, its weight, and the distance thrown during the competition. Each group gave a ten minute presentation on the last day of class and submitted a report on the day of the final examination.

Concrete Frisbee Construction

Approximately three weeks before the competition, the students constructed their concrete Frisbee. The groups were provided with Portland cement powder and were responsible to bring their own recycled aggregate or reinforcement mesh, and mold. The recycled materials that the groups used as aggregate and reinforcement included: a loofah sponge, steel wool, fishing wire, eraser shavings, aluminum can tabs, shredded aluminum cans, polystyrene cups, rubber bands, polyurethane foam, a badminton racket head, badminton racket strings, aluminum foil, cork, steel wire, glass, shaved chalk, and mini ping pong balls. The majority of the groups used an existing

Frisbee as the mold; however one group used a 3D printer available on campus to create their own mold.

Concrete Frisbee Results

A summary of specifications of each group's concrete Frisbee and the competition results are shown in Table 1. Figures 1-4 show several Frisbees both before and after the competition. Out of 16 total groups, six Frisbees were damaged too severe to allow a second throw. However, 5 groups casted a backup Frisbee in case the 1st Frisbee is damaged during the unmolding process. These groups were allowed to utilize their back up Frisbees in the 2nd throw. Nine groups were able to utilize the same Frisbee for the 2nd throw and eight of these groups achieved a further distance on their 2nd throw. This confirms comments that students made after the competition in which they described that they felt it was awkward throwing the concrete Frisbee both because it was thicker and heavier than a traditional Frisbee. This suggests that in future competitions it may be an advantage for students to construct multiple Frisbees. One Frisbee will be used for the competition and the students can use the others for practice throws to get accustomed to throwing a concrete Frisbee. Group #10's first Frisbee broke apart while it was being thrown; as a result the distance thrown was recorded as 0 ft.

Table 1: Concrete Frisbee Specifications

Group #	Weight (lbs)	Diameter (inch)	Density (pcf)	Throw #1 (ft)	Throw #2 (ft)	Average Throw (ft)
1	1.3	8.5	82	51.7	56.5	54.1
2	4.3	10	94	27.5	-	27.5
3	3.6	10	80	29.5	32.0	30.8
4	2.6	9	46	29.3	44.3	36.8
5	5.2	10	94	51.0	46.0	48.5
6	1.2	8.5	71	64.5	89.8	77.1
7	3.5	10	103	43.5	43.8	43.6
8	1.9	9	84	54.0	59.5	56.8
9	1.7	8	65	62.6	26.5	44.
10	5.9	9	133	0	58.6	58.6
11	5.0	10	137	40.25	62	51.1
12*	2.5	10 (8)	127	66.75	-	66.75
13*	0.9	10 (8)	55	116	116.6	116.3
14	3.5	9	126	41.3	-	41.3
15	2.15	9.75	165	60.25	-	60.25
16	1.03	8	45	80.6	79.6	80.1

* Frisbees cast as a hollow ring, inner diameter in parenthesis.

Figure 1: Concrete Frisbee before the competition

Figure 2: Concrete Frisbee that broke after the 1st throw

Figure 3: Concrete Frisbee that broke after the 2nd throw (edge broke off)

Figure 4: Concrete Frisbee that cracked after the 2nd throw

Figure 5: Concrete Frisbee with the Furthest Distance Thrown (116')

Figure 6: Concrete Frisbee Cast in a Ring Shape

Survey Results

The success of the project was assessed by evaluating the students' interest and level of engagement in the project. 74% percent of the students either agreed or strongly agreed with the statement that "the concrete Frisbee project was best part of the course". The high level of agreement with this statement was attributed to the nature of the project which allowed the students to work on a hands-on project that required them to be creative and learn technical concepts at the same time. Additionally, 78% of the students either agreed or strongly agreed with the statement that "the project was both complex and exciting". This showed that the students were not merely rating the project highly because it they thought it was fun; instead they recognized the technical complexity of the project's goal to construct a Frisbee light enough to fly, but also possess sufficient strength and durability. One of the main goals of the concrete Frisbee project was to provide the students with a hands-on way to learn about concrete mix design. 68% of the students responded that they learned more about the concrete mix design process through the project than they did in the lectures. This demonstrated that they project was successful in teaching concrete mix design to both the auditory and visual learners that perform better in lecture classes and kinesthetic learners that perform better from hands-on projects [11].

Future Concrete Frisbee Competitions

Due to the overwhelmingly positive feedback, this project will be reused in future semesters with two major changes: 1) to assign the project earlier in the semester so that the students have time to construct several Frisbees and be able to make changes and improvement to their target specifications, mix designs, and construction techniques and 2) an updated scoring system to rank

the groups during the completion. The new scoring system is adopted with modifications from the PSWE/ASCE competition[2]. The current scoring system only ranked the groups on the distance thrown and did not consider other factors. Many students felt that it was unfair that the concrete Frisbee that was thrown the farthest distance during the competition also shattered in impact. Additionally, the distance thrown is dependent on both the athleticism of the individual that actually throws the concrete Frisbee and the quality of the group's design. A solution is to score each group based on 4 categories: Distance Thrown (25 points), Weight (30 points), Durability (30 points), and Aesthetics (15 points). All of the categories except for aesthetics will be scored quantitatively, whereas aesthetics will be evaluated qualitatively. The weight and durability categories are awarded the most points since they directly measure the quality of a group's design.

The group with the farthest distance thrown will be awarded the full 25 points for distance thrown and all of the other groups will be awarded a corresponding percentage of 25 points based on the ratio of their distance to the farthest distance.

$$Points\ for\ Distance\ Thrown = \frac{Distance\ Thrown}{Farthest\ Distance\ Thrown} \times 25$$

The group with the lightest concrete Frisbee will be awarded the full 30 points for weight and all of the other groups will be awarded a corresponding percentage of 30 points based on the ratio of the lightest concrete Frisbee weight to their concrete Frisbee's weight.

$$Points\ for\ Weight = \frac{Weight\ of\ Lightest\ Frisbee}{Weight\ of\ Frisbee} \times 30$$

The durability category will be evaluated based on the weight of concrete that is lost after the concrete Frisbee is thrown and lands. If the Frisbee breaks into several pieces, the largest single price will be regarded as the Frisbee and the total weight of all the smaller pieces will be the weight lost. A weight ratio will be calculated for each concrete Frisbee and the group with a weight ratio closet to 1.0 will be awarded the full 30 points for durability. All of the other groups will be awarded a corresponding percentage of 30 points based dividing the weight ratio of their concrete Frisbee to the weight ratio of the most durable concrete Frisbee.

$$Weight\ Ratio = \frac{Weight\ of\ Concrete\ Frisbee\ After\ Competition}{Weight\ of\ Concrete\ Frisbee\ Before\ Competition}$$

$$Points\ for\ Durability = \frac{Weight\ Ratio\ of\ Frisbee}{Weight\ Ratio\ of\ Most\ Durable\ Frisbee} \times 30$$

The aesthetics category will be evaluated based on the following factors: visual appearance, uniformity in shape, and surface roughness. Each one of these three factors will be individually scored on a scale from 1 – 5.

Several groups commented in their reports that they felt time constraint was an issue with the project. Specifically, they would have liked the project to have been introduced earlier in the course which would have allowed them time to make several trial concrete Frisbees so that they could have iterated through several Frisbee designs, concrete mix designs, and construction techniques. Future iterations of the project may also include the students casting test specimens from their lightweight concrete and performing tests to determine mechanical properties such as compressive strength and impact strength.

Conclusions

The concrete Frisbee term project, which was introduced into the Civil Engineering Materials course at Manhattan College, provided students with a hands-on project to learn about concrete mix design, sustainable concrete practices, and lightweight concrete. The student survey results indicate that the project was effective in achieving the stated goals. After reviewing the results of the competition held in the Fall 2016 semester the course instructors have agreed to use the project again in future semesters due to the overwhelmingly positive feedback. Several modifications are suggesting in order to improve the competition aspect of the project. This includes making significant changes to how each group is scored during the competition. During the competition in the Fall 2016 semester the groups were only evaluated on the distance traveled and in future competitions it is proposed that the students additionally are evaluated on durability, weight, and aesthetics.

References

[1] R. Hamid, S. Baharom, M. R. Taha and L. K. Kadaruddin, "Competition as an Innovative Student-Centered Learning Method for Open-Ended Laboratory Work," *Procedia-Social and Behavioral Sciences,* no. 102, pp. 148-152, 2013.

[2] ASCE/PSWC, "The ASCE Pacific Southwest Conference (PSWC) Students' Competition 2017 Specifications," 2017. [Online]. Available: http://pswc2017.weebly.com/uploads/7/9/2/4/79241790/concrete-frisbee.pdf.

[3] National Research Council: Committee on Criteria and Benchmarks for Increased Learning from Undergraduate STEM Instruction, Improving Undergraduate Teaching in Science, Technology, Engineering and Mathematics, R. A. McGray, R. L. DeHaan and J. A. Schuck, Eds., Washington, DC: National Academy Press, 2003.

[4] National Research Council: Committee on Development in the Science of Learning and Committee of Learning Research and Educational Practice, How People Learn: Brain, Mind, Experience, and School: Expanded Edition, A. L. Brown, R. R. Cocking, M. S. Donovan, J. D. Bransford and J. W. Pellegrino, Eds., Washington, DC: Natiuonal Academy Press, 2000.

[5] National Research Council: Committee on Recognizing, Evaluating, Rewarding, and Developing Excellence in Teaching of Undergraduate Science, Mathematics, Engineering and Technology,

Evaluating and Improving Undergraduate Teaching in Science, Technology, Engineering and Mathematics, M. A. Fox and N. Hackerman, Eds., Washington, DC: National Academy Press, 2003.

[6] National Research Council: Committee on Undergraduate Science Education Center for Science, Mathematics, and Engineering Education, "Science Teaching Reconsidered: A Handbook," National Academy Press, Washongton, DC, 1997.

[7] National Research Council: Committee on Undergraduate Science Education Center for Science, Mathematics, and Engineering Education, "Transforming Undergraduate Student Education in Science Mathematics, Engineering and Technology," National Academy Press, Washington, DC, 1999.

[8] National Research Council: Committee on the Fundamental of Assessment, Knowing What Students Know: The Science and Design of Educational Assessment, J. W. Pellegrino, N. Chudowsky and R. Glaser, Eds., Washington, DC: National Academy Press, 2001.

[9] A. El-Zein, A. Airey, P. Bowden and H. Clarkeburn, "Development of a Course on Environmental Sustainability, Ethical Decision-making and Communication Skills in Engineering," in *International Conference on Engineering Education*, 2007.

[10] G. Nossoni, "An Innovative Way to Teach Sustainability in Civil Engineering Material Class," in *ASEE Annual Conference & Exposition*, Indianapolis, Indiana, 2014.

[11] R. M. Felder and L. K. Silverman, "Learning and Teaching Styles in Engineering Education," *Engineering Education*, vol. 78, no. 7, pp. 674-681, 1988.