Haitian Rebuilding Initiative: Technological Solutions That Hinge on Empowerment

JUINTOW LIN
California State Polytechnic University, Pomona

MICHAEL FOX
California State Polytechnic University, Pomona

INTRODUCTION/BACKGROUND

At the time of writing this paper, nearly two years after the magnitude-7 earthquake in Haiti, more than a 600,000 Haitians are still homeless, living in camps with little more than tents or tarps over their heads (Weisbrot). Despite nearly two billion dollars being pledged to aid, little has been done in the aftermath to develop permanent housing solutions and even less to empower Haitians in the midst of the earthquakes consequential economic crisis. The project described in this paper hinges on enabling Haitians through a housing project that that is built entirely in Haiti, with local labor and a minimum of imported materials.

An entire house is constructed almost solely with a unique resin-coated corrugated paper core sandwiched between and glued to magnesium board panels which are manufactured locally. The combination of local initiative and a unique-technology applied to the construction process enables the house to be constructed within a very short time (4 days) and at a very low cost. Development efforts have already been carried out by a third party development company and their Haitian counterpart, through the establishment of a complete manufacturing and fabrication facility in Haiti. The technological innovation in this project resides both on the unique prefabricated panel system as well as the Building Information Modeling (BIM) method of delivery for a modular, panelized building system.

This paper outlines a series of studios and seminars at Cal Poly Pomona that focused on the design and construction detailing for the disaster relief housing. The work has resulted in an initial prototype section of a house constructed at the University campus in the United States and the first full house completed in Haiti (see Figure 1).

Figure 1. The Takit-EZ House as built at the Haiti Housing Exposition in Port au Prince will become a permanent home for a Haitian family after the exposition closes

COLLABORATION WITH HAITIAN BUILDING COMPANY

The academic work was carried out in collaboration with the development company of Pacific Green Innovations of Portland, Oregon. PGI is one of the approved vendors selected by the Haitian government to rebuild Haiti. Together with their Haitian partner *Societe Haitienne De Promotion Immobilier S.A.*, they have jointly founded a building products manufacturing facility, Haitian Building Solutions, to locally manufacture the structural honeycomb panels. All of the core materials and panels are made in Haiti with local labor at the facility in Port-au-Prince. The factory is able to produce panels that can be easily assembled by five persons in only a few days to create a fully functional move-in ready home. The Cost of a 53 square meter finished home (utilizing structural panels for floor) is $8,000 USD. Local materials are utilized in the construction and finishing of each structure, which includes windows and doors as well as tile, paint, concrete and fixtures.

The housing initiative promotes job creation in Haiti as a central goal. The unemployment rate in Haiti is estimated at a staggering 70%. In 2010, the US government spent $1.1 billion in Haiti, all of which went to six US government entities and seven UN agencies. None of it went to the Haitian government or to Haitian NGOs or contractors (Yaffe).

A LOCALLY APPROPRIATE BUILDING MATERIAL

The advantages of the honeycomb composite panel include 1) a great reduction of the need for importing materials, 2) creating lightweight housing that will be safer in the event of structural failure, 3) a very fast erection time, and 4) the integration of local labor.[1] The panels are impervious to fire, water, insects, mold, and mildew.[2] Once completed the panel has a compressive strength of over 200 tons per square meter and a bending strength of 0.96 kips at a thickness of 2”.[3 4]

BUILT PROJECTS

The Takit-EZ house was designed by students[5] and built both as a prototype on campus and as a fully functional house in Port-au-Prince Haiti as part of the Building Back Better Communities Expo organized by the Haitian government. This expo showcased model homes by approved vendors, including PGI. This particular house was the only house of sixty model homes built entirely in Haiti, with Haitian labor (see Figure 2). Once the Expo is finished, the house will be given to a family.

Design Process

The implementation of the entire project was realized through a series of courses that spanned an academic year. The process of designing and building the prototype house involved a close collaboration with several experts in disaster relief, professionals in structural engineering as well as representatives from the development company of PGI. Students initially learned within the context of a design studio, how to design within the constraints of a specific modular building material and within the cultural understanding of the context of Haiti. With the knowledge of the possibilities and limitations of the panel system, the process began with a series of rather inclusive design goals that included culture and climate as well as materials and methods of construction.[6]

Figure 2. Haitian Factory and site-build team

Design Goals

For this project, there were a number of general design goals which included:

- *Design for the Haitian culture and climate*
- *Design for affordability*
- *Design for flexibility*
- *Design to withstand natural forces*
- *Design for sustainability*
- *Design for constructability*

A primary consideration was that the design should respect Haitian culture and should be desirable for Haitians to live in. Background research was done into the typical house for Haitians. There are numerous examples of failed attempts by foreign architects creating designs that are inappropriate to local cultural and climatic contexts. The bottom line is that the design must be one that people will want to live in. The main points that were taken from the research were the considerations of a front porch, minimal circulation, security issues, sloping roofs, indoor-outdoor living, area for outdoor cooking, and colors.

A strict material budget of 65 panels was given from PGI. All of the designs were done with panel count and panel simplification in mind. An important point was that it should be possible for families to expand their houses easily and without causing structural failure. Often, Haitians often invest in their homes, and it is therefore important that they have the flexibility for improvement and expansion.

Another important additional requirement was that the designs should be able to withstand typical sustained hurricane winds and should be lightweight so as to reduce loss of life in the event of falling materials. In addition, the designs should promote thermal comfort and work without the need for active heating or cooling.

Lastly, the design should have built-in tolerances for poor construction quality. With this in mind, the approach of prefabrication is well suited as most of the work is able to happen in a factory in a controlled setting. The workers will become very skilled at building one house type through close instruction and repetition.

PRELIMINARY DESIGN

The justification for the selection of the Takit-EZ House design (see Figure 3) hinged on a number of factors. The asymmetric roofline is quite common in Haiti. The plan is efficient in the way that it minimizes circulation (there are no hallways). The design included clerestory windows which encouraged cross and stack ventilation. French doors provide a connection from the house to both front and back yards.[7] The enlarged porch allowed for outdoor cooking, and a pass through window is available to pass items stored and locked. As well, in terms of flexibility, additional bedrooms can be placed to the back.

Design Optimization

Next the design was optimized in terms of affordability, structural, sustainability, and constructability issues.

Figure 3. Rendering of the Selected Design – the Takit-EZ House

DESIGN FOR AFFORDABILITY

The first step in the Design Development was optimizing the designs for cost. The primary goal was to reduce the amount of material used, or the overall panel count. Designs were optimized for material count and minimal cutting. A few of the reductions included: shortening overhangs to use full length panels, reducing bedroom sizes from 8' x 12' to 8' x 9'-3"). The porch was changed from 6' wide to 4' wide. With these simple reductions, the panel count which had previously exceeded the allowable amount was reduced from 75 to 65.

The original design consisted of cutting windows and doors out of the center of a panel. This strategy was revised in favor of trying to minimize waste. The idea is to place one structural panel next to a non-structural panel, so that non-structural panels could have large openings taken out to maximize the ventilation. Windows became 4' wide. This strategy saved 2 panels per house.

MINIMIZE IMPORTED MATERIALS

The original design included a tie-down system with a bolt extending from foundation to roof. This tie-down system was designed for wind as well as seismic considerations. This bolted detail was changed to a cable-tie system, which is much easier to source in Haiti, and uses considerably less metal. To simplify the construction process, this tie-down extended above the roof and can be adjusted from the outside of the building.

Also, typical SIPs construction uses continuous 2x4 wood studs to connect the wall to the floor. Additional studs are often used between panels. For this project, we were given a material budget of 10' linear feet of metal studs. Instead of using continuous studs, metal studs are used at the floor to reinforce the connection between panels as well as from wall to floor, and wall to roof. Due to the deforestation problem in Haiti, we avoided using wood where possible.

In terms of the foundation, slab on grade is expensive in Haiti, about $3,000 for a 26' x 22' slab. It is also more difficult to run utilities when the technology for such infrastructure becomes more abundant. Therefore the designs were made using concrete footings. The prototype was constructed with reinforced CMU blocks, but these require a high degree of precision and detailing to get a level raised platform floor. The footings can be changed to simple slurry footings which would be more flexible and affordable. Railings were designed with renewable and local resources in mind so they will be constructed either from bamboo or a similar quick-growing tree, or from welded rebar.

DESIGN FOR CONSTRUCTABILITY AND STRUCTURAL STRENGTH

As mentioned in the introduction, another significant factor that must be taken into account is the labor force. There is a lack of skilled labor in Haiti, and therefore the construction of the project should not depend on highly complicated details. The design for this project minimizes the number of various details and conditions. In the summary sections below we highlight a number of specific issues that were resolved related to both the constructability and structural integrity of the house.

Maximizing openings while maintaining structural stability

An important consideration in designing with a lightweight, modularized panel system within the climatic and geographic context was to optimize the design for structural performance. The design was primarily examined for lateral support stability and hurricane forces were calculated for sustained 100-150 mph winds. Shear walls were designated and sized, and openings in shear walls were moved away from corners and outside edges. The tie down quantities, locations and strength were calculated. This structural analysis resulted in a number of changes in the design, which primarily involved adjustments in the locations of openings. The most common resulting change was that windows previously located in the corners were moved toward the center of a panel.

Foundation Tolerances

At the site level, the foundation system was designed to have a maximum tolerance level. In addition to rebar, 6" bolts were embedded into the concrete piers. They extended 2" below and 4" above the level of the concrete block. Leveling plates were attached (with nuts) to these bolts. This allowed for 4" tolerance in setting the piers level. It was found that this method was ideal but also that it required a fairly high degree of skilled labor in positioning the piers, maintaining an approximate relative height of the piers and centering the bolts. While the bolts had a 3-1/2” tolerance (to land within the cavity of a panel), this was sometimes difficult and would be worsened on uneven or ungraded terrain. We have proposed that future houses use piers in combination with a leveled beam substructure to support the floor panels.

Site Corrections

The panels were designed to minimize cutting, and thereby saving material, and reducing labor. Most panels are 4’ wide, with some panels at 2’. On the drawings, one panel on each side is designated as the field-correction panel. In the event that things don’t quite fit as planned, that panel can be adjusted to fit.

Tie-down Adjustments

It has already been briefly described that the bolted tie-down system was replaced with a more simple and economical adjustable cable tie-down system. The cables are initially secured to an eye-bolt placed in the foundation slab on grade or reinforced piers. The cable then runs through the center cavity of a wall panel and is extended through the roof and secured with a top adjustable eye-bolt. The bolts on the roof are then covered with a plastic cap and caulked to prevent rain penetration. This system additionally allows for future adjustments of the tension on the cables as required due to building settlement.

DESIGN FOR SUSTAINABILITY

In terms of sustainability, a number passive strategies were used in order to increase the thermal comfort of inhabitants. The primary strategies for this climate type are shading, light colors, and natural ventilation. In addition, various design permutations were created for varying orientation conditions.

The shading strategy for this project is a balancing act. The overhangs were minimized in order to reduce uplift and to reduce material use. Exterior shading was the preferred goal. In order to save on cost and provide shading, shutters were designed in lieu of windows. These shutters keep the rain and sun out when needed, and could be made from the magnesium board panels. In addition, the roof is painted white in order to reflect the solar heat gain.

Both cross and natural ventilation were considered. Clerestory windows above the low shed roof also allow hot air to escape. The living room spans from the front of the house to the back, encouraging ventilation through the space. In order to maintain visual privacy and still allow ventilation, ventilation above the doors are provided to encourage airflow through the bedrooms. In addition, all bedrooms have windows on at least two walls, again to encourage cross ventilation.

The designs are flexible in their orientation. Depending on the master planning, the bedroom area should be placed at the north or east. The asymmetric roof can also be mirrored to promote maximum airflow. Where there are fast prevailing winds, the design can be made so that winds come through the clerestory windows. Where the site airflow is minimal, the clerestory windows can be oriented to promote stack ventilation, where cooler air from the outside travels through low inlet windows and out the higher windows.

Where possible, the design reduces the need for imported materials. Site walls, if appropriate are to be made from rubble from the earthquake. In addition, the foundation could sit on a gabion walls or a mat foundation made from rubble. This rubble not only is structural support for the house but also allows water to flow through it, so that in the event of a flood, the foundation support should be stable.

It is preferred that design methods allow for inhabitants to adapt their house to future needs without needing to tear down their existing houses. The house was designed with flexibility of space in mind. If needed, the inhabitants can easily change one of the front bedrooms or living room to a shop or an office. This entrepreneurial commercialization of the house and front porch is often found in Haiti and was an important consideration to facilitate.

Construction Drawings

The students made a cursory set of construction documents for the prototype that was built on campus. As part of the spring course, students developed a more detailed set of construction documents for the construction of the house in Haiti.

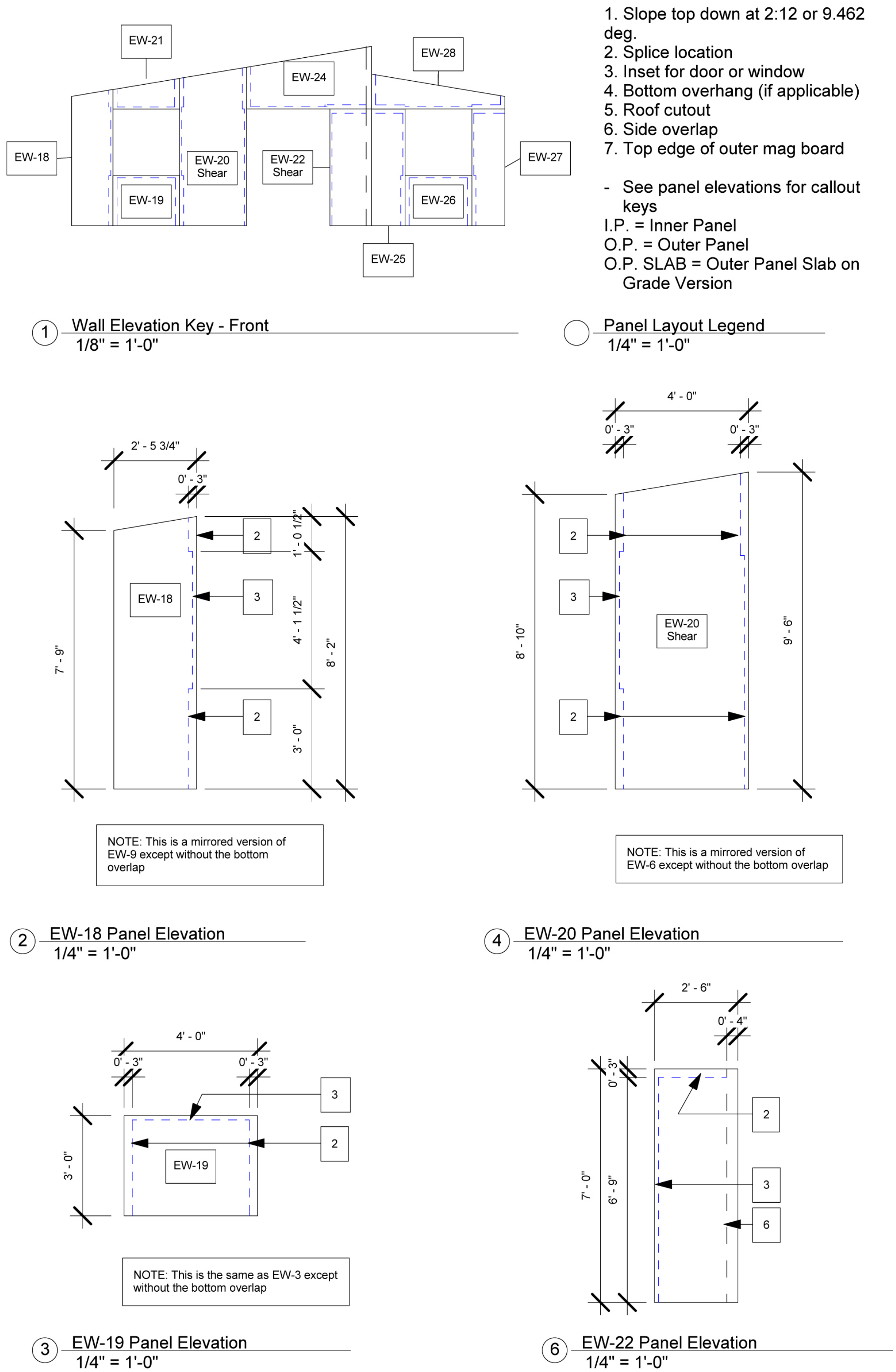

Figure 4. Panel Elevations from Revit

USE OF BUILDING INFORMATION MODELING

The technological innovation in this project hinges not only on the unique prefabricated panel system but also on the method of delivery for a modular, panelized building system. In this respect, a BIM Model was created using Autodesk Revit™. This model was created in order to:

- Reduce errors and, produce a well-coordinated drawing set
- Generate schedules for material takeoffs, including panels, glue and paint, cable length, etc.
- Generate schedules for panel characteristics, including types and quantities, and basic information such as dimensions, splice condition, etc.

A custom parametric family was made that described all the panel characteristics. The one family type was then flexed with a number of shared parameters.

The schedules were instrumental in providing counts of everything from panels to tie-downs and metal studs needed for the project by this the Haitian Building Crew. Also, last minute changes were quickly managed through the model. For example, the magnesium board panel used in the end was 10mm rather than 6mm. Because of the parametric nature of the model and the rigorous use of reference planes and locking, this change was easily accomplished. The BIM model provided a full set of drawings, from site plan to foundation plan to details to renderings.

Panel elevations (see Figure 4), were created with the use of legends. Elevations were in turn dimensioned and keynoted. Quantities of panels were used to budget the project and order shipments. All drawings were done at 8.5” x 11” to facilitate ease of printing and even reading on a mobile phone, which happened on occasion during construction.

Prototyping

Students were eager to develop, prototype, and test the most crucial aspects of a design. Communicating design intent often requires methods of demonstration rather than simulation. The value of the built prototype on campus has immeasurable value for this ongoing project; we view it as a malleable entity that will be ideal for future testing and analysis which can be continually added to and modified. The course focused on prototyping as a means to learn as well as to inform the ongoing optimization. Students designed details and built the project at all levels, from site preparation to gluing and preparing of each panel, to final finished construction such as painting and hanging doors (see Figure 5).

Figure 5. Students shown making panels, and with the finished Full-scale mockup

The honeycomb, magnesium board, and glue were donated by Pacific Green Innovations. The prototype cost was $1,000. This included the cost of concrete blocks, cement, reinforcing steel, door, and miscellaneous metal.

As in real life, last minute changes were made in the field to make the construction process easier. This is valuable for students to understand that architects draw something thinking that that is the way it will get built, whereas in reality, contractors often solve problems in the field that supersede the design. For example, we designed the foundation as poured in place concrete. In construction, this was changed to concrete blocks.[8] In addition, flashing was used to cap the exposed honeycomb at roof edges rather than magnesium board. The prototype is on site and available for future testing and analysis.

Construction in Haiti

The house was constructed in Port au Prince, Haiti as part of the BBBC Expo. The government of Haiti hosted the Building Back Better Communities (BBBC) design competition which began with over 10,000 entrants and culminated in the BBBC Expo. The competition allowed the government to study different housing types before commissioning them with representatives of foundations that will potentially underwrite their construction. The expo is dedicated to best-practice solutions alongside wider urban themes such as green energy, transportation and use of local materials and production.

The Expo Requirements differed slightly from the original program brief. All houses built for the Expo required electricity, a full indoor kitchen, and indoor plumbing. In order to accomplish this, the footprint of the building and overall roof design was modified. The front exterior wall on one side was pushed out 8′, thereby enclosing the 8′ x 8′ enlarged section of porch. This area had been previously enlarged to act as an outdoor kitchen, so functionally the program stayed the same. In addition, the floor was built as slab on grade rather than raised floor.

The Expo House also required windows with glass. The large 4′ x 4′ openings proved to be cost ineffective due to large non-standard windows. In reality, it was determined that the cost increase for windows with large openings of non-standard size may be greater than the cost saved due to the reduction of wasted panels. Also, the panels were pre-assembled in the factory in groups of 2 and 3, and the large openings made it difficult to transport. It was determined that the best method to create the openings was to cut them with a hand saw on site after they had been erected.

Current Developments

With respect to the panels themselves, the structural objectives are very difficult to achieve in that we are working with a combination of materials that essentially come together to make a novel untested panel product. At the time of this writing, integrity testing is being completed on panels both with and without laminate and with both Kraft paper and Polyethylene Terephthalate (PET) core. Several tests are also being completed to eventually make the product acceptable to US codes including compression, tensile, shear, deflection, water absorption and many more. In some instances, construction within these parameters may involve using a steel frame structure and using panels as infill.

Full production is expected to begin in the Haitian factory soon. PGI has several small orders of homes coming in now. These are primarily orders for 4-6 homes at a time and most are being built within Port-au-Prince or its immediate surrounding areas and will be occupied by persons who have been displaced. Additionally, they are also are working on a 1,700 home project that is being funded through several foundations and have submitted RFIs for other large projects being funded by USAID.

Educational Outcomes

This project has been an enormous opportunity for all involved and especially the students. It provided experiences in coursework whereby students were engaged in complex and realistic design activities that synthesize knowledge from a number of previous courses. It also increased the students' awareness in terms of the impacts of the built environment on the very real human need for shelter. This project is in a unique position to make a very real positive contribution which includes understanding considerations of cultural and contextual conditions, and the necessity to overcome simplified assumptions about costs, fabrication, and politics. Students learning these skills now will bring a new palate of strategic design to the profession as they mature and integrate themselves professionally.

A number of valuable educational objectives were achieved including that students: 1) appreciate the global and ethical impacts of their design decisions, 2) recognize real world political situations related to disaster relief housing, 3) apply their discipline-specific construction and materials skills to an interdisciplinary problem, 4) design effective housing where cost and simplicity are primary constraints. The project also integrated the educational value of understanding the international politics surrounding disaster relief housing. From a project standpoint, students learned to design schematic buildings using a number of real material and budgetary constraints. They also were forced to reconcile and understand real strategies for fabrication, delivery and assembly related to the unique construction details that they developed.

APPENDIX

The following students took part in the classes mentioned in this paper.

Fall 2010 Elective with Professor Fox - Liliana Alvarez, Ryan Barnacastle, Milagro Carpio, Erica Christie, Sharon Clay, Julie Coleman, Adilene Contreras, Michelle Fong, Nathan Houck, Calvin Huang, Kellene Kaas, Amy Marino, Candice Myers, Long Nguyen, David Phan, Rebecca Radojicic, Daniel Schnizler, Layla Shaikley, and Eylyana Soto.

Winter 2011 Topic Studio with Professor Lin - Kristina-paula Alvarez, Liliana Alvarez, Gabriela Barajas, Jennifer Clare, Adilene Contreras, Marshall Ford, Peter Fox, Nicole Graciano, Jennifer Guerra, Nathan Houck, Amy Marino, Ashi Martin, Fariba Mostajer, Kenneth Pang, John Tubles, Ryan Raskop, Daniel Schnizler, Miguel Simental, Eylyana Soto, Christopher Stanford, and David Wang.

Spring 2011 Elective with Professor Lin - Maro Asipyan, Gabriela Barajas, Adilene Contreras, Peter Fox, Nicole Graciano, Jennifer Guerra, Nathan Houck, Michelle Houser, Ashi Martin, Fariba Mostajer, Ryan Raskop, Daniel Schnizler, Miguel Simental, Eylyana Soto, Christopher Stanford, Matthew Terry, Caleb Wong, and Christopher Young.

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ENDNOTES

1 The paper core is made with recycled paper cellulose, soaked in a resin, and compressed under high temperature and pressure to make a new homogenous material. This new material is turned into honeycomb strips, which are then combined and extruded to create the structural honeycomb core onto which siding panels can be applied. Two structural magnesium board panels sandwich the resin impregnated honeycomb core to create the fished panel product. The final product is extremely lightweight, structurally stable, as well as fast and easy to process.

2 In a month at 90 degrees celsius and 100% humidity, there was only a 1.5% absorption of water

3 It is possible to insulate the material by filling in between the honeycomb cells; however, this was not carried out for our project in Haiti because the windows and doors are almost always open, thus negating the effects of insulation.

4 The honeycomb paper is currently imported into Haiti and can be extruded and cured in nearly any size or thickness at the factory in Haiti. A future goal is to manufacture the paper from locally recycled paper or PET. The controlling factor for panel size is the magnesium board, which comes in sizes of 4'x8', 4'x9', and 4'x10'. These panels are in turn connected together with a glued splice piece, which runs the length of the panel and is approximately 6-8" wide. The panels can span up to 10'.

5 The development of this project has been a three part course. The first course was by Professor Fox in the Fall of 2010, and students designed Transitional Shelters and houses using the material mentioned above. In the second quarter, Professor Lin taught a studio on the subject matter and the project included the design for buildings, such as houses, school/orphanages, medical centers, and a master plan design for a housing community. In the spring, Professor Lin continued with a number of students on additional designs and the construction of the prototype and production of construction drawings. For the purpose of this paper, we will only elaborate on the first Haiti house constructed: the Takit-EZ House.

6 Next, a number of preliminary designs were completed that satisfied both the general goals as well as the design particulars for a house. From these preliminary designs, a single house was selected for further design development: the Takit-EZ House. This design was then optimized for affordability, structural strength and constructability as well as sustainability. The design was also considered within the larger community context at the level of a neighborhood. Lastly construction drawings were developed that were informed through the construction of a full-scale prototype section of the house. The prototype which was constructed on campus informed the design through real-world testing of the design detailing decisions.

7 It is important to have the door to the back for a number of reasons, including 1)safety – in the event that burglars enter from the front, you can escape through the back, and 2) a connection to the backyard, which may be used for gardening or outhouse.

8 Each foundation pier consisted of 8 concrete blocks reinforced with reinforcing bars and filled with concrete. The blocks went 16” into the ground and 16” above ground