A Studio's Multi-Exploration of the Prefabricated Dwelling

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Abstract

Even though prefabrication has been around for centuries, the rising cost of labor and materials and increased environmental sensitivity has brought prefabrication back to the eyes of the public and has created a renewed push within the housing and design industries for prefabrication. The terminal project-level studio I taught in Spring 2008 grappled with the idea of prefabricated dwellings as a research design topic and created an amazing variety of work this paper will illustrate and discuss.

The studio began with a review of the history of prefabrication, dating back to the 1600s, where modular homes were shipped in pieces to be rebuilt by the first settlers upon reaching America, and up through Buckminster Fuller's Dymaxion home and Lustron home by Carl Strandlund. The students also looked at contemporary case studies, such as the weeHouse by Alchemy Architects and the Drop house designed by architects Antoine Cordier, Olivier Charles and Armel Neouze. New technologies were also researched to support their designs, from off-the-grid systems to the CNC fabricated work of William Massie.

From this research the students designed a program or matrix using the answers to the following questions to guide their designs: who is the dwelling for: second homes, disaster relief victims, a single family, multiple families? How will this be delivered, flat box or modular? What level of permanence: temporary, semi-permanent, permanent? Is this a modular or component driven project, or both?

This matrix and the students' own creativity created a wide variety of work. The projects to be discussed in this paper will be as follows: the ellipse home designed down to the built-ins that plug into the home's structural system; a modular disaster relief unit designed to create a sense of community, and the ability to be reused as building blocks for homes; and a new CMU block system for a downtrodden village in Tanzania which is designed to be plugged together and dry stacked by uneducated laborers to build their own shelters. This paper will discuss these projects and the process used to teach the studio.

Introduction

In the spring of 2008 I taught a final studio of the students' first professional degree focused on prefabricated dwellings. While the studio synopsis specified that students would be researching methods and designs to deliver a prefabricated building, the program details (type of building, its purpose, size, etc.) would be defined by the students throughout the course of the semester. The vagueness of the brief was by design to allow each student to choose the direction of his/her final project before receiving a degree.

The first project, the Ellipse house, shows how design can be a holistic approach to dwelling, where the design meets not only our living needs but also the systems needs of a home. Each component is interdependent, providing all of the necessities and desires of dwelling: shelter, heat, water, power, natural light, ventilation and furnishings.

The disaster relief dwelling creates a design to be CNC fabricated and then quickly and easily shipped to even the most difficult to reach sites. This shelter parcels out modules for our basic needs of shelter, providing a flexible system with a layout that can be simply recomposed to meet a specific need of one family or many families in their time of need.

The final project, C-block, is a simple construction method wrapped in a specialized form. It brings to the uneducated builder in Tanzania a method to create shelter with a material on hand, concrete. This system is humane and thoughtful, created with sensitivity to an impoverished people's needs.

Studio methodology

In preparation for the actual studio, students took my programming course a semester prior to the design studio. In the programming class, the students researched the history of prefabrication, dating back to the first European settlers in 1624 at Cape Ann, where modular homes were shipped in pieces to be rebuilt upon reaching America[1], and up through Buckminster Fuller's Dymaxion home[2] and Lustron home by Carl Strandlund[3]. These early examples and the history of prefabrication in home building inspired the students to choose a dwelling or home as their focus in the spring.

The students then looked at contemporary case studies, such as the Loblolly house[4] by Kieran Timberlake Associates, the weeHouse[5] by Alchemy Architects and the Drop house[6] designed by architects Antoine Cordier, Olivier Charles and Armel Neouze. Research into some of the newer technologies that might be used in their designs was also documented, from off-the-grid systems to the CNC fabricated work of William Massie[7]. A final document was assembled that included the outcome of the students' research into programmatic concerns, infrastructure systems, case studies, computer fabrications, and materials.

From this research, each student designed an individual program for the Spring 2008 studio using the answers to the following questions to guide the designs: Who is the dwelling for: second homes, disaster relief victims, a single family, multiple families? How will this be delivered: flat box or modular? What level of permanence: temporary, semi-permanent, permanent? Is this a modular or component driven project, or both?

As students answered these questions and developed their individual programs, they were pushed to be innovative in all aspects of the project: programmatic considerations specific to the intended user; cost, availability, and durability of materials; and much more. Individual design choices often required more research. In addition to the functional and technical design decisions, students were constantly reminded to remember the aesthetic quality of the dwelling. It became a mantra from me that creating a beautifully working machine is not the same as creating a beautiful place to live.

Technology

Students looking into the process of manufacturing needed to be able to test ideas within this paradigm. The students often used our new laser cutter to facilitate this. This machine allowed the students to create accurate representations and to simulate CNC (Computer Numerically Controlled) fabrication techniques. In prefabrication, CNC devices have become one of the main ways in which a new type of prefab structure is being produced, as is seen in the works of William Massie[7]. This equipment allows for precision and craft without increasing costs of labor and time. Using CNC devices gives the architect more control over the final outcome along with the flexibility to mass customize the design for a growing design-savvy public[8]. An example of flexibility and customization will be shown in the first project, Ellipse house.

Public responsibility

Within this next generation of designers, I have found there is a large segment who want to be more sensitive to the needs of people in distress or the underprivileged. Over the last few years, architecture students at Kansas State University have volunteered time and effort in two major endeavors: "The House of Dancing Feathers" in New Orleans' Ninth Ward[9] following Hurricane Katrina and the project "Greensburg Cubed" in response to the EF-5 tornado that hit Greensburg, Kansas[10]. This sense of public responsibility extended into my studio. Some students found prefabrication methodologies to be an ideal way to quickly respond to disaster efforts and low income housing alternatives, as will be seen in the final two projects.

Each project will demonstrate an idea driven by prefabrication. However, each of these three projects has a different type of user, delivery, scale, and social implication. Each project provides a different understanding of how to create a prefabricated dwelling.

Ellipse house

The Ellipse house[11] was designed around two concepts. The first was to consider the project as analogous to a tree, where each part is interdependent for its survival. Each component of the tree—roots, trunk, branches, and leaves—is necessary for the tree to not only survive, but thrive. Some parts provide struc-

ture or collect solar energy; others are involved in water distribution and absorption. This type of interconnection and interdependence provided the basic framework for the Ellipse house.

The second concept follows a trend in consumers that are clamoring for unique personalized merchandise[8]. A consumer can go to the BMW dealership to buy a Mini Cooper and custom fit it to personal desires on the exterior and interior. Similarly, music, shoes, and other items are customized to reflect personal statements. The Ellipse house asks, "Why not customize the house?"[12] To accomplish this, the elliptical object was used to give the home immediate recognition and to create a prefab single family home that literally breaks the proverbial box. The unique form and many different "snap-in" components to the home provide the user endless customization options.

Structure

The basic rib structure of the Ellipse house is designed to provide connection possibilities not only for a variety of skin components but for interior snap-ins as well. Each plywood rib is designed to be cut by a CNC router in pieces and then flat packed and assembled on site. The pin connections used to sandwich the double layers of the rib will also be used to fasten the interior snap-ins to the walls.

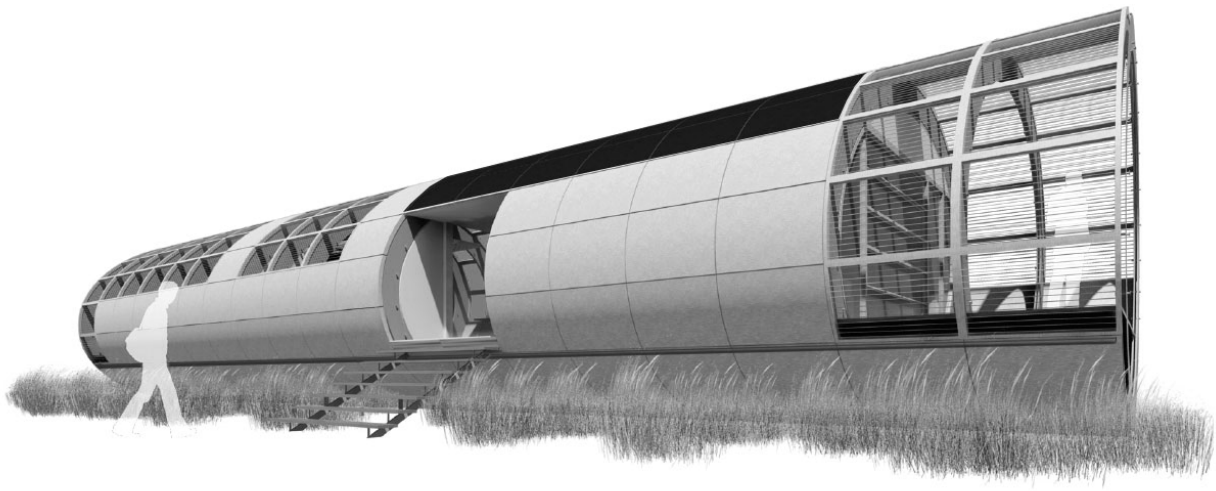

Fig. 1. The Ellipse house: one of the many configurations of glazing versus solid panels possible. Other custom features include an open-air porch and photovoltaic panels. Assembly of the structure was designed to be simple, as each piece—from anchors to floor boards and flooring—is precut and fabricated. All connections are bolted or screwed, so only a minimal amount of tools and skills are necessary to construct the home.

Skin

A variety of skin components were designed so clients could customize their home as specifically as desired. Glazing can be plugged in where needed or exchanged at a later date for a solid panel. Each panel can also be outfitted with a flexible photovoltaic (PV) film (as shown in Fig. 1). The elliptical form of the house allows the users to order PV panels which optimize their given latitude's solar collection.

Snap-ins

Another customized and interdependent system is the snap-in component. A consistent gap between the structural ribs is created using a spacer and bolt connection. This gap and bolt provide a basic hanger for the interior components to fasten. The interior components consist of wall panels with a special fin, allowing it to be lifted and held in place by a friction connection. This snap-in wall then allows one to layout an Ellipse house as desired, again and again. The other snap-ins, consisting of kitchen cabinets, desk, shelving, closet storage, dresser, etc., are similarly held by a friction connection and gravity. Each has a metal bracket custom designed to allow the unit to be installed and then nestle into the ribs simply and precisely. This type of installation makes it possible for the users to personalize their layout for their initial needs, but also allows easy modification of the home at a later date to fit new needs or desires.

Systems

In keeping with the tree analogy, the systems of the home are also integrated into the design. As mentioned earlier, solar energy is collected by the PV film-coated panels with battery storage located in the belly of the home.

The home has exterior panels with an integrated gutter system located at floor level that channels rainwater into tanks in the house's belly. Natural water tension will allow most of the water that hits the exterior surface to follow the convex curve, even though the gutter is past vertical. This water is treated and used for potable water. A second tank will collect grey water for use in toilets and irrigation.

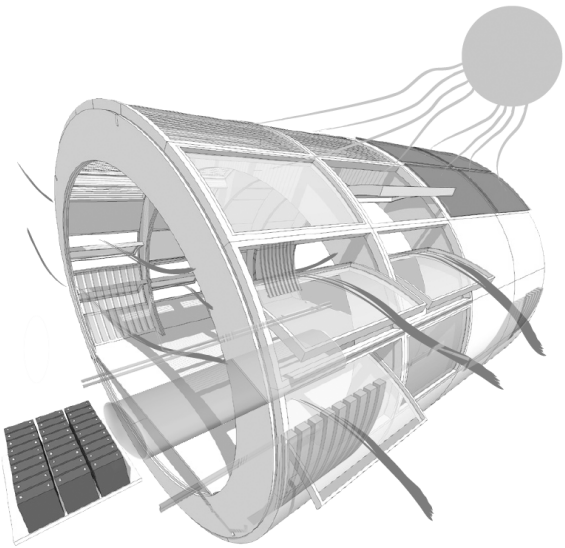

Fig. 2. The systems of the Ellipse house are fully integrated within the skin, the cavity between ribs and the belly of the house below the floor.

The narrow footprint allows for cross ventilation as well as stack ventilation to occur simply, providing passive cooling. For colder seasons, the house will have a radiant heating system running in the cavities between the ribs.

Modular disaster relief unit

The Modular Disaster Relief Unit[13] was developed in response to the need for better disaster relief housing in New Orleans and surrounding areas following Hurricane Katrina. The Federal Emergency Management Agency (FEMA) trailer and the next FEMA answer to the housing problem, the "Mississippi Cottage," were used as case studies.

Both attempts at housing had major flaws. Beyond bureaucratic and administrative problems, there were also difficulties delivering both the trailers and cottages to the sites where they were needed in mass. Although the FEMA trailers could be manufactured in large numbers, the materials used in building the trailers released toxic levels of formaldehyde, forcing many residents to flee their disaster relief housing[14]. The cottages provided a much higher quality of living than the trailers, but never reached the quantities needed even a year after Katrina hit, let alone the numbers needed immediately after a disaster of this scale[15].

In response to the difficulties noted with the FEMA solutions, the design of the Modular Disaster Relief Unit addressed the issues of delivery and installation and use of non-toxic materials. In addition, the student designed for the eventual reuse of disaster relief housing as building blocks for future housing.

Modules

Housing large numbers of families in need of shelter requires thoughtful, efficient design. Instead of relying on one unit design to solve all issues, this project divided the units into three modules: living/sleeping, kitchen and bathroom. These three could be attached to create one home or consolidated in mass during the first phase post-disaster. Modules could be spaced out and one kitchen and one bathroom module could serve several families at once. After the initial crisis, additional kitchen and bathroom units could be built as necessary, if the need remained, to provide more privacy. The modules also allow for a general reuse and recycle as members of the community got back on their feet. Units no longer needed by one family could then be distributed to others in need to provide a complete set of three or more modules per family unit.

Each module has a certain amount of built-in furniture. In the living/sleeping unit, custom furniture was designed to allow the user to fold up the beds to create places to sit. In other cases, the beds are flipped to create desk and storage opportunities.

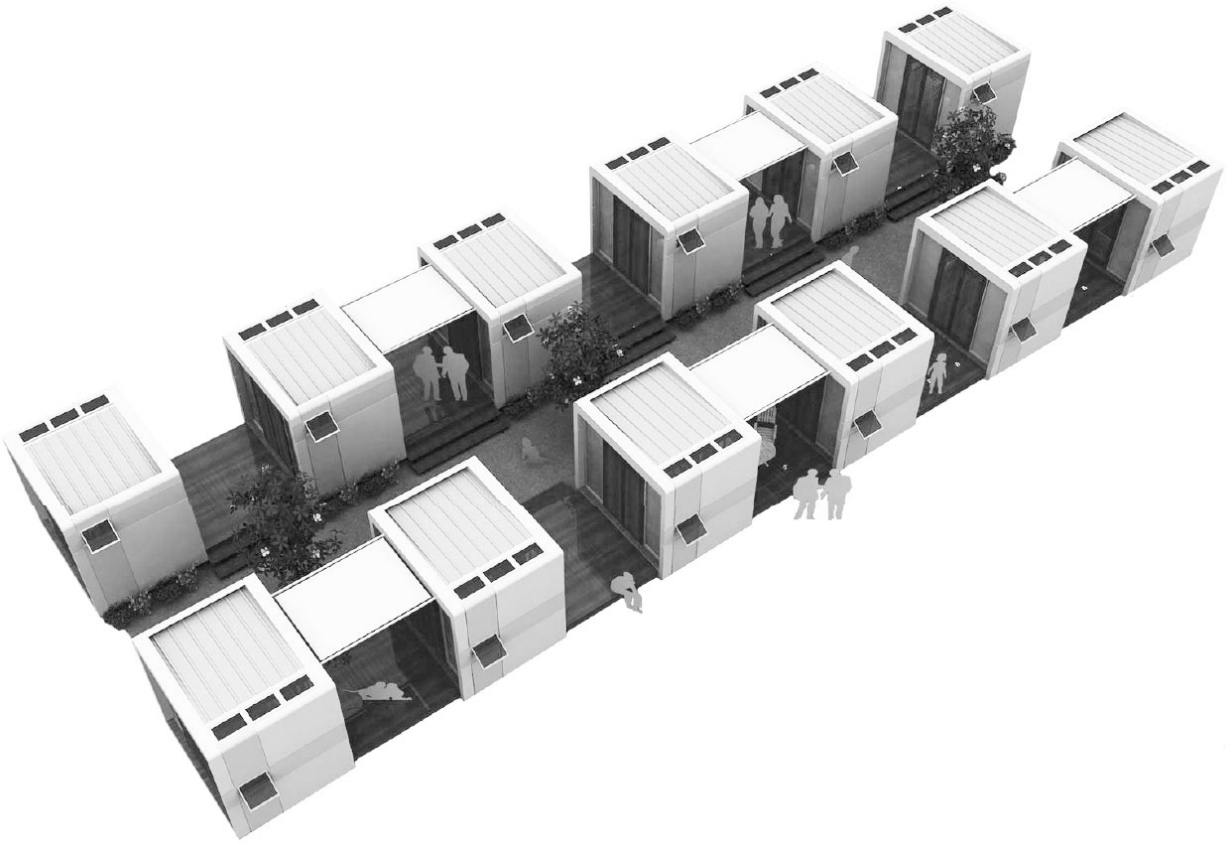

Fig. 3. The modules representing a disaster relief community layout.

Construction process

The modules are constructed considering a certain amount of flat packing to get as many shipped as quickly as possible to a site. The shell of the module is delivered in an eight by ten by three foot container. The eight-foot width allows the module to be loaded on all conventional transports and, if needed, on small trailers being pulled by standard trucks for sites which are difficult to reach.

Each module is designed to be a simple, clean cube with an eight by ten foot footprint. The exterior is low riding to allow for ADA access if needed. The feet are adjustable to contend with variations in site slope, and each side is layered in the container to be folded out and assembled on site.

For easy assembly, most of the structure is cut and notched by a CNC router out of Firestall, a fiberboard product made from post-consumer recycled newspaper, containing no asbestos or formaldehyde additives. Firestall is currently only being used as a roof decking material, but the student designer proposed it be applied as a lightweight structural frame. Given this construction material, the modules will be considerably lighter and a more sustainable alternative than traditional framing methods.

Each module has been designed to harvest rain using the shed roof to collect water in an integrated gutter and drain. This feeds a filtration system and tank for potable water. Underneath the link, all of the water supplies, in and out, as well as the electrical connections happen.

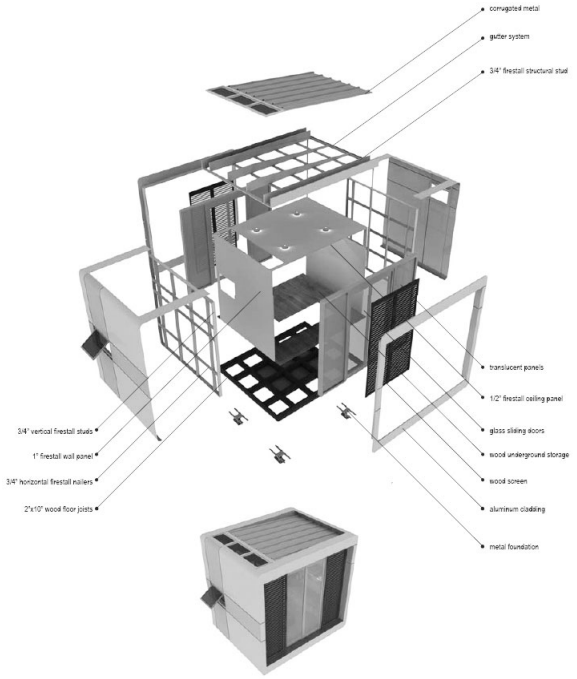

Fig. 4. Exploded perspective of the assemblies of a typical module.

In a disaster relief community, this allows all necessary services to be established and keeps this infrastructure out of the way of the general public.

Community design

In the case of Katrina, some people were not given the affirmative to rebuild for six to nine months after the hurricane. This called for the consideration of long-term disaster relief "cities." The units housing these people needed to be flexible and able to provide thousands with at least some sense of community and quality of living.

This design gives people a very compact version of the lives they left behind. Each living/sleeping module provides a living space that doubles as a sleeping area. This module has a large connection to outdoors through sliding glass doors and a deck with an awning to provide an outdoor gathering place typical of New Orleans living. This link also literally doubles the amount of living space for each module.

Improving Housing in Keko Magurumbasi

In this project, the student didn't necessarily design a dwelling but designed a component for building. He designed a component and construction process where tools necessary for assembly are minimal, where skill level for construction is also minimal. This type of design is full of compromise; however, there is clearly the potential to affect many who are in need of help and normally forgotten by designers.

The people of Keko Magurumbasi in Tanzania are quite poor with little to no education. The shelters they have, if they have any, are built from locally made CMU blocks and scraps of whatever lumber and metal can be scavenged. The current CMU houses are built poorly with little to no ventilation or light. Most Keko people live and work from home either making crafts and tools to trade or sell.

C-blocks

Given the situation of the Keko people, the C-block was created[16]. The C-block would utilize a block design in the profile of a "C" with an interior and an exterior block facing each other, dry stacked to create the dwelling. The two block system created an interlocking system where one block would be a traditional weather resistant concrete and the other would be a sun dried mud and portland cement mix. This type of two C-block construction offers a more sustainable system, relying on indigenous soil for the interior block and also allowing for a smaller block system. After attempting some full-scale at 12" wide by 24" long by 12" high, as well as half-scale mockups, the half-scale mockups were found to be ideal. It is an extremely ergonomic block

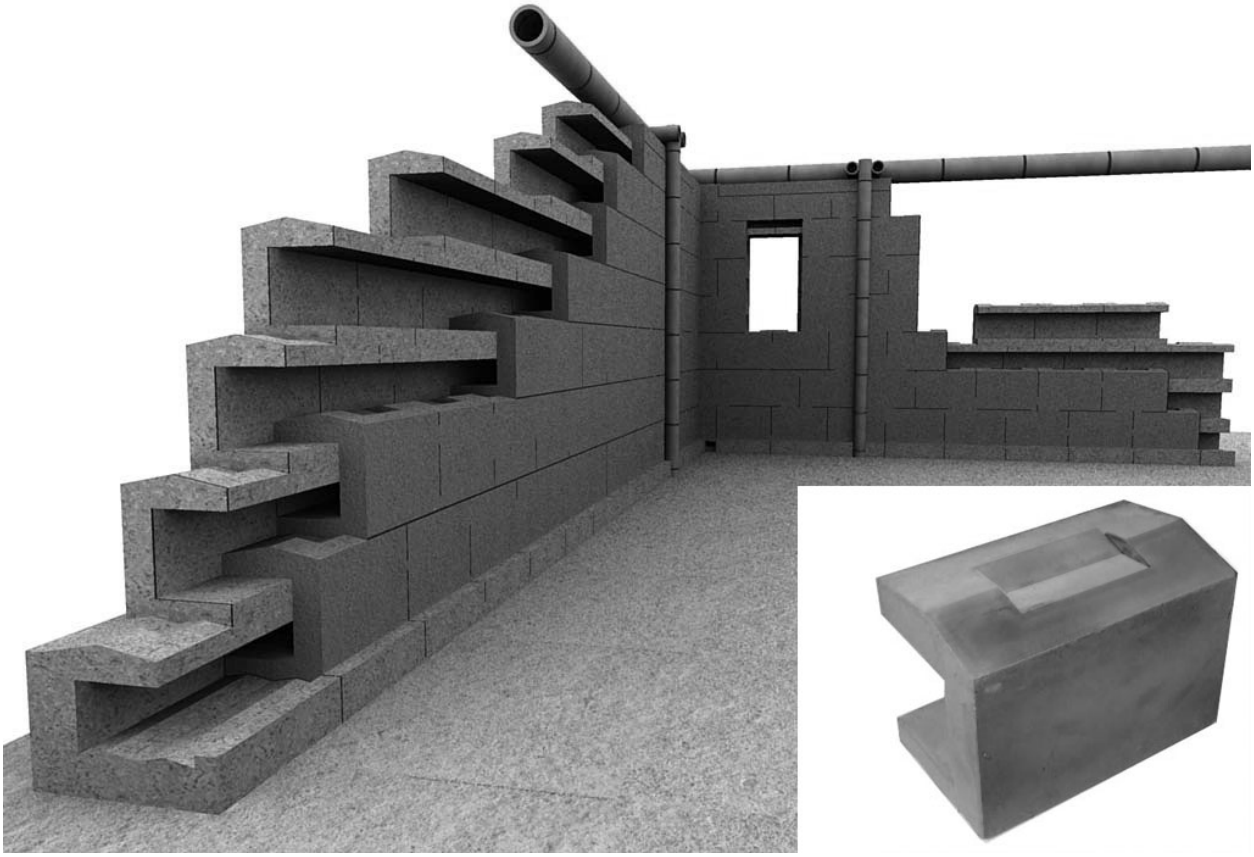

Fig. 5. A construction diagram of the C-block being assembled along with a full-scale prototype.

closer to the quality and weight of a traditional brick but with all of the advantages of a dry stack plug together block. This version made the block 6" wide by 12" long by 6" high, weighing approximately 15 lbs.

Each block has a pitched top with a "V" groove in the center. The bottom of the block is then molded as the inverse of the top. The pitched top of the block serves to create a surface to shed any water attempting to infiltrate the wall. It also develops an interlocking system, so stacking the next block on top is a simple procedure and provides some lateral strength.

Making the blocks

Manufacture of the C-block could be done by industry; however, the designer wanted a more hands-on approach. Silicon molds needed to form the top and bottom of the block would be provided to the villagers. The straight sides could be framed with plywood, also provided. Once a few blocks were created, these blocks would then be used to create concrete forms to form more top/bottom molds, thus making a self-replicating system.

Construction process

Currently the construction process works through laying a base course on top of level compacted earth. A much heavier block is used for the first course (Fig. 5). This base block allows the interior C-block to rest on the base block's ledge. After this first course, the C-block courses stack quickly.

Bamboo serves as the main structure of the roof of the house, and also serves as part of the C-block wall. With long spans of C-block walls and no mortar helping hold the wall together, lateral stability is a concern. Bamboo is used to sandwich the wall every four feet with hemp rope laid between courses and then twisted taut. This simple compression connection provides the necessary lateral support.

In situations where building materials and construction skills are minimal, the C-block provides a means to achieve private dwellings. Its form gives the complex problem of sheltering a simple solution by taking the one readily available building material, concrete, and giving it new form to make it more accessible to and usable by the public.

Conclusion

Prefabrication historically inspired architects and inventors to create new paradigms for housing. It continues to be a topic to inspire designers to think about the masses, designing projects to make the places we live unique to our individual needs, shelters to serve us in our most dire time of need or perhaps a building block more easily assembled by two hands into a beautiful shelter.

The diversity of work shown from this studio is in large part due to a flexible program. This program did a better job of asking questions than in giving facts. The questions: who is the user, what is the delivery, what type of permanence, is this component driven or modular; their multiple answers created a scenario where each student designed within a unique framework. Yet all were still grappling with the main question of prefabrication.

For those colleagues considering prefabrication as a main topic, the dwelling worked quite well a building type. This building type was familiar enough to students that its fabrication could become a more central focus, although it must be emphasized that these designs were not solely focused on construction. The quality and design sense of the overall dwelling were equally important for success.

A difficulty in teaching this type of studio is the technical proficiency in prefabrication the students must master in order to create a believable argument. This was dealt with by demanding large-scale prototypes of major ideas. In some cases a full-scale mockup is required to more fully understand a concept, as it was in the C-block project. This type of mockup is not new, but must be demanded in order for the student to give proof of their claims in designing prefabricated dwellings.

Having students grapple with prefabricated dwellings was a very rewarding studio. Their innovative ideas have influenced my own research, including teaching a seminar that investigates the C-block further, in addition to other building component studies.

Notes

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