



## **An innovative way to teach sustainability in Civil engineering Material Class**

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Dr. Goli Nossoni specializes in the area of civil engineering structures and materials she has worked in multidisciplinary research laboratory. Her research recently expanded to include innovative green and recycled materials. She taught the Civil Engineering Materials course the last two years, and has tried to encourage her students to think critically about the environmental impact of the materials they use and be more creative. She recently has received an EPA-P3 grant for a multidisciplinary project to develop a sustainable desalination system using solar energy and recycled concrete membranes.

## **An Innovative Way to Teach Sustainability in a Civil Engineering Materials Class**

### **Abstract**

Sustainability concepts were introduced into the Civil Engineering Materials course at Manhattan College by requiring students to design their own “Greencrete” using recycled materials for their term project. Students were allowed considerable freedom in choosing the recycled materials, and were challenged to predict the strength of the “Greencrete” they developed. In addition to introducing students to sustainability concepts, the project developed their creativity and critical thinking skills, enabled them to learn concrete design concepts more thoroughly, and provided a challenging yet fun learning environment that they enjoyed.

### **Introduction**

Civil engineers are being increasingly expected to develop sustainable solutions to infrastructure and technology problems, yet they may find themselves inadequately prepared to provide answers.<sup>1</sup> In a 2006 study, the rating of new graduates’ knowledge of sustainable principles was only 2.8 out of 10, department support for teaching and research in sustainability was 4.7 out of 10, and the university leadership’s support of sustainability was 3.0 out of 10.<sup>2</sup> A paradigm shift is thus necessary to educate students to recognize sustainability as a changing constraint in engineering.<sup>3</sup>

In the past decade, the green building movement has gained momentum and there is a need to equip engineering students with a wider knowledge base in terms of environmental, economic, and social attributes of engineered systems, works, and materials. Students not only need an understanding of sustainability to make significant engineering decisions, they also need the critical thinking skills and creativity to supply effective solutions to complex technical problems.<sup>4</sup> In this context, an active learning environment—including problem-based learning and student designed laboratory experiments oriented around sustainability issues in the civil engineering industry—is useful for students to develop practical skills.<sup>5</sup> Civil Engineering courses should also be developed to encourage students to think outside the “technical” box,<sup>6</sup> work in groups, develop leadership and team building skills, and work in a cross-cultural and multi-disciplinary environment. This sort of cross-disciplinary thinking and skills are important for successful execution of projects related to sustainability.

Sustainability is a perspective that can be introduced in early classes and not only as a technical topic to teach at the upper level. Schools such as Carnegie Mellon University, Syracuse University, and Arizona State University have successfully implemented courses in sustainability in civil engineering freshman and sophomore courses.<sup>4-8</sup> Lower level sustainability courses can be related to the knowledge gained in the required math, science, humanities, and social science courses. Incorporating sustainability in the civil engineering curriculum is difficult due to an already full program. Bielefeldt (2011) discusses an alternative approach for incorporating sustainability early on in the curriculum and reports that the awareness of sustainability in subsequent assignments was present even when students were not specifically prompted to include sustainability.<sup>9</sup> Upper level design courses can then be mapped to the sustainability concepts learned in the lower level courses. However, incorporating sustainability in the civil engineering curriculum is often difficult due to an already full program. A way to overcome this constraint is to introduce sustainability concepts

into core engineering courses while maintaining the original course objectives. Aurandt and Butler (2011) were successful in introducing sustainability concepts into core engineering courses while maintaining the original course objectives, but noted a general lack of educational materials and learning tools available for this integration of sustainability into the core courses.<sup>10</sup> A course into which sustainability concepts can be readily incorporated is the civil engineering materials course.

### **Course Overview**

A civil engineering materials course is typically one of the core courses that all civil engineering students take 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 process, and their behavior under different loading conditions. The content of this course is flexible and the course content can be modified to introduce both green and traditional materials and give students the opportunity to compare their behavior. Introduction of green materials in this course need not sacrifice core concepts. Sustainability concepts were introduced to civil engineering student in the Civil Engineering Material course at Manhattan College through an innovative term project dealing with the creative use of recycled materials in concrete.

### **Term Project**

In inquiry-based and experiential learning students discover knowledge through direct experience, taking place inside or outside the classroom, on campus or in the larger community. This approach is a good fit for learning about sustainability because it provides the opportunity for students to develop problem solving and system thinking skills that can be applied to interdisciplinary issues".<sup>12-13</sup> Segalas et al.<sup>14</sup> found that "*multi-methodological* experiential active learning education increases cognitive learning of sustainability." A survey performed by Bhandari et al. (2011) reported a lack of knowledge of the social considerations of sustainability in a newly implemented course, and identified a need for collaboration with social scientists on the subject.<sup>15</sup> Also, at a recent Center for Sustainable Engineering Workshop (May 2011), participants indicated a gap in the social metrics of measuring sustainability.<sup>16</sup>

Consistent with the findings summarized above, the creative use of recycled materials in concrete was introduced to students within a term project in the Civil Engineering Materials course at Manhattan College during the past three years. In the term project students engage in research to design their "Greencrete" using recycled materials, industrial waste products or industrial byproducts. Students are expected to engage in research and design their very own new green materials and perform life cycle assessments of these materials. Students work together as a group to perform all the steps of the project from design to manufacturing and testing. In alignment with Constructivist Learning Theory,<sup>11</sup> students work in groups, and engage in group discussion to predict the mechanical behavior of their "Greencrete" based on the type and percentage of the recycled material used. Each group is required to propose a real application for their Greencrete, which could be load bearing or non-load bearing, based on the predicted mechanical behavior. Each group is required to build a laboratory scale sample and design experiments. Students also have the opportunity to improve their written and verbal communication skills by submitting the final reports, presenting their work to colleagues, testing their concrete in class at the end of their presentation, and validating their prediction. During the term project students learn how civil engineering materials can be made more environmentally friendly.

## Learning Outcomes

The term project advances the work done at other universities<sup>17-21</sup> and stimulates the students to think more creatively. Students learn how to design new systems with limited resources and materials and identify successful green ideas through experimentation while incorporating sustainability into their thought process. Students understand how the use of green materials can yield both sustainable and cost-effective solutions and learn how to compare the life-cycle costs of using traditional versus green materials.

The project learning outcomes are formulated thoroughly to target a higher level of cognitive achievement in three of the outcomes listed in the Civil Engineering Body of Knowledge:<sup>22</sup> Outcome 5-Material Science, Outcome 10-Sustainability, and Outcome 23-Lifelong Learning. Table 1 shows a sample of the project outcomes.

**Table 1:** Project Outcomes Adopted from the ASCE Body of Knowledge

| Knowledge  | Comprehension  | Application   |
|--|--|---|
| <i>Identify</i> existing green materials for civil engineering | <i>Describe</i> behavior of existing green materials under load using laboratory experiments and compare them with that of traditional materials | <i>Create</i> new materials for use in civil engineering, <i>evaluate</i> their performance and find suitable <i>applications</i> |

## Student Assessment and Course Evaluation

The success of the project was evaluated through two different aspects: student interest and student performance. Student interest was evaluated through the course evaluation and student performance was evaluated using the rubric shown in Table 2.

**Table 2:** Evaluation Rubric for Civil Engineering Materials Course

| Outcomes<br>(Addressed in Table 1)   | Exemplary<br>3  | Satisfactory<br>2   | Unsatisfactory<br>1   |
|--|---|---|---|
| <i>Identify</i> existing green materials for civil engineering applications  | Is familiar with current trends in green materials and approaches. Respects the impact of engineering solutions on the environment. | Is aware of current trends in green materials and approaches. Is aware of the impact of engineering solutions on the environment. | Is unaware of current trends in green materials and approaches. Is unaware of the impact of engineering solutions on the environment. |
| <i>Describe</i> behavior of existing green materials under load using laboratory experiments and compare them with that of traditional materials | Formulates detailed experiments. Analyzes and interprets data carefully; relates theory to data.                                    | Develops simple experimental plan and some analysis and interpretation of results; can relate theory to data.                     | No systematic plan or data gathering; makes no attempt to relate data to theory.  |

|  |  |   |  |
|--|--|---|--|
| <i>Create</i> new materials for use in civil engineering, <i>evaluate</i> their performance and find <i>applications</i> | Does significant research gathering background information. Clearly demonstrates and identifies need for new material. Develops several good applications. | Gathers background information. Identifies and formulates the need for the new material. Takes some corrective action based on the results. Focuses on more than one application. | Does not do adequate literature search. Does not formulate the need for the material. Only focuses on one application. |
|--|--|---|--|

## Results

Over the past three years (2011-2013) student interest in the project increased considerably. The Civil Engineering Materials course at Manhattan College is offered by two different professors and some students enroll in the section offering this project and become very excited about it.

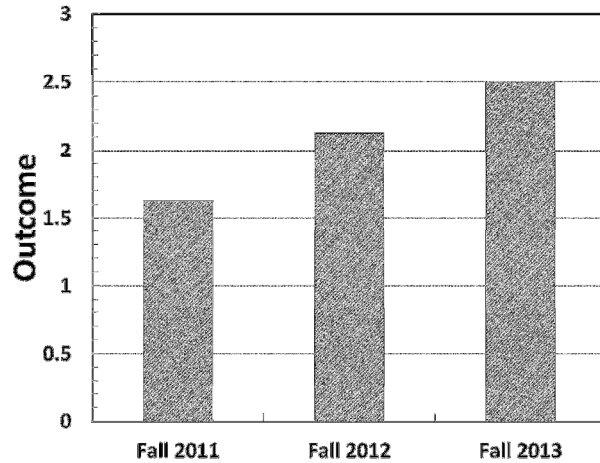
In the grade distribution only 5% is assigned to creativity and 95% is assigned to other elements such as the degree of difficulty, formatting of the report, calculation accuracy, etc. Over the past three years students have paid more and more attention to the creativity factor.

The rubric shown in Table 2 was used to evaluate student learning outcomes after the course ended. The first and second course outcomes were evaluated individually for each student based on his or her performance in exams, quizzes and homework that were based on the material covered during the course. The third course outcome was evaluated for each group based on the term projects and their performance was rated as exemplary, satisfactory or unsatisfactory based on the criteria listed in Table 3.

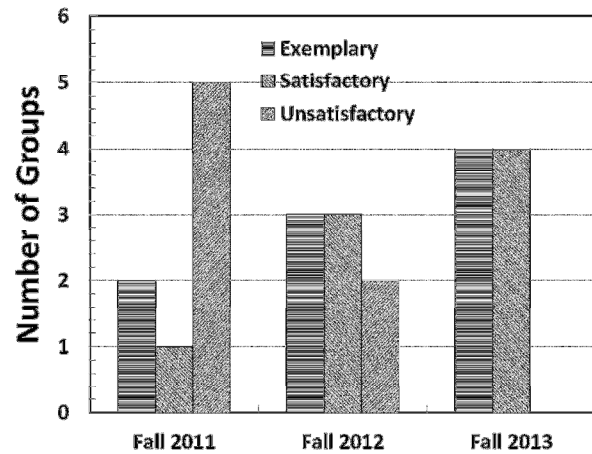
**Table 3:** Criteria for Rating Term Projects

| <b>Rating</b>  | <b>Criteria</b>   |
|----------------|---|
| Exemplary      | Created very own new Greencrete; performed a complete literature review on the recycled materials used, their availability, price, and mechanical performance; proposed a proper application based on their findings; and predicted the mechanical behavior correctly |
| Satisfactory   | Did not perform a complete literature review; did not propose a new Greencrete; did not predict the behavior correctly; but proposed a reasonable application for the Greencrete  |
| Unsatisfactory | Used a recycled material in concrete that was used by industry or proposed by researchers.  |

Figures 1 and 2 show the results from the last three years for the third outcome only since it is the focus of this paper.



**Figure 1: Project Outcome**



**Figure 2: Student Performance**

In the first year only one group of students used a recycled material that had not been used in concrete before (coffee) and created a “Coffecrete”. All the other groups just performed a literature review and reproduced concrete with a recycled material that had been used before in concrete by researchers or ones that were produced at the industrial level such as shredded tires and recycled steel scraps. In the second year the number of groups that tried new ideas increased to five and students created various interesting concretes such as “Tabcrete” (containing can tabs), “Jeancrete” (containing shredded jeans) and “Cocrete” (containing coconut husks). Last semester, students were more excited about the creative aspect of the project and they only wanted to use a material that had not been used in concrete either by researcher or by previous year’s groups. Unfortunately some groups only focused on the creative aspect of the project, did not think about the application for their “Greencrete” during the design process, and used some materials in their concrete that would not give a high strength such as “Chikcrete” (with chicken bones) and “Christmascrete” (with Christmas lights), although they tried to turn the lights on during the compression test! Although these “Greencretes” were not acceptable as a concrete, the instructor did not prevent students from trying their new ideas to create something innovative. One of the main purposes of the project was to encourage students to think outside the box and if their “Greencrete” was designed correctly based on the physical properties of the recycled materials, they could propose a real application—load bearing or non-load bearing—for their “Greencrete”.

Course evaluations indicated that students found the hands-on laboratory project related to sustainable concrete materials enhanced their learning and also was enjoyable. Over the three years 55% to 85% of the students expressed in the course evaluation that they sought information through multiple sources for their project and did extensive literature review to come up with the most interesting and novel idea. 60 to 80 % of the student expressed that they understood the concepts of concrete design better through the term project since they were using materials other than gravel and sand as aggregates. Also, each year some groups had to do extra tests such as measuring the specific gravity, moisture content and absorption capacity of their recycled material to be able to design their “Greencrete,” which served another purpose of the project—learning through hands on activity. One of the interesting observations during the last three years

was that most of the groups took their “Greencrete” home after testing to keep it as the first material they created!

## Conclusions

As industry demand for engineering students with broader knowledge of environmental, economic, and social attributes of engineered systems grew, universities have tried to come up with more innovative ways to equip their students with an understanding of sustainability and critical thinking skills. However, due to overcrowded civil engineering curricula it has been a challenge to dedicate a course to teach sustainability to engineering students. At Manhattan College, sustainability concepts were introduced to the students over the past three years through a term project incorporating the use of recycled materials in concrete.

Student interest, the degree of creativity of the project, and the overall students experience improved considerably over the past three years. Although some of the students focused on the creative aspect of the project more than the civil engineering aspects, they nevertheless created something new, understood the concept of concrete design better through hands-on activities, experimented with new materials, and found the experience interesting.

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