An Innovative Way to Teach Sustainability Concepts in Construction Materials Course

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Introduction

Construction management programs have an important role in sustainability education for their graduates as they produce future workforce for construction industry, one of the major industries, which influences our economy and natural environment. Due to limited natural resources and increased environmental awareness, construction professionals are increasingly expected to develop sustainable solutions to infrastructure and technology problems. However, they may find themselves inadequately prepared to provide sustainable solutions. A study by Bhattacharjee et al. (2012) found that only one third of the Associated Schools of Construction (ASC) member universities offer individual courses on sustainable construction. Additionally, American Council of Construction Education (ACCE, 2016) states "understand the basic principles of sustainable construction" as one of the 20 Student Learning Outcomes (SLOs) for accredited Bachelor of Degree programs in construction. Therefore, a paradigm shift is necessary to educate students to recognize sustainability as a changing constraint in construction.

As construction industry demands for graduates with broader understanding of impact of construction projects on environment and overall quality of life, universities have tried to come up with innovative ways to teach students with knowledge of sustainability concepts. However, due to already full construction management curriculum it has been a challenge to equip students with various sustainable solutions. One of the solutions to this constraint is to introduce sustainable material concepts into an existing core course while maintaining the original course objectives. Therefore, the aim of the proposed study is to integrate sustainability concepts in the Construction Materials course through an innovative term project (called as Green Concrete) dealing with the creative use of recycled materials in concrete. Green Concrete project covers one of the major topics of sustainable construction which is building infrastructure using materials which can reduce the impact on the environment.

Background of Sustainable Construction

Sustainable construction indicates that buildings are well designed, constructed, operated and then demolished in an environmentally friendly and energy efficient manner (Bosch and Pearce, 2003). Guy and Kibert (1998) defined sustainable construction as concepts that prevents environmental degradation and utilizes resources efficiently so that the environmental, economic, and social benefits justify the environmental degradation created through the life cycle of buildings. Nicholson (2004) defined sustainability as representing a balance that accommodates current human needs without diminishing the health and productivity of natural systems, and without diminishing the ability of future generations to accommodate their own needs.

Sustainable construction brings many benefits to our society, environment and economy. Ahn et al. (2009) summarized benefits of sustainable construction at both social, environmental and economic levels. The construction industry actively implements sustainable rating systems such as Leadership in Energy and Environmental Design (LEED) to accomplish benefits of sustainable construction. The Environmental Protection Agency (EPA) also address nation's environmental

policies and worked with the Department of Energy (DOE) for developing programs, rules and laws to deal with the environment and encouraged sustainable construction.

According to the US Energy Information Administration (EIA, 2012), US consumed 19% of world's energy in 2010. Primary energy (41%) in the US was consumed by the buildings sector, compared to 30% by the industrial sector and 29% by the transportation sector. Construction programs in the US play a vital role in sustainable education because they can impact vast consumption of energy and resources in the US. Bhattacharjee et al. (2012) conducted systematic search of the curricula of construction programs offered by the Associated Schools of Construction (ASC) member universities to identify courses on sustainable construction. The results from this study indicated the lack of general consensus on the content and delivery method of the courses associated with sustainable construction.

According to Nossoni (2014), sustainability is a perspective which should be introduced in early classes. Price and Aidoo (2013) introduced sustainable design principles in freshman civil engineering design course. The primary objective of this study was to increase students' awareness of sustainable design through the introduction to sustainability concepts, such as the triple bottom line, life-cycle assessment, and carbon footprint, through discussion of concrete as a construction material and case studies of building construction. Pre- and post-surveys confirmed an increase in study awareness and understanding of sustainable design concepts. Bielefeldt (2011) discussed an alternative approach for incorporating sustainability in first year courses as a module. Upper level courses can then cover more technical topics which can be mapped to the sustainability concepts learned in the lower level courses.

Ahn et al. (2009) investigated the level of construction students' familiarity and interest regarding sustainability in the built environment, their ability to identify recognizable sustainable rating systems, the important areas of sustainable knowledge and factors affecting students' attitude toward sustainability. It was found that construction students perceived that they had a relatively a high level of familiarity with sustainable construction and sustainability. LEED was recognized as the most widely used sustainable construction rating system by construction students. Several factors such as professors teaching toward sustainability and courses associated with sustainable development were perceived to affect students' attitude toward sustainability.

Siddiqui et al. (2012) reported the integration of sustainability in the curriculum through a capstone project. The capstone project focused on the impact of sustainable design choices on the construction management aspects such as time, cost, quality and safety. The results from this study indicated that the course was a huge success from the students' perspective as it exposed them to a relevant body of knowledge that was not in their original curriculum.

Course Structure

The Construction Materials course is typically one of the core courses that all construction management students take in the junior year at Illinois State University (ISU). This course allows students to gain knowledge about fundamentals of different construction materials, strength of material and standardized testing procedure. This course is offered every fall and spring semester. The course meets twice per week for 110 minutes for 15 weeks. This is a combined lecture and

laboratory-based course in which three-quarter of the semester consisted of five lab activities during which students learn about sample preparation and testing in compression, tension, flexure and shear modes. Entire class was divided into four groups consisting of five to six students. Specifically, topics covered in this course were material testing introduction, masonry, Portland cement concrete, asphalt materials, alternative concretes, steel and wood. The following is a tentative listing of lab activities: density, compression testing of concrete and wood, flexure testing of wood and concrete, tensile testing of metals, wood and concrete, and a wood adhesive activity. The laboratory experiences are designed to be completed within the allotted time in the class hours.

The required tasks in this course are quizzes, laboratory reports and final presentation. Quizzes are given frequently in this class in order to help measure comprehension of the lecture and reading material. Most of the quizzes required reading material or watch posted audiovisual and complete questions. Quizzes were taken online through Sakai learning management system (called as ReggieNet) or in the class in paper format. Laboratory activities were assessed through reports related to laboratory activities and final presentation. Additionally, out-of-lab activities were provided occasionally. The purpose of out-of-lab activity was to utilize time when students are not working in the lab and provide students with background information related to laboratory report questions. At the end of each lab activity students prepared and submitted laboratory report. Each individual student was required to submit his/her own report via ReggieNet by due date.

Green Concrete Project

The sustainability concepts is introduced to students within a project in the Construction Materials course entitled 'Green Concrete' project. In this project, students begin after mid-semester with extensive literature review to come up with the most interesting and novel idea. Then, engage in research to design their Green Concrete using recycled materials, industrial waste and by-products. Students work together in groups to perform all the steps of the project from design to manufacturing and testing. Each group is also required to build laboratory scale samples, conduct compressive and tensile strength testing, determine cost and propose a real-world application for their Green Concrete, based on the experiments. Students are also given the opportunity to improve their written and verbal communication skills by delivering a final report and class presentation, respectively. Approximately, half of four classes and two full classes (440 minutes) were devoted for literature review, discussion, sample preparation and testing required for Green Concrete project per semester. Additionally, in the last class student groups made project presentations. Overall, during the Green Concrete project students learn how construction materials can be made more environmental friendly and economical.

Student Learning Outcomes

The Green Concrete project learning outcomes are formulated thoroughly to target a higher level of cognitive achievement in four of the outcomes listed in the SLOs by ACCE (2016), i.e., "analyze methods, materials, and equipment used to construct projects," "understand the basic principles of sustainable construction," "create written communications appropriate to the construction discipline," and "create oral presentations appropriate to the construction." Specifically, following are the student learning outcomes of this study:

- Understand the concept of concrete design better through hands-on activity.

- Identify successful sustainable material (Green Concrete) through experimentation.
- Create new product by using recycled or waste material in concrete.
- Understand how the use of Green Concrete can yield both sustainable and cost-effective solutions.
- Improve written and verbal communication skills.

Student Assessment Data Collection

The population of this study comprised of undergraduate students enrolled in one fall and one spring semester. Based on the enrollments, each semester had 24 students and as per the class size, students were divided in four groups containing six students. The success of the Green Concrete project was evaluated through two different aspects: student perspective on the project and student performance. Student perspective was evaluated through the course evaluation and survey questionnaire. The specific survey questions are as follows:
Q-1 Green Concrete project helped you in understanding sustainability concepts.
Q-2 Hands-on-activities through Green Concrete project increased student participation and improved student learning in this course.
Q-3 In the future, this course should continue Green Concrete project.
Q-4 Green Concrete project presentation and report improved your learning in this course.
Q-5 I am able to accurately define what is meant by sustainable design practice in construction projects.
Q-6 The lessons in this course provided me with an awareness of sustainable design practices.
Q-7 I tried to relate material covered in lecture(s) to group project assignment.
Q-8 I fairly contributed in the sample preparation part of the lab project.
Q-9 I fairly contributed in the sample testing part of the lab project.
Q-10 I fairly contributed in the report writing part of the lab project.

Each question was rated on the scale of 1 to 5, 1 representing strong disagreement, 3 representing the neutral or not sure response and 5 representing the strong agreement. All the students were asked to complete the survey at the end of the course. The responses of students on the survey had no impact on student's grade. All the responses were kept confidential. The collected data was analyzed for evaluating perceptions of students about Green Concrete project. The questions were focused on the learning in Green Concrete project. All the ten questions of survey emphasized on impact the Green Concrete project work had on the student's learning about sustainability concepts. The purpose of survey questionnaire was to know whether the students actually were able to take advantage of Green Concrete project and also whether each group member contributed to the project in best possible way or not. Additionally, following three separate questions were given for getting written comments and feedback from students:
Q 1 Discuss the challenges you had to face or breakthrough during this project.
Q 2 Write how this project can be done differently in the future.
Q 3 Please provide any other comment or feedback on Green Concrete Project.

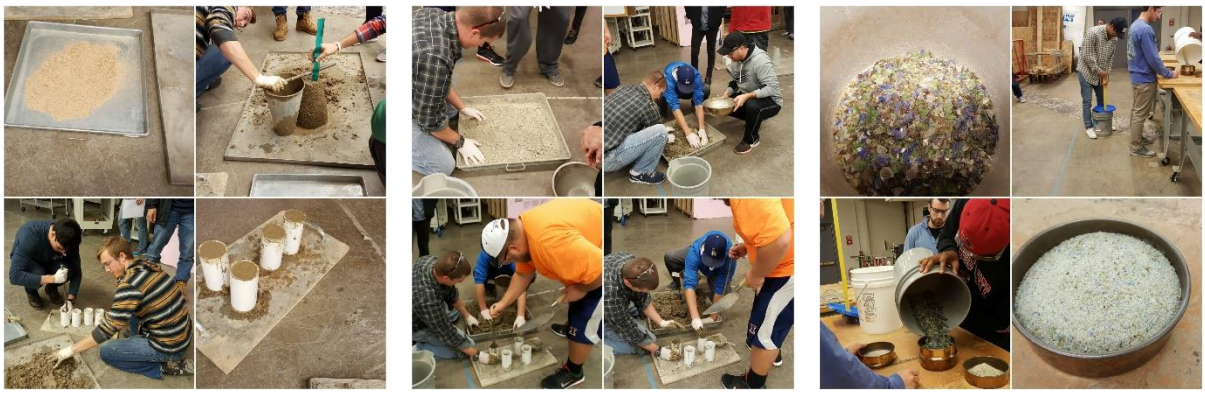
Findings and Discussion

In the grade distribution 15% is assigned to Green Concrete project activity and remaining 85% is assigned to other learning activities such as quizzes, exams and five lab reports. Out of 15%, 10%

is assigned to Green Concrete project report and 5% is assigned to oral presentation. Student performance in Green Concrete project oral presentation was evaluated using the rubric presented in Table 1. Instructor found that few individual students showed above average performance compared to their peers in the same group. However, overall performance of all the groups was satisfactory in both reports and presentations. Also, based on his teaching experience, instructor found that students were more engaged and enthusiastic during Green Concrete project. Students used different waste materials such as saw dust, demolished concrete, scrap tire and glass for preparing Green Concrete samples, as shown in Figure 1. After 7 days of curing, Green Concrete samples were subjected to loading until failure for evaluating compressive and tensile strength values (Figure 2).

Table 1: Evaluation Rubric for Oral Presentation of Green Concrete Project in the Construction Materials Course

CRITERIA	4	3	2	1
EYE CONTACT	Holds attention of entire audience with the use of direct eye contact, seldom looking at notes.	Consistent use of direct eye contact with audience, but still returns to notes.	Displayed minimal eye contact with audience, while reading mostly from the notes.	No eye contact with audience, as entire report is read from notes.
BODY LANGUAGE	Movements seem fluid and help the audience visualize.	Made movements or gestures that enhance articulation.	Very little movement or descriptive gestures.	No movement or descriptive gestures
POISE	Student displays relaxed, self-confident nature about self, with no mistakes.	Makes minor mistakes, but quickly recovers from them; displays little or no tension.	Displays mild tension; has trouble recovering from mistakes.	Tension and nervousness is obvious; has trouble recovering from mistakes.
ENTHUSIASM	Demonstrates a strong, positive feeling about topic during entire presentation.	Occasionally shows positive feelings about topic.	Shows some negativity toward topic presented.	Shows absolutely no interest in topic presented.
ELOCUTION	Student uses a clear voice and correct, precise pronunciation of terms so that all audience members can hear presentation.	Student's voice is clear. Student pronounces most words correctly. Most audience members can hear presentation.	Student's voice is low. Student incorrectly pronounces terms. Audience members have difficulty hearing presentation.	Student mumbles, incorrectly pronounces terms, and speaks too quietly for a majority of students to hear.
SUBJECT KNOWLEDGE	Student demonstrates full knowledge by answering all class questions with explanations and elaboration.	Student is at ease with expected answers to all questions, without elaboration.	Student is uncomfortable with information and is able to answer only rudimentary questions.	Student does not have grasp of information; student cannot answer questions about subject.
ORGANIZATION	Student presents information in logical, interesting sequence which audience can follow.	Student presents information in logical sequence which audience can follow.	Audience has difficulty following presentation because student jumps around.	Audience cannot understand presentation because there is no sequence of information.
QUALITY OF PRESENTATION	Quality of slide is excellent; every slide is interesting, creative and informative with balanced amount of information	Good quality of slides.	Average quality of slides.	Very poor quality of slides.
MECHANICS	Presentation has no misspellings or grammatical errors.	Presentation has no more than two misspellings and/or grammatical errors.	Presentation has three misspellings and/or grammatical errors.	Student's presentation has four or more spelling and/or grammatical errors.
PROFESSIONAL DRESS	Student wears professional dress			Students wear shorts and flip flops/casual dress



(a) (b) (c)

Figure 1: Students preparing Green Concrete samples by using (a) saw dust, (b) demolished concrete, and (c) glass

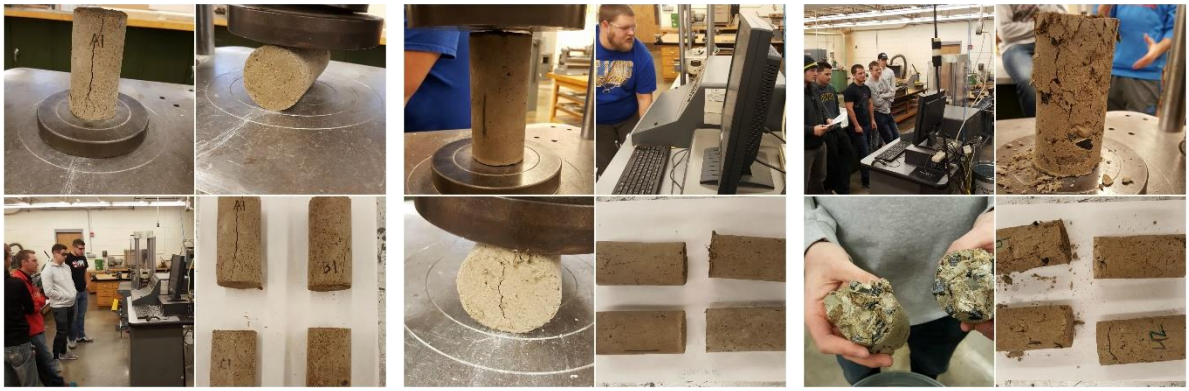


Figure 2: Different groups conducting compressive and tensile strength tests on Green Concrete samples

As discussed earlier, at the end of Green Concrete project students were given questionnaire. The responses of 48 subjects in questionnaire are presented in Table 2. Based on responses to Question#1 and #5 presented in Table 2, it is evident that more than 75% subjects gave a response of 4 or 5 (moderately or strongly agree) which indicates that Green Concrete project helped students in understanding sustainability concepts. The responses to Questions#2, #4, #6 and #7 indicated that all subjects agreed that hands-on-activities through Green Concrete project work increased students participation and improved learning in this course by relating lectures to lab project. Learning assessments such as presentation and report also enhanced learning and they became aware of sustainable design practices. The response to Question#8, #9 and #10 indicated that more than 79% students participated fairly in the sample preparation, testing and report writing part of Green Concrete project.

Course evaluation and feedback was also positive and some of the students expressed that they enjoyed hands-on-learning a lot. One student wrote “I think it went very well and was definitely more rewarding and a better way to have a final.” Students also liked the innovation and competition aspect of this project which enhanced team work skills. Few students also provided comments for future improvements in the Green Concrete project. For example, one student wrote “I am sure most groups choose similar green materials year after year, but having a list of options

or possibilities may be helpful." Few students were also in favor of extending the time frame of the project. Overall, students were positive towards Green Concrete project.

Table 2: A Summary of Students's Responses to Survey Questionnaire

Question#	**# of subjects with grading of 1 or 2 (Disagree) [%]**	**# of subjects with grading of 3 (Neutral) [%]**	**# of subjects with grading of 4 or 5 (Agree) [%]**
Understanding Sustainability			
1) Green Concrete project helped you in understanding sustainability concepts.	2 [4%]	10 [21%]	36 [75%]
5) I am able to accurately define what is meant by sustainable design practice in construction projects.	0 [0%]	10 [21%]	38 [79%]
Hands-on Activity Value			
2) Hands-on-activities through Green Concrete project increased student participation and improved student learning in this course.	0 [0%]	6 [12%]	42 [88%]
4) Green Concrete project presentation and report improved your learning in this course.	0 [0%]	12 [25%]	36 [75%]
6) The lessons in this course provided me with an awareness of sustainable design practices.	2 [4%]	8 [17%]	38 [79%]
7) I tried to relate material covered in lecture(s) to group project assignment.	0 [0%]	6 [12%]	42 [88%]
Equitable Participation			
8) I fairly contributed in the sample preparation part of the lab project.	0 [0%]	6 [12%]	42 [88%]
9) I fairly contributed in the sample testing part of the lab project.	1 [2%]	5 [10%]	42 [88%]
10) I fairly contributed in the report writing part of the lab project.	2 [4%]	8 [17%]	38 [79%]
Others			
3) In the future, this course should continue Green Concrete project.	0 [0%]	12 [25%]	36 [75%]
Total	7 [2%]	83 [17%]	390 [81%]

Concluding Remarks

This study integrated sustainability concepts in Construction Material course through an innovative hands-on Green Concrete project. In this project, students engaged in research to design their Green Concrete using recycled materials, industrial waste and by-products. Each group also prepared laboratory scale samples, conduct compressive and tensile strength testing, determine cost and propose a real-world application for their Green Concrete, based on the experiments. At

the end of the semester, students were also asked to complete a questionnaire. Data from all the questionnaires were collected and analyzed.

Overall, during the Green Concrete project students learnt how construction materials can be made more environmental friendly and economical. Survey questionnaires showed that students exhibited an increased knowledge of sustainable design concepts due to the information acquired through Green Concrete project work. Hands-on-activities through Green Concrete project work increased students participation and improved learning in this course by relating lectures to lab project. In contrast to the approach of offering a separate course in sustainability, the Green Concrete project enabled a deeper learning opportunity for students to compare the benefits of the sustainable approaches with traditional curriculum approaches.

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