AC 2010-551: THE DORMATECHTURE PROJECT: AN INTERDISCIPLINARY EDUCATIONAL EXPERIENCE

Bekir Kelceoglu, Indiana University-Purdue University, Indianapolis

Mary Ann Frank, Indiana University-Purdue University, Indianapolis

David Cowan, Indiana University-Purdue University, Indianapolis

David Goodman, Indiana University Purdue Unversity Indianapolis (IUPUI)

Joseph Tabas, Indiana University-Purdue University, Indianapolis

Cluny Way, College of the North Atlantic
Project Leader for Service Learning Engineering Technology Centre

J. Craig Greene, College of the North Atlantic
Instructor AET Ridge Road Campus

Patricia Fox, Indiana University-Purdue University, Indianapolis

Sandi Perlman, Indiana University-Purdue University, Indianapolis

The DORMaTECHture Project: A Multi and Interdisciplinary Educational Experience

1.0 Introduction

There are many studies and innovative projects that discuss the re-utilization of shipping containers for the purpose of shelter and housing. For example, there are extremely large projects (e.g., Keetwonen, Amsterdam[1]) that utilize more than one thousand containers for the creation of experimental student living quarters. Similarly, in 2008, in Uxbridge, London, an eight-story, hundred-room Travelodge hotel was built using intermodal shipping containers[2].

These are just two extreme examples of what can be done by using shipping containers in innovative ways. However, there are few, if any, projects that directly address the use of shipping containers for dorm rooms and, more importantly, self-contained dorm rooms that have a prime focus upon green, sustainable technologies. Many of the current projects (such as those noted above) focus upon the art of container architecture and there are few that go beyond the mere selection of shipping containers as a claim to their green and sustainable quality.

There appear to be several sources that discuss alternative, green and sustainable housing designs and methods (e.g., Gauzin-Müller, 2006[3]; Stang, Hawthorne, 2005[4]) as well as more recent publications that discuss the use of intermodal shipping containers for a variety of building types (e.g., Sawyers, 2008[5]; McLean, 2008[6]). These are often devoted to the glossy graphic display of innovative concepts and/or to the physical process of constructing various shelters. Similarly, there are also other contemporary sources (e.g., YouTube) that advance the use of shipping containers for the superstructure of various housing projects.

This project intends to advance the use of intermodal shipping containers for shelter both from a green perspective as well as from an educational standpoint. Once this project is built, it will serve to function as an educational repository of sustainable technologies. As well, through the design and build process, and with the help of cooperating institutions, this overall project will be attempting to ensure that each particular container and site becomes an opportunity for examining container use in a variety of climatic conditions.

Hence the DORMaTECHture project is much more than an alternative solution to public housing; it also becomes a classroom of the future: a living laboratory for the exploration of green and sustainable technology. This paper discusses the development of this project during the design phase and, in doing so, illustrates how it developed and created a unique multi and interdisciplinary educational experience.

2.0 Current Methodological Steps

To date (January 2010), at the lead institution, Indiana University Purdue University – Indianapolis (IUPUI), this project has utilized a series of qualitative methods to set up an environment for the exchange of ideas and development of research data. They consist of the following:

2.1 Focus Groups

Focus groups, or design charrettes, were initially set up to call all interested parties to the design table. This included a mixture of tradespersons, professional engineers and architects, students, administrators and professors. Multi-faceted teams were created so that each team had a mixture of expertise (approximately five individuals within five teams). Time limits were set to determine overall concepts and goals, whereupon a summary session was held to review ideas.

Two large focus groups sessions like this were held. The first was an afternoon session devoted to teasing out all of the creative ideas associated with the concept of creating dorm rooms for students using shipping containers. After all groups reported, a smaller, yet still diverse team, set out to synthesize and edit the design ideas. This led to several plans and concepts that were reported back to the focus group at a later time. At this second meeting, design ideas were solidified and a direction was decided for the overall design concept that satisfied the majority of team members. Smaller groups then set out to tackle individual design concerns.

2.2 Multi-disciplinary Undergraduate Research Teams (MURI)

IUPUI has a program that is devoted to multi-disciplinary undergraduate research (MURI). The DORMaTECHture design team applied for a grant from this internal source and set up a team of six students who also worked on the project (as well as the focus groups noted above). These students consisted of an interior design major, a construction major, and several engineering and engineering technology majors.

This group has been helpful in identifying problems that others may not have thought about on their own. As well, the MURI group will form an alternative research team that can be used to compare ideas, technologies and strategies as the project progresses.

2.3 Design Teams

Individual design teams were formed after the second focus group meeting. These consisted of a team of interior designers, a team of technologists and a team of tradespersons skilled in plumbing, carpentry and kitchen design. A graduate student was responsible for overseeing the progress of each design team and for coordinating the ideas, problems and concerns that surfaced as the designs advanced. As well, project teams were set up in several regular architecture and interior design classes to generate yet another set of design ideas. It should also be noted (see below) that design teams will and have been set up at partnering institutes around the world in order to generate a wider context and richer data set for this educational project.

2.4 Literature Reviews

Each design team, as well as the MURI students, was assigned to complete a literature review. Due to time constraints, this was ongoing at the time of design rather than preceding it. It did allow each team to assess their direction in light of research that preceded them. This research is ongoing and will be brought to the design table prior to the launch of the construction stage.

2.5 Key informant Interviews

Informal interviews with experts have been ongoing during the design process. Experts in green materials, solar technology, green roofs etc. have been helpful as sounding boards to the team's design ideas. This has also included key university personnel that will serve to advance the concept on campus and to determine its eventual site.

3.0 Design Development: Innovative Concepts and Processes

This project involves, above and beyond the shipping container, several other elements that are crucial to the design of the dorm. Experts have been consulted on all fronts in order to determine the most effective and affordable solutions to this project. Plumbers, electricians, building suppliers, and alternative energy experts were all consulted before final decisions could be made. Design teams typically have reported this information back to the graduate student project manager who then assesses the information with others before proceeding.

Described below are some of the innovative concepts, processes and collaborations that have been developed to widen the scope and breadth of this innovative project.

3.1 International Collaborations

Students of the College of the North Atlantic (CNA) in Canada are also, in tandem with IUPUI in the United States, undertaking a series of multi-disciplinary studies into the viability of converting used shipping containers into an Intermodal Steel Building Unit (ISBU) student dormitory. Initial studies are slated to begin in January, 2010 and will follow upon those studies noted in this paper that were conducted at IUPUI.

Students in the third year of the Architectural Engineering Technology program at CNA in Canada will be conducting detailed technical design studies in three key areas of this application under cold climate conditions, while ensuring that all applicable codes and life-safety standards are met. These particular studies include:

- Investigation into options for exterior cladding systems;
- Design and integration of all mechanical and electrical components within a framework of sustainable design;
- Design of a structural system that will allow disassembly of components for transportation and relocation.

(All student work will be carried out within the framework of regular program curriculum.)

The 2010 fall semester will be used to conduct a follow-up project to studies completed by students during the earlier winter semester. This work is aimed at confirming the results of these previous studies. In order to do so, CNA is planning to acquire a used, forty foot shipping container in September, 2010. At that time, its conversion into an ISBU dormitory unit will begin. This conversion process is expected to occur over several weeks and involve several campuses of CNA.

The ISBU will initially be moved to CNA's campuses offering trade programs such as cabinet making, carpentry, electrical, plumbing, sheet metal, and welding. Customized modular prefabrication of cabinetry, interior partitions, exterior cladding systems, electrical wiring and conduit, hot and cold water piping, sanitary sewer piping, ventilation ductwork, external water collection, and exterior landings and stairs will be carried out at these campuses. All of these customized components will be collected and stored inside the unit.

Additionally, the ISBU will also be moved to CNA's campuses offering programs in Environmental Technology, Manufacturing Technology, and Mechanical Engineering Technology. Student applications in alternate energy sources such as wind and solar energy will be integrated into the unit design. This is aimed at minimizing or eliminating any demands on the electrical grid by the completed dormitory unit.

The ISBU will eventually be moved to its final location, a designated campus of CNA. Students from both the Civil and Geomatics Engineering Technology programs will then participate in the final placement upon a prepared concrete foundation orientated for maximum solar and wind energy gain. Students from a number of programs will then participate in the final assembly of the dormitory unit. This final assembly process is expected to occur over a two week period.
It should be noted that this initial project has been planned mainly to raise the profile of this green and sustainable approach to student housing. And while transporting the ISBU to the various campuses of CNA may not be a green approach in itself, it does serve to initially orient a variety of CNA programs to the DORMaTECHture project, and maximize student participation in this multi-disciplinary pilot project.

Data from this Canadian cold climate condition will then be shared with students from the United States (and other partners) so that viable solutions to using intermodal shipping containers for housing can be compared across borders, climates, and cultures. It is intended that this type of shared design knowledge and project will be extended into partner institutions in Asia (Thailand) and Australia in the summer of 2010. In this manner this project becomes an international education project and resource that can be used to study the application of various sustainable technologies within a variety of climates and cultures. This will hopefully lead to innovative methods and solutions to housing and building science around the world.

3.2 Public Engagement and Education

In order to achieve a successful transition to future energy sources, educators must develop methods of educating that involve public understanding and acceptance of new and emerging energy technologies. People at all levels and varied interests must be educated about the need for new energy technologies, the uses for these technologies, and their role in the energy solutions of the future. Additionally, it is imperative to create a highly educated workforce who can contribute to overcoming future energy challenges.

One method of supporting public education is to conduct as much of the design/build process of this project in a highly visible public environment, so that people can see what is going on, become interested, ask questions, and even join in the activity. Engineering and technology educators must develop new curriculum solutions in advanced energy technologies to fill the gaps in existing coursework and prepare the next generation of students to support global sustainability and workforce development[7]. The DORMaTECHture project allows for both; with local marketing we have drawn in students, educators, and professionals from various backgrounds and as we begin the build phase in a public context we invite more participation. Several professors are also including design components in their classes and offering independent study credits (see above). Previous research also supports this, for it has been noted that offering the renewable energy projects has demonstrated initial success in increasing student understanding of renewable energy sources and their significance for lifelong learning[8].

3.3 Solar System Development

The design of the solar hot water system and the photovoltaic system followed standard processes[9,10,11] with two exceptions. Typically the first step in solar design is to identify and reduce loads due to the cost of installing solar equipment. The first design exception was to temporarily ignore load reduction and energy efficiency and to design a baseline system for an average American dorm student (i.e. one with no green philosophy, which is to say no attempt to modify behavior or address their energy footprint). This was necessary because the project exists at multiple levels and with multiple disciplinary components. The primary project group consists of volunteer students, professors, and industry professionals that operate outside of the standard class schedule. To include the project in the discipline specific classes, a scope of work had to be defined that was reasonable for a fifteen week project. For the electrical and mechanical engineering technology students, that meant a solar thermal domestic hot water system for two adults living in the shipping container with an option for additional radiant heating for one team project and a solar photovoltaic system to provide power for all typical dorm room loads as well as the solar thermal system loads for a second team.

Figure 1: External Perspective, South

The second exception relates to the development of a novel way of combining the systems, which we have not located in the literature search and requires construction and testing in a future phase in order to complete the solar thermal design. In lieu of that data, the solar thermal system design consists of one, thirty tube, evacuated tube, heat pipe collector with an eighty gallon thermal storage tank and a forty gallon hot water tank. The hot water tank also includes an auxiliary heating system which uses an eco-friendly ethanol fuel. The photovoltaic system is composed of twelve panels in a 2.2kW array with eight sealed, lead-acid batteries that provide four days of energy storage. Depending on future decisions related to lighting, heating, electrical load reduction, thermal insulation levels, and the combined system performance, one or both system designs may be reduced in size (number of panels, thermal collector size, or thermal storage size).

Figure 1 shows the overall position of the solar panels and solar hot water system relative to the container's orientation to the sun.

3.4 Lighting Solutions

The lighting design for this project is soon to be initiated, yet as a point of discussion for this paper, and as a classroom of the future, the DORMaTECHture design team will follow a process of design for its lighting utilizing a methodology that students employ in studio lighting design projects. Thus the following overview provides an insight into the educational process and strategies that will be applied to the lighting design for this project.

After first identifying programming for the lighting component of the project, it is determined that functional requirements include basic kitchen and bath tasks, as well as studying and general living. This implies a need for general or ambient lighting and task lighting.

Sustainable design goals contribute to the second step of the process where appropriate light sources are identified. It is determined that LED sources can achieve both of the task and ambient light requirements as well as achieving energy efficiency goals. Fluorescent lighting can also achieve these goals and may be utilized in the project as appropriate.

The next step of the lighting design process that students employ in a studio project is to identify the desired lighting effects. For this project, direct lighting will be needed for task work and can also be implemented for ambient lighting, however indirect light will soften ambient lighting in a small space such as the DORMaTECHture project. Therefore a combination of direct and indirect light will be considered.

The final step of the design process is to select appropriate fixtures that satisfy the design requirements proposed. To achieve the goals of cost efficiency for this project, fixtures designed and constructed by the project team will be employed as appropriate, with purchased fixtures included as necessary.

Completing the design process for a lighting project as described above, the design team proposes to build LED fixtures to satisfy task and ambient lighting as appropriate. Several considerations are included to address quality and quantity of lighting that students learn to evaluate in their studio design projects. Quality of light sources – whether LED or fluorescent - will need to address a high color rendering index (CRI) and a color temperature similar to incandescent for this residential application. This implies a CRI in the 80-90 range and a color temperature in the 2700K-3000K range. For LED sources, it will be important to evaluate consistency of these characteristics for a uniform lighting effect. Design students in this project will also learn the importance of binning of LEDs when constructing luminaires.

Quantity of lighting will take into consideration recommended light levels by the Illuminating Engineering Society (IES) for functional areas of a residential project. Foot-candle values will be calculated for each area of the DORMaTECHture space to meet IES recommendations while also considering the subjective effects of brightness levels based on finishes and materials specified.

Evaluation of brightness will be important with LED sources so that recommended light levels are achieved with a minimum of cost for required equipment. As light output, light quality, and purchase cost are currently important factors when considering LED sources, students will learn the effects of these factors and determine whether LED or fluorescent sources will best suit the goals of the project. Energy efficiency will balance design decisions toward sustainability goals so that this is a classroom of the future for the art and science of lighting.

3.5 Interior / Industrial Design Solutions

Due to the narrow floor plan of shipping containers, the approach to interior space planning needed to be non-traditional. To understand container based interior design issues, students and experts from all interior design related fields were needed. Therefore, a team of five designers - one instructor specialized in interior / industrial design (leader), one green design expert, one kitchen and bath expert, and two senior level undergraduate interior design students, came together to work on the interior design component of the project. The team immediately started its studies examining existing shipping containers, overall requirements for building mechanics (e.g. plumbing and electricity), and possible space planning themes for different sizes.

After the initial research and several space planning proposals, different designs for different container sizes were presented to the whole team during the second design charrette. Mainly, the interior design team concentrated on three different ideas: “twenty-foot single unit” dorm room for one occupant, “forty-foot double unit” dorm rooms for two occupants, and finally “forty-foot single unit” dorm room for two occupants. After experts’ input, the forty-foot single unit for two occupants was selected. This configuration and the external paneling option can be seen below in Figure 2. Panels are reversible allowing the dark side to collect the sun’s energy during winter and reflect the sun’s ray during summer.

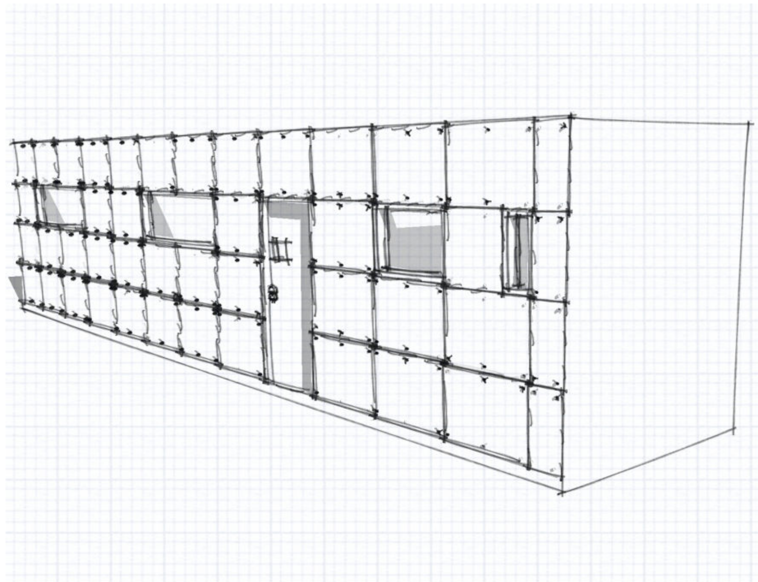

Figure 2: Concept Sketch

As well, due to strict space restrictions, multi-functional furniture needed to be designed. Using multi-functional furniture offered not only space saving benefits, but also provided space modifications for different purposes, such as using a kitchen table as a study surface. Using anthropometric data from already published literature, (e.g., Panero & Zelnik, 1979[12]; Tilley & Henry Dreyfuss Associates., 2002[13]) it is possible to design pieces of multifunctional furniture while keeping the proportions and usability in the design process (Figures 3, 4, 5). In keeping with the nature of this project, all interior design materials were selected from sustainable resources to promote healthful living conditions.

Figure 3: Kitchen Rendering

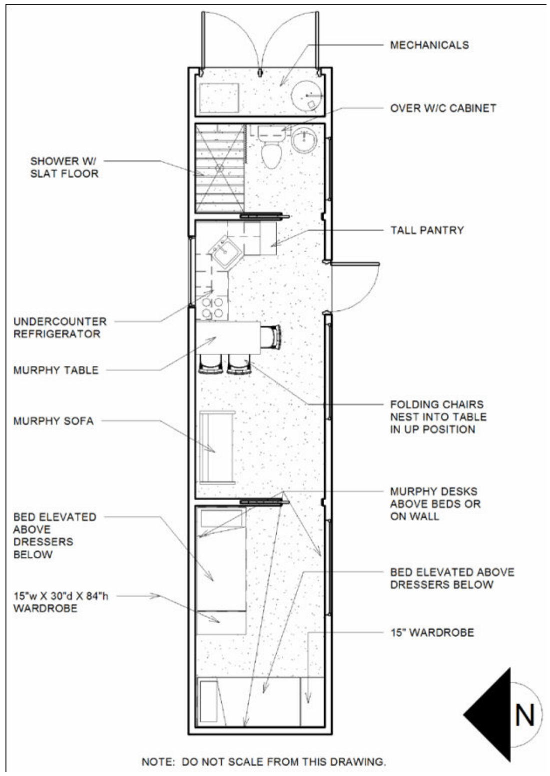

Figure 4: Floor Plan

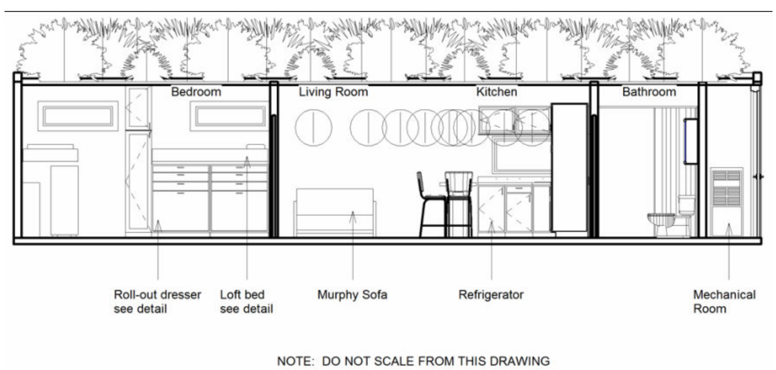

Figure 5: Building Section, South

3.6 Plumbing, Kitchen, and Bath Design

Under the watchful eye of a local expert in kitchen design and plumbing, a design team consisting of tradespersons and students (graduate and undergraduate) has developed guidelines that will lead the design of the plumbing, kitchen, and bath. To date, they have determined that we will be using a fresh water supply which will be partly from collected rainwater and shipped in storage.

There will also be a separate septic system, fully mobile, located under the unit. The water heater will be a 90% efficient water heater and gray water runoff from the green roof, as well as drain water from the sinks and tubs will be used for secondary watering.

In the kitchen and bathrooms the cabinetry will be wood from a recycled or sustainable source. All will be made and designed locally. The countertop will be made of recycled glass terrazzo and the flooring will be Marmoleum. Carpet will be made of corn, and paint and finishes will all be non-VOC.

The students worked alongside the kitchen design and plumbing expert during this design process and, through consultation with local suppliers, determined this list of materials. They are currently integrating it into the design and build phase of the project.

3.7 Conclusions Reached

To date, as we near the exit of the design phase and move onto the building phase, there are several conclusions that can be reached:

- Develop strong, clear purposes and objectives for the project.
- Appoint someone who is in charge of the overall project who was the originator of the concept and who will remain steadfast in their commitment to the overall objectives and purposes.
- Involve a wide variety of expertise so that creative ideas can be spawned yet tempered with practicality.
- Rely upon experts to lead the charge with respect to adopting various technologies.
- Let creative solutions drive the project rather than easily acquired solutions.

4.0 Assessment Methods

This project had several preliminary stages, meaning that the use of shipping containers was time-tested both in the classroom and on a directed study design-build project in Hawaii during the past summer (2009). Reflective papers written by students, post project discussion groups and surveys, as well as student-based course evaluations have all been used as preliminary feedback before this project began. It was also interesting to see that this project was championed by one of the students who was heavily involved in the Hawaii project.

As the project moves forward, these techniques will be used to monitor the effectiveness of the project. As well, sophisticated monitors will be attached to the structure to monitor the energy efficiency of the building relative to its usage. This will be done at all international locations so that a rich set of data can be complied and collected over time.

5.0 Insights and Recommendations

Projects built upon interdisciplinary group design and consensus take both time and patience. One quickly comes to realize the myriad of decisions and ideas that need to be generated, edited, respected or discarded. This can only effectively come about, if, upfront, everyone is reminded that this is a group and team effort and project and ideas must be vetted through the group. Oftentimes this attacks egos, design sensibilities, and values. However, if the project's objectives and goals are clearly defined upfront then this will lead to fewer diversions.

Projects that come to exist on public land are also subject to a great deal of scrutiny. Shipping containers appear to have a NIMBY (Not In My Backyard) connotation and, consequently, the aesthetics, safety, and healthiness of shipping containers are often brought into the limelight of the discussion. Team members should be willing to address this and willing to advance the concept of progressive, innovative design over the status quo.

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