Four Research Projects, One "Green" Theme

Introduction

The purpose of this paper is to suggest ways that faculty can motivate students to do research through the timely and important issue of sustainable or "green" materials in architectural engineering. This paper will briefly describe four research projects undertaken by seniors in our architectural engineering department. Following these descriptions will be a series of pros and cons that the author has detected while mentoring these projects. Suggestions for best practices will then be presented as well as a discussion of how we assessed these projects. Finally, one of the research projects will be highlighted, with the goal of demonstrating how the student was motivated, and how the project was guided.

The "Green" Motivator

Green projects can spur student interest in doing research. Several recent studies found that the green theme was an excellent motivator to encourage undergraduates to undertake a research project. For example, Jahan [1] found that a green study was a launching point to inspire students to do research and for some, to ultimately pursue advanced degrees. Flynn et al. [2] have incorporated green research aspects into many of their classes because of the intense student enthusiasm for the subject.

Students can benefit from such a research experience in several ways. Today's students often feel a need to incorporate sustainability issues into their lives, and they do so with admirable passion. At our university, students are beginning to see sustainability as an over-arching academic theme, not one assigned to a typical classroom slot. We are even considering requiring a sustainability component as a requirement for graduation. Sustainability is often defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs. [3] The president of our university recently publicly signed an action plan committing our campus to sustainability and environmental literacy in teaching and practice, known as the Talloires Declaration. [4]

Thus, a green research project can inspire some students in more ways than traditional research because it aligns itself with some of their core beliefs and it helps them distinguish themselves at the university. Hamilton [5] has argued that incorporating such key inspirational opportunities into the undergraduate experience is critical to the successful preparation of lifelong learners. And if the project touches the students' core beliefs, the project becomes personalized and researchers have shown that having personalized goals in undergraduate research is a key implementation strategy that leads to successful projects [6].

Green Materials as the Starting Point

Green materials themselves are an excellent starting point for research because the field is currently evolving, new materials are always being developed and consequently there are many unexplored topics. Furthermore, using the material itself as the genesis of the research allows for great creative latitude. In architectural engineering there are a number of such green materials that may inspire students. For example, one could propose that students study reclaimed lumber, or straw bale design, or sod roofs, or adobe masonry, or recycled plastics reinforced with agricultural fibers. All of these materials are used as structural or architectural elements and a substantial amount of literature has been devoted to each of them. In our department, seniors have taken on the study of composites made of recycled plastics and agricultural fibers and they have looked at the material science aspect of such composites, and their constructability, and finite element modeling coupled to experimental testing. But other avenues could be explored such as a life-cycle analysis, or a study of how to make structural connections efficient and effective with these materials. Other possibilities are fire-resistance tests or long term creep studies.

Since buildings in the US account for enormous use of wood and energy, it is imperative that the architectural engineering begin to take a closer look at using green materials. The Green Building Alliance [7] defines building products that minimally impact the environment as: recycled, rapidly renewable, salvaged or nontoxic. Higher education must take the lead in providing students opportunities to study, to research and to champion such materials [8].

The Four Projects

The projects described in this paper all used wood/plastic composite materials as the primary structural element. This material was fabricated from recycled high density polyethylene (HDPE) and was reinforced with agricultural fibers such as those from small diameter trees, waste-stream wood, rice hulls, or kenaf. The structural units were tiles which were laid flat in a staggered fashion in order to cover or break the joints of adjacent layers. This method of construction resulted in an extremely thin shell arch or vault.

One project focused on the constructability of a spiral staircase using this laminated vaulting technique. The second project looked at the constructability of arches and three dimensional hyperbolic paraboloids. A third project modeled the laminated spiral staircase structures using the finite element method. A fourth project used the arch building technique as the basis for an outreach program to 6th grade students interested in engineering. As can be seen from the four projects just listed, student creativity was allowed to flourish, yet the mentor kept the projects manageable because they were all interconnected. Such careful “reigning in” of undergraduate research projects has been recommended previously [9, 10].

Since green materials are still relatively unstudied, it is vital to gather fundamental material properties at the onset of the study. Figure 1 shows a student gathering shear strength data on the mortar between two wood/plastic tiles. ASTM standards may or may not exist for such tests, thus engineering creativity is once again encouraged.

Figure 1. Shear Testing of Composite

Figure 2 shows another test to gather fundamental material properties. Here, the student devised a method of testing sections of tile and mortar together in compression. We reasoned that such data would be representative of the way the material was actually used in a structure.

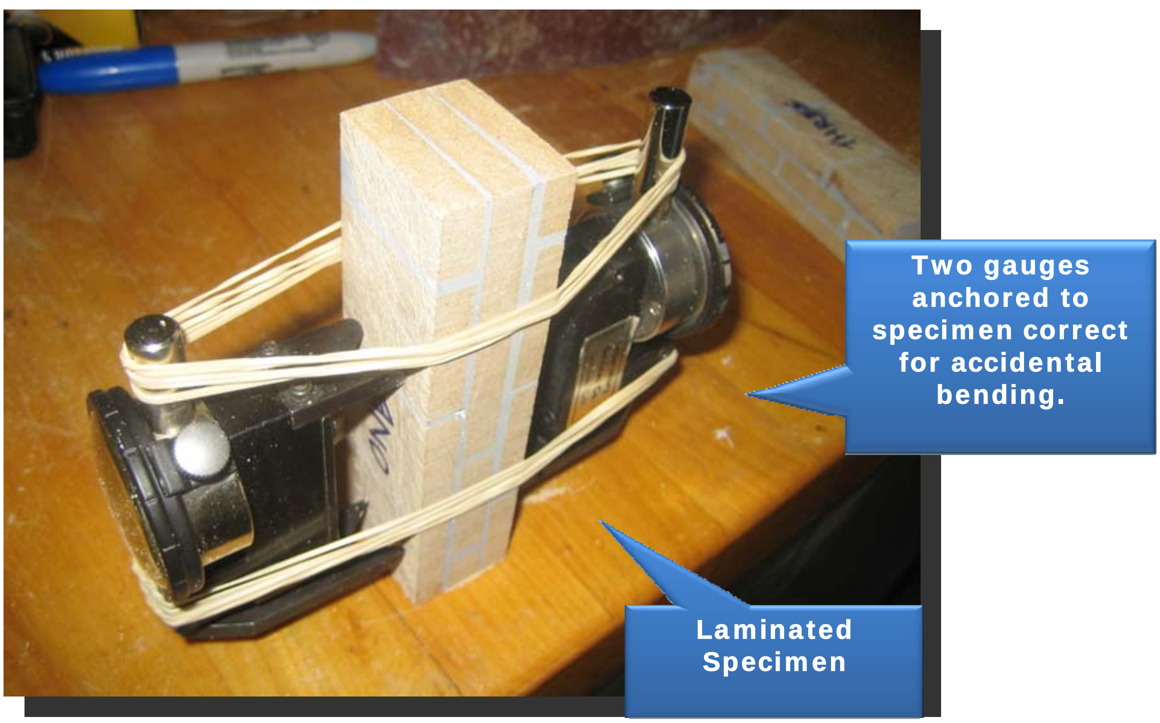

Figure 3. Compression Testing of Composite

Figure 3 shows modular units of hyperbolic paraboloids made from these wood/plastic composite tiles. The student doing this research was interested in the constructability issues surrounding this material.

Figure 3. Modular Hyperbolic Paraboloids Made of Composite

Figure 4 documents some of the progress made during the construction of a spiral staircase formed from this material. The total height of the model was approximately one meter.

Figure 4. Benchtop Scale Spiral Staircase Made of Composite

Figure 5 shows some of the finite element output of a student's study of these spiral staircases. This study will be highlighted at the end of this paper.

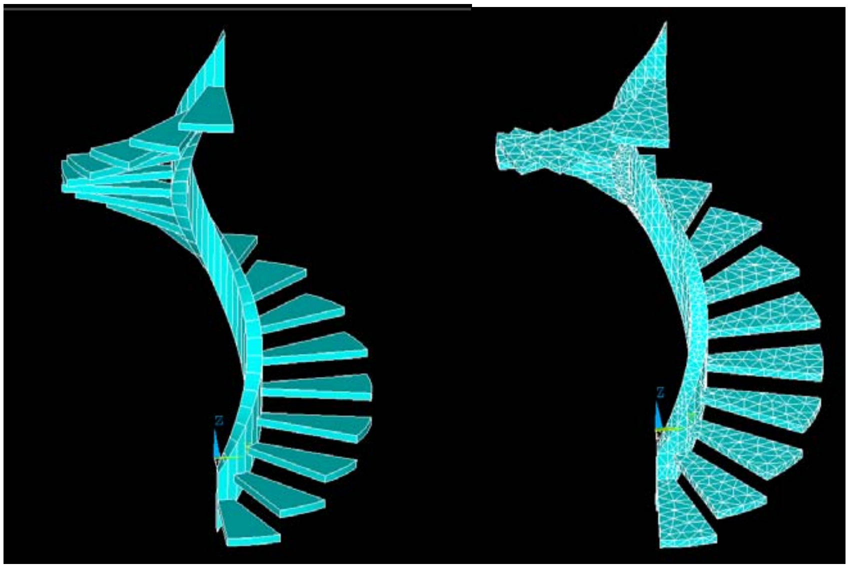

Figure 5. Finite Element Models of Spiral Staircase

The Pros and Cons

Several general trends were detected in these four projects. The pros included:

- Good student energy. The students were generally enthusiastic about their research
- At our university, a senior project is required of all students. Having the students work on a research project allowed them to fulfill this requirement, but it also had the added benefit of moving my own research program along. This is a challenge for me because we are primarily an undergraduate institution.
- A few select students will become highly motivated, which can result in a published paper or perhaps it becomes the motivation to embark upon graduate school.
- This is a tremendous opportunity for personalizing the educational experience. Student/Faculty interaction is very tight and it is different than the typical classroom interaction. We get to know each other and we have fun as we work together.

A few cons were detected, but they are not specifically related to green research projects, but rather to undergraduate research projects in general:

- Other classes are often on the "front burner" for students because research tends to be open-ended, whereas traditional classes march along on a weekly basis with a familiar rhythm. This necessitated gentle reminders that the research project must be chipped away at steadily and cannot be neglected.
- Typically these projects have a slow start and a fast finish. The students will get the job done, but it could have been better with a more organized start.
- Our students are uniformly weak at performing literature reviews. This can be improved by a formal research methods course, but other suggestions will be offered in the following section.

Suggestions for Best Practices

Having mentored these projects the following suggestions for best practices are offered.

- It is beneficial to have at least a loose coalition between projects. Student projects tend to immediately form into "silos". The faculty mentor can facilitate "breaking down silos" by having the students relate their progress to each other in semi-formal meetings. These can be quick "what I've done this week" presentations.
- Start each project with a broad wish-list of goals. Students can branch off from the wish-list, or pick and choose to concentrate on a few things. This gives them a sense of ownership but keeps them from straying too far if you (the mentor) come up with the original wish-list.
- Weekly or bi-weekly meetings are critical. Keep notes of these meetings, and photocopy them, one copy for you and one for them. Be sure to put the date at the top of the notes page! After a few meetings, review all the gathered notes up to that point. Has progress been made? Have unnecessary sidetracks been pursued? During these weekly meetings, narrow the original wish-list. Thus the wish-list takes the shape of an inverted pyramid. Others have suggested posting these notes on a site like BlackBoard to increase accountability [10].
- While it is important for students to learn the literature, at the undergraduate level it is equally important for them to unleash their own creativity. The green projects I have mentored are a good opportunity for this because some aspects such as materials testing or finite element modeling of these materials are new and not yet firmly entrenched in the literature.
- As previously stated, our students are not skilled at literature reviews. To overcome this deficiency, we have instituted a new research methods course for seniors, which is co-taught by an Architectural Engineering Professor as well as an English Professor. Another resource is the research librarian at the university library; we have asked them to make a targeted presentation to our students. Finally, we have developed a research guide which we handed out to students which shows the proper format for report writing, and it contains suggestions of how to use engineering databases and what *not to do* when using internet resources.

Assessment

Initial assessment is subjective. It is tantamount to making sure some progress is being made. This is conducted through the weekly or bi-weekly meeting. Then, as the project progress, greater scrutiny of the student's results is required. Public reviews at the end of each quarter are important. Students should make a public presentation and get feedback from their peers and from other faculty members. Written evaluation forms are very useful here, they can also serve a dual purpose of providing some ABET paperwork for some of the "squishier" outcomes. The best projects can culminate in peer reviewed publications which is the most rigorous assessment we have.

Exemplary Green Research Project

One student, Kyle, approached me with the desire to do a materials testing, prototype building and computer modeling project focusing on the green composite material I am working with. He was interested in working with green materials, but he wasn't sure what he want to do, thus he came to me with a very broad agenda. We started out with a wish-list of many items, including shear testing, compression testing, and bending testing of the material. Eventually, we dropped all the tests except the compression tests because the laminated thin shells we build are primarily subjected to compression. Kyle devised a simple compression test setup which was shown in Figure 3. We recognized that we could not eliminate all testing because the finite element modeling of the green composite required a nonlinear stress versus strain curve. Further down the road, Kyle dropped all prototype building and he handed that portion off to another student. This demonstrates the "breaking down of silos" previously mentioned. It turns out that Kyle excelled at the finite element modeling portion of the project, far exceeding what I imagined. He developed a novel way of creating the finite element model in MATLAB and then importing the model into ANSYS for the final analysis. The results of his study will be published in a peer reviewed conference paper this coming spring.

Conclusion

The study of green materials is a particularly exciting vehicle for getting students excited about doing research. Many students are naturally interested in sustainability and green materials and this interest fuels their creativity and energizes their work. This paper has demonstrated some lessons learned from mentoring such research projects and has provided a suggested list of best practices. It is hoped that other faculty members will share their experiences in this emerging field.

Bibliography

1. Jahan et al., (2005), "Undergraduate research in pollution prevention and sustainability", *ASEE Annual Conference and Exposition, Conference Proceedings,* 2005 ASEE Annual Conference and Exposition, Conference Proceedings, Portland.
2. Flynn, A. et al. (2006), "Teaching Teachers to Teach Green Engineering", Journal of STEM Education Innovations and Research, Vol.7.
3. Bruntland, G. (ed) (1987), Our Common Future: The World Commission on Environment and Development, Oxford: Oxford University Press.
4. http://www.ulsf.org/programs_talloires.html
5. Hamilton, S. and Meyer, F. (2007), "Inspiring Students-The Key to Learning for the Future", *ASEE Annual Conference and Exposition, Conference Proceedings,* 2007 ASEE Annual Conference and Exposition, Conference Proceedings, Honolulu.
6. Bowman, M. (2002), "Personalizing the Goals of Undergraduate Research", Journal of College Science Teaching, Vol. 32 Issue 2, p120.
7. Shades of Green (2006), Report of the Green Building Alliance.
8. Beckman, E. et al. (2007), "Combining Educational Studies, Research and International Experiences in Sustainable Engineering, *ASEE Annual Conference and Exposition, Conference Proceedings*, 2007 ASEE Annual Conference and Exposition, Conference Proceedings, Honolulu.

9. Saliklis, E. (2006), "Putting a Fence Around Architectural Engineering Undergraduate Research Projects", *ASEE Annual Conference and Exposition, Conference Proceedings*, 2006 ASEE Annual Conference and Exposition, Conference Proceedings, Chicago.
10. Schuster, P. and Birdsong, C. (2006), "Research in the Undergraduate Environment", *ASEE Annual Conference and Exposition, Conference Proceedings*, 2006 ASEE Annual Conference and Exposition, Conference Proceedings, Chicago.