Crossing Disciplines: A Necessity for Comprehensive Design in Architectural Education

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In the professional practice, the Architect is known to work on a daily basis with his design and engineering consultants, the contractors, and the construction trade. It is imperative that an office engaged in innovative work operates seamlessly with its related trades and professions; ergo, collaborative skills are an essential part of the professional's daily activities. In the university setting, although architecture students study courses in structure, mechanical systems and building construction, it is rare for the student to work in concert with students from beyond their major or to physically construct their design projects. The recent entry for the Solar Decathlon produced at Virginia Tech provided an excellent avenue for interdisciplinary engagement and, through the design-build process, provides a continuing opportunity in architectural education.

Fig. 1. The 2005 Virginia Tech Solar House ready for competition on the National Mall in Washington D.C.

The 2005 Solar Decathlon was an international competition sponsored by the United States Department of Energy which challenged universities to design, construct, and operate a self-sustainable, energy efficient, solar powered house. The event promoted the use of alternative energy systems and encouraged the design schools to integrate such systems into contemporary home designs. Each university spent three years researching, designing, and constructing their projects. In October of 2005, seventeen houses were relocated from each university's home campus to the National Mall of Washington D.C. to undergo a week-long design and performance competition.

Virginia Tech fared well in the competition, placing first in all of the design-related categories of the event, including Architecture, Interior Design, Natural Day lighting and Artificial Lighting. The team placed third in overall engineering and fourth in the competition as a whole. Additionally, the National AIA honored Virginia Tech's entry as the "best house" design on the Mall. Virginia Tech attributes much of this success to the multidisciplinary composition of the design team and careful integration of all trades involved in the project; this is reflected in the theme for our project, "No compromise, the integration of the technical and the aesthetic." The multi-disciplinary team included students from Architecture, Landscape Architecture, Mechanical, Electrical and Structural Engineering, Interior Design, Industrial Design, Building Construction, and the College of Business. The dynamics were promising, Students struggled to respect and understand each other's disciplines, and a successful project was the result. The students also consulted with alumni and professionals in their respective fields which added an even more professional layer to the project. The result was a highly successful model for design-build education within the context of the university. In this paper, I discuss aspects of the interdisciplinary work throughout the entire process—from concept to construction and finally, operation.

Fig. 2. The house arrived on the mall at 2 a.m. By noon, the house was fully operational. Trusses in the vertical position for transport eventually fold down to become the framework for a cedar wrap-around deck

The Virginia Tech house arrived on the National Mall in Washington D.C. on the night of October 22 in the most wonderful form. Designed to arrive in one piece utilizing its own frame as the actual transportation chassis, upon placement in its designated site on the mall, two components—front gooseneck and rear bogey axles—were hydraulically removed and stowed away until future relocation. Two truss elements which provided necessary support to the structure during transport folded down like butterfly wings to become platforms for a wraparound wood deck system. Within hours, the house was competition-ready with all systems operating from solar energy gathered by the photovoltaic panels. The house size was modest but cleverly designed to feel spacious. Clerestory glass filled the interior spaces with light and translucent walls of polycarbonate and nanogel insulation allowed highly insulated walls without sacrificing plentiful light. The walls were also vent able and incorporated motorized shades to provide additional environmental adaptation. Materials that are renewable, recyclable and reflect low embodied energy were used in combination to reduce the level of adverse environmental impact. These materials were carefully selected as to maintain the comfort of the house; therefore wood based products, warm colors, and materials with architectural integrity were selected, tested, and utilized. Lighting levels met competition minimum lumen requirements, using L.E.D. technology to keep the electric consumption low. The tunable LED lighting in the translucent wall assembly allowed for a colorful, low-energy display at night. This display changed the atmosphere of the interior space at night and allowed for possibilities of "psychological comfort". The colored light also provided a distinct nighttime identity for the house. The roof was lightweight, insulated and well structured based on the stressed-skin, folded plate technology most commonly seen in aircraft wing sections. The south-facing plane of the butterfly roof housed the photovoltaic system and the convex curvature of the roof allowed for rainwater collection in two 300-gallon cisterns housed under the deck system. Landscape plantings using marshland materials made up a gray water filtration system for water recycling. The unique structural chassis and transportation was the result of close collaboration between architecture and civil engineering students, ultimately fulfilling the needs of rigidity during transport and reuse once deployed in position.

Fig. 3. The seamless integration of the technical components with the architecture of the north "core" wall.

Research

The initial step for the project, long before the design or construction, was to offer a three-credit-hour course for students to research all aspects of the design of an energy efficient, prefabricated, self sustainable, solar powered house. Forty-five students across many disciplines participated by individually researching a topic relating to solar home design. Students researched materials and contacted manufacturers and suppliers in pursuit of new applications and used class time to present their research findings. Research topics included solar cell technology, energy storage, environmental design, prefabrication, computer simulation programs, solar home design precedents, modular home design and transportation systems, material research and sustainability, innovative building construction techniques, energy efficient building assemblies, and energy efficient appliances and fixtures. Through this course, the students from various disciplines began to work together and understand the scope of each other's research. It was also this early interaction between the architect, industrial designer, engineer, supplier and manufacturer which encouraged the development of more efficient and elegant building components.

The research-based class also studied the previous Virginia Tech solar house, which was produced for the first Solar Decathlon held in 2002. Strengths and weaknesses of the design and performance of this project were recorded and utilized as valuable information for future use. In fact, the entire transportation scheme for the new project was inspired by the less successful attempt of the first house. By the semester's end, a booklet was compiled of the research and was then made available to the design teams of an open, cross university competition offered in the following semester.

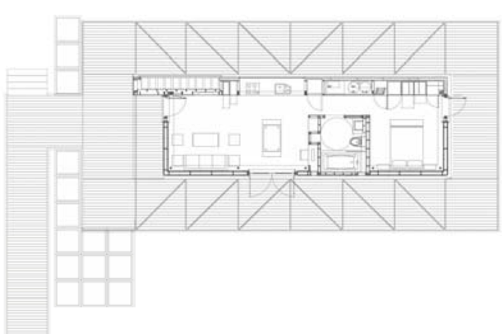

Fig. 4. In the plan one can find efficient space planning, a very compact and multifunctional north "core" wall, a bathroom "core" separating public and private, west, south and east insulated translucent wall assemblies, the wrap-around deck with converted truss framing, and the landscape water filtration planters.

Design

A university-wide design competition was held to search for the solar house design concept. Because of the complex technical nature of the design, Architecture students were encouraged to form teams with students from the other disciplines, many of whom were familiar through the research class. The competition resulted in fifty projects, seven of which were selected for a second stage and thus further development. Eventually, one scheme was selected and a base interdisciplinary team was formed. The resulting design concept was simple— a roof as collector of energy which hovered over a simple energy efficient translucent wall system. One full year went into the development of the design before the construction began. Engineers tested photovoltaic systems, architects developed prototypes of wall and roof sections and interiors and industrial design students explored materials and mocked up furniture ideas. This year was actually the critical period and main primary reason for the success of the house design since there was much pressure by many to prematurely rush into the actual construction.

With the strict requirement to keep the footprint of the project under 800 square feet, the emphasis of the design team was on 'architecture of small space'. The challenge was to integrate the technical requirements into a small volume without a sacrifice of comfort, light, or quality of space. The result was a compact north "core" wall which holds all of the electrical, mechanical, kitchen, and storage. This compact design was a result of meticulous coordination between the engineers and the architects. A second "core" wall divided the plan into private and public divisions and accommodated the bathroom and home office. Similar correspondence between disciplines occurred for roof design between electrical engineers, materials science and architecture, and civil engineering and architecture with the chassis design.

Both the engineers and the architects used advanced visualization and simulation tools to study the design. A comprehensive 3D computer model of the project was generated and placed in a CAVE (Computer Automated Virtual Environment) The CAVE is a multi-person, room-sized, high-resolution 3D video and audio environment where graphics of the design are projected in real-time stereo onto three walls and the floor, and viewed with stereo glasses creating a virtual representation of the buildings interior and exterior. The CAVE environment allowed the students to explore integration alternatives of routing pipes, electrical and data communication cabling within a space-constrained compact plan. The CAVE also allowed students to present their intentions of their project to the public by having a media advertised "virtual tour." Engineers also worked with the architects in the use of energy simulation programs. These programs were used to project the building's year round environmental performance.

Over a two year period of project development and construction, the team members sometimes changed hands; however, the team always consisted of a good cross section of multiple disciplines and made for colorful arguments and debates about the systems designs.

Construction

Students learn more effectively by doing. The opportunity for the students to physically construct a 1 to 1 scale model of their project made for an ideal educational experience. Materials were tested at full scale. Ideas were rejected or accepted through the process of trial and error. Architecture students realized the importance of good drawings and good detailing and the engineers grew more aware of the importance of aesthetics, form, and space. Building construction students learned of the importance of design in the construction process.

Industry

The student team utilized architects and engineers from the industry as well, usually through alumni contacts. Professionals were consulted from Architecture and Interior Design firms, usually by way of design critiques, and structural engineering firms were utilized for structural development. A trucking company and flatbed chassis manufacturer were used as a consultants for the transportation strategies and wood science engineers for the roof structural development. Engineers from the product manufacturers also offered assistance in product installation and integration. Students gained invaluable experience in working with the professionals and the professionals were thrilled to work with the youth on such innovative fresh ideas.

Education

In this project, not only was the student's education enhanced by the tangible realization of a school project, but the education was enhanced by the cross-disciplinary work. Students learned about the other disciplines long before their paths would eventually meet in the professional world. They learned the value of consulting with each other early in the project, discovering that it not only simplifies integration but bolsters the strength of the design. Architects worked with landscape architects integrating the water filtration systems with the plantings, Structural engineering students worked with the architecture students in designing foldable truss systems. Structural engineers worked with the architects and flat-bed manufacturers on the chassis/building frame design. Electrical engineers worked with the architects and mechanical engineers to coordinate the photovoltaic electrical systems with the heat pump air and water systems in the north core wall.

Fig. 5. The 570 square foot house feels spacious largely in part by the abundance of light, the upward curving ceiling and the very compact north wall which holds the kitchen, mechanical, electrical and storage.

Results

Aside from the high ranking in the Solar Decathlon competition, the follow-up to the project is rich. The Cabot Corporation, polycarbonate company and LED manufacturer now are working together to bring to production the LED illuminated translucent wall assembly developed by students at Virginia Tech. The cabinet company who worked closely with the students in the design and production of wheat-board cabinetry are now considering the use of the sustainable material as a substitute for plywood on their assembly line. The transport system utilized to move the house low to the road, making for easier clearances under bridges, is a very viable solution for modular home relocation, reusing the more expensive gooseneck and bogey for mass moving. The furniture designed for the house also uses sustainable butcher block panels and is a successful line suitable for low cost furniture production. Häfele, an international hardware manufacturer, has developed an AIA continuing education course for architects from the 2005 Virginia Tech Solar House project. The house continues to be utilized to educate the public on sustainable design and is currently being moved from Blacksburg, Virginia to Richmond, Virginia to be publicly exhibited at the Virginia Science Museum as a model for sustainable design.

Conclusion

Comprehensive design-build projects have proven to be effective methods to educate students in architecture. The interactive approach to design and detailing allows for tacit design investigation, full scale experience in space making and detailing, application of real materiality and structure to designs, and the ability to test and re-test design ideas. For the more advanced students, the design-build opportunities not only allow but require the need to work across disciplines. The 2002 Virginia Tech Solar House was a great example of the integration of architecture and technology where a strong design concept was complemented by a sophisticated level of systems integration. Working with many disciplines allowed all students to understand and respect each other's areas of study and allowed them to see their profession as part of a whole rather than the isolated perspective many receive in the classroom.

Ultimately, the goals set out for the project could not be met by a single discipline acting in isolation; success must be achieved in a mode where each group contributes its expertise in a interconnected fashion. We believe that educational experience that goes far beyond traditional classroom practice has been provided to our students. Through the primary vehicle of design/build, we have exceeded the range of experience available to the student through mirroring traditional studio practice. Through the careful guidance of faculty who are also active practitioners, this competition has spanned the breadth of research, ideation, design, prototyping, industry liaison, communications, construction, transportation, operations, and evaluation. With new and expanding phases of this project we will continue to engage practitioners seeking a closer tie with the academy providing a two-way exchange of ideas and experience.