AC 2009-395: GREENING THE CAPSTONE

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Greening the Capstone

Abstract

The Senior Design Project course at George Mason University provides a capstone design experience that integrates the fundamental knowledge employed by a contemporary civil engineering design team in areas such as land use planning, transportation design, water and sewerage management, grading and storm water design, site analyses and layout, and economic, environmental and regulatory restrictions. In response to the growing need for civil engineers with a solid foundation in sustainable design principles, the Fall 2008 capstone course required seniors to design a neighborhood based on the concepts delineated in *The LEED for Neighborhood Development Pilot Program.* An actual site is used in the design to provide an experience for the students that is as realistic as possible within an academic setting. The target for the development was Silver Certification, or between 50 and 59 points out of a possible 106 points. The site selected was a parcel within an existing office park in Fairfax County, Virginia, already developed with an office building and surface parking. Students were required to redevelop the site for residential use to include 120 total units, with a roughly equal mix of townhouses and condominium units. In addition to meeting the requirements for LEED certification, the students were required to either meet the requirements of the jurisdiction or identify the waivers and modifications to the requirements that would be required to permit the development, including assessment of cost and schedule impacts to the developer. Students were directed to incorporate deconstruction practices for all existing structures and to obtain guidance from the Sustainable Sites Initiative. Evaluations from the project presentation by a panel of professional engineers and developers are presented, along with student evaluations and anecdotal results of the student learning experience. One significant finding was that the sustainable design requirement inspired great creativity in the students and a desire to perform well beyond articulated requirements. Another was that the students experienced some frustration in trying to create an environmentally conscious development in a highly regulated jurisdiction whose goals are not entirely in sync with LEED principles. Despite the challenges, the project proved to be a valuable exercise, providing a solid foundation for incorporation of sustainable design elements in the Senior Design Project course for following sessions.

The Green Capstone Description

The Senior Design Project course at George Mason University (GMU) provides a capstone design experience that integrates the fundamental knowledge employed by a contemporary civil engineering design team in areas such as land use planning, transportation design, water and sewerage management, grading and storm water design, site analyses and layout, and economic, environmental and regulatory restrictions. In response to the growing need for civil engineers

with a solid foundation in sustainable design principles, the Fall 2008 capstone course required seniors to design a neighborhood based on the concepts delineated in *The LEED for Neighborhood Development Pilot Program.* One significant finding was that the sustainable design requirement inspired great creativity in the students and a desire to perform well beyond articulated requirements. Another was that the students experienced some frustration in trying to create an environmentally conscious development in a highly regulated jurisdiction whose goals are not entirely in sync with LEED principles. Despite the challenges, the project proved to be a valuable exercise, providing a solid foundation for incorporation of sustainable design elements in the Senior Design Project course for following sessions.

The course is generally structured with four- to six-member teams, each of which is tasked with developing a complete engineering design for a particular land use. The same site is used for each of the teams, to encourage sharing of existing and regional information related to the project site. Typically, the site is developed as a commercial site, an industrial site, a residential site, and a mixed use site, with a variety of uses proposed. Generally, a site of 10-20 acres is used. Teams are structured to balance students' interests in various areas, including environmental, hydrology, structures, transportation, and land development.

An actual site is used in the design to provide an experience for the students that is as realistic as possible within an academic setting. A benefit of this approach is the ability of the students to access available, web-based GIS data related to the site including topography, soils, environmental corridors, zoning, and utility maps. The target for the development was Silver Certification, or between 50 and 59 points out of a possible 106 points. The site used for the fall 2008 course was a 16-acre parcel within an existing office park in Fairfax County, Virginia. The site is currently developed with a six-story masonry and glass office building and a large surface parking lot. The site is bounded by the Dulles Toll Road to the north, by a 4-lane divided roadway to the south, and by office developments to the east and west. Significant existing utility systems traverse the site including storm drainage, sanitary sewer, water main, and overhead electric transmission lines on towers through a major easement on the south end of the site. Students were required to redevelop the site for residential use to include 120 total units, with a roughly equal mix of townhouses and condominium units. In addition to meeting the requirements for LEED certification, the students were required to either meet the requirements of the jurisdiction or identify the waivers and modifications to the requirements that would be required to permit the development, including assessment of cost and schedule impacts to the developer. Stormwater management for the entire business park is provided in campus ponds. As such, the students were not required to design stormwater management facilities from scratch – instead, they were required to re-model the facilities using their new development program to determine that the facilities continue to operate as required post development.

Teams received a 15+ page syllabus at the first class meeting, which is structured in the same way as a project scope document, outlining the development program, and providing detailed requirements and deliverables for submission deadlines at 15%, 50%, 90%, and 100%. Students

did not receive grades at these milestone submissions. Instead, a detailed technical review of the plans for engineering content and compliance with code and course requirements is conducted, and students receive comments, which must be incorporated into the design for the following submission(s). Students have the option to decline to comply with a comment, but must then defend their designs and decisions with code references and sound engineering judgment. Students were required to work with each other as a team, and with other stakeholders to develop the program. Each team had a faculty 'client', whose job was to modify the program through the 15% submission to optimize function and cost effectiveness of the project. Each team also had an industry mentor, whose job is to help the students identify constructability and permitting challenges during the periodic reviews. The course professor acts as facilitator, hearing requests for waivers or modifications of the jurisdictional requirements and providing general assistance with plan preparation, regulatory guidance and ordinances, and development of the designs using industry standard software solutions.

Achievement of Gold Certification

The goal of the residential design was to obtain enough points to qualify for Silver certification under the LEED Neighborhood Pilot Program. Early in the project, the LEED team chose to design for Gold certification. The team was able to identify enough points to earn Gold – 63 of 106 possible points. The team earned ten points for Preferred Location with the residential site centered within an existing office park. The existing site was developed with an office building and parking lot, which the team deconstructed to prepare the site for the proposed residential development. The project site is located within an existing heavily developed area in Fairfax County Virginia in close proximity to the Dulles Airport Route 28 corridor, close to shopping, schools, services, jobs and transportation. As such, the team easily earned points for proximity to these facilities, and earned points for reduced automobile dependence, bicycle network, and walkable streets. The team also earned points for compact development, diversity of uses and housing types, affordable housing, reduced parking footprint, and access to transit and recreation spaces, among others.

Local Approvals

Few of the students correctly identified waivers that would be required to obtain approval of the project through Fairfax County. However, most students felt they had adequately met the requirements of the local jurisdiction. In the limited time available to conduct this course, it is impossible to ensure compliance with every rule of the jurisdiction. Many issues are identified during the required reviews by the industry mentors and reviewers. Many others are overlooked or not required to allow students to focus on other matters.

Cost and Schedule

The students were instructed to include an assessment of cost and schedule impacts to the developer to complete this project, but unfortunately, were ill-equipped to complete this task.

The approval of engineering plans in a heavily regulated jurisdiction like Fairfax County is a full-time job that requires significant dedication to master, like engineering design. A project of this order of magnitude would require significant negotiation with the local jurisdiction and approval of several zoning actions, waivers and modifications to the published ordinances. According to the developer of Eco Village in Loudoun County, a nearby sustainable development in Loudoun County Virginia, it took nearly five years to secure all the approvals required to allow the construction of the project. This project would also require a significant time commitment that would be considered in a cost benefit analysis by the potential developer.

Evaluations by the Jurors

A panel of industry and faculty jurors was surveyed following the presentation of the LEED project. All were impressed by the sustainable design presentation. The jurors gave the LEED team marks averaging between 4 and 5 out of 5 in every category with the exception of design and local code compliance, which was sacrificed to some extent to allow the in-depth study into sustainability. Comments from the jurors follow:

- "Outstanding treatment of sustainable development concepts. The design is unprecedented in the senior design course with the level of sustainability concepts presented. However, the project seems to have more planning than engineering. There was little discussion of hard engineering criteria – mostly softer, aesthetic ones."
- "This design was less focused on land development than previous projects – liked traditional design better."
- "Excellent team work on sustainable development, but design and local code compliance were not well explored."
- "Besides gold certification, it's not clear what success the team had in fulfilling the clients' requirements."
- "Team presentation was excellent – one of the best ever. Vast improvement over past projects – this has been needed for many years."
- "Certainly showed how to 'design to LEED', which is a first."

Evaluations by the Students

Students were also surveyed following the course to see what how they viewed their experience. A summary of their answers follows.

Is your design approvable?

Eighty percent (80%) of the students thought their designs were approvable by local regulators. One student more correctly stated: "Our design would have a tough time passing some of the

codes…. The point of our design was to think outside the box and incorporate as many items for LEED as possible. The details could be accomplished if more time was put into this specific project to meet county codes."

Is your design constructible?

Ninety percent (90%) of the students thought their designs were constructible. Several students identified the need to further develop the construction details and admitted the designs they developed were expensive.

How well did your design address contemporary issues?

Students incorporated many contemporary ideas in their designs including new materials and products. They spent significant effort researching deconstruction methods and firms who work in this field. They incorporated current thinking in the management of stormwater, with the adoption of several low-impact and sustainable features. Students were concerned with the appearance of their designs and compatibility with surrounding development. They were also concerned with the cost and durability of the materials selected for construction.

The LEED students recognized that their design might be "too green" for most people. For example, parking was placed far from the dwelling units. This may be a benefit in terms of noise, dust, and exhaust control, and may encourage walking, biking and the use of public transportation, however, most of the students felt that the parking might be too inconvenient for most home buyers. The students clearly recognized that this type of development requires a concerted effort to re-train homeowners. They recognized the need to blend traditional elements into the design to create a balance between the expected and the unexpected.

How well did your design address environmental concerns?

The site was designed to significantly reduce impervious area on the site, thereby reducing the demand on the downstream conveyance systems. It incorporated multiple facilities to improve the quality of storm water runoff, and created several new open, passive recreation areas that were previously paved. The site was designed to minimize automotive travel and to use sustainable energy to reduce the carbon footprint.

How well did your design address social concerns?

The students realized their design would attract a certain type of homeowner. As part of their research into this project, the students visited Eco Village in Loudoun County, Virginia, an existing nearby sustainable site, where they took a tour and heard a presentation about the site development and community governance. Many of the practices in place at Eco Village were incorporated into their proposed development. Owners of this type of development would necessarily accept "the philosophy that the environment should come before personal gain". To that end, the development incorporated community gardening, bicycle sharing, use of public

transportation, an extensive trail network within the community and connecting beyond the community, and a community center where residents would be encouraged to share meals. It is, in one student's words, "a new way of living." The design was "meant to get neighbors to interact with one another and for the community to be very welcoming and everyone to be involved."

How well did your design address life-cycle economic concerns?

The designs took advantage of natural light and ventilation. The design incorporated the use of solar panels for street lights. Students noted that the green roofs provide a cooling effect and reduced the air conditioning load. The students recognized there is significant expense in many of the elements of the design, especially the green roofs. No life-cycle cost analysis was performed. Similarly, trade-off analyses were not performed on the sustainable features incorporated into the design. Students were focused on accomplishing LEED Gold accreditation…at whatever cost.

Student Successes

Without exception, the students felt as though they exceeded the requirements of the course, were motivated to deliver more than was asked of them, and were proud of the work they produced. The students felt a real sense of accomplishment, of standing out – even compared to their classmates, who prepared a more traditional design. Students felt that this project allowed them to acquire a level of knowledge greater than they had in previous courses by working together to interpret requirements, learning from each other, and by developing the type of documentation that would demonstrate they had met the intent of the points and the regulatory ordinances that governed their designs. The incorporation of the sustainable design requirements caused some students, who were unfamiliar with LEED, to learn how to apply new technologies. Beyond that, the students are expecting that their LEED knowledge and design experience will give them a competitive advantage as they apply for jobs and develop as engineers.

Challenges, and Successes, for Faculty and Conclusion

It is the opinion of the course instructors and faculty that the incorporation of LEED requirements into the senior capstone project was generally a success and that the incorporation of sustainable design elements should be continued. It was observed that the heavy focus on LEED requires a relaxation of some technical requirements. The challenge for the faculty is to require students to adopt a more realistic design that better meets the current demands while still representing a sustainable solution. Although sustainability is important, due consideration must be given to traditional engineering design topics (hydrology, structures, transportation, soils engineering, utility design), solving a complex problem using real design guidance and requirements on a real piece of land, and preparing a set of construction documents that present a cost-effective, approvable, and constructable design. Sustainable design has been incorporated into the Spring 2009 capstone class with a greater emphasis placed on cost, code-compliance,

and constructability. The lessons learned from the Fall 2008 course allowed faculty to tailor the syllabus to provide better direction to the students in an effort to achieve even greater success in the second effort.