Making Prefab: A Panelized System for an Off-Grid Office/Studio

Architectural design can be described as an activity leading to the production of complex documents which describe in details the intricacies of a physical object that is a building. But no matter how detailed architectural drawings are they only represent the end result of an elaborate process and do not describe that process itself.

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In fact architects are expected to be highly knowledgeable about materials and construction techniques in order to produce drawings that take into account all phases of a construction process without actually describing that process. The fact that builders focus on construction process and architects on the end result of that process, in other words, the disconnect between design and construction has had a profound impact on the production of architecture and education.

In that context design-build projects could be approached on the basis that they present an opportunity to resolve some of the issues associated with the structural disconnect between the act of designing and that of building.

The prefab Office/Studio project presented here was initiated as an opportunity for students to develop an understanding of building techniques and plan an entire construction process. Ultimately this project focuses on ways in which construction can inform design. Beyond the recurring temptations towards formalism in architecture education and professional practice the primary goal of developing a design-build project featuring prefabricated components was to emphasize process over the sole concern for a finish product.

PROJECT SCOPE

The physical scope of the Prefab Office/Studio was determined by the fact that it had to be designed and built in one semester within a lecture type course, in this case Materials and Methods and fulfill the required course content. Another requirement of this project consisted in the fact that the small design-build structure had to be fabricated and assembled inside the School of Architecture. Prefabrication was therefore selected as the project delivery method.

The project itself consists of an 8’ x 16’ prefabricated structure and includes an 8’ x 8’ enclosed office/studio adjacent to an 8’ x 8’ covered patio. To the exclusion of the floor system the overall structure is built using a prefabricated panelized system.

Power is provided by means of a photovoltaic system in order for the pavilion to operate off grid.

This project was an integral part of a Materials and Methods course offered to third-year students at Florida A&M University School of Architecture and Engineering Technology (SA+ET). The project presented an opportunity for students to test and apply the knowledge acquired during the course in the form of design exercise. This assignment was also conceived as a practical introduction to construction documents, creative detailing and project scheduling. The overall goal was to empower students to plan an entire construction process and understand the critical importance of construction as a means to inform design.

In terms of overall planning the structure was prefabricated in the shop at the SA+ET and then assembled in one of the school's large indoor atrium. Ultimately the structure would be taken apart and reassembled on a permanent site.

DESIGN

Project Design Requirements

The project was first presented to students as an assignment with a series of broad guidelines. The main design challenge consisted in developing a prefabricated system that would bring the building program to a successful resolution and address issues such as cost, construction efficiency and sustainability. The panelized system had to be light enough to allow installation without heavy equipment and be built with a minimum of material waste. The overall design requirements presented to students are outlined below.

Program, Size and Shape

Design a small structure consisting of an enclosed space (office/studio) and a covered porch. The enclosed space should function as an office/sleeping area whereas the porch would provide an outdoor extension to the enclosure and a place to relax.

Material Efficiency

The dimension of the overall project should be governed by the dimensions of standard building components so as to minimize waste.

Energy Efficiency

The prefabricated panels should be built with standard wood framing materials, sheathing and receive a layer of rigid insulation on the exterior side. The final exterior finish material would then be applied over the rigid insulation.

Natural Light Access

Openings should be designed in order to fulfill a variety of functions such as bringing natural light, providing views to the outside and allowing natural ventilation.

Solar Power

A small photovoltaic system installed on the roof would power interior and exterior LED lighting as well as power receptacles inside the office space for up to 6 hours.

Flexible Space Planning

In order to function both as an office and sleeping area the interior layout must include built-ins and movable components.

DESIGN SOLUTION

The final design presented here was not the work of a single student but the result of combining successful solutions proposed by number of students.

Program, Size and Shape – Small and Simple

Based on the need to create small but usable spaces with modular dimensions the overall footprint of the project was defined as an 8' x 16' rectangle. The porch and office/studio spaces were respectively 8' x 8' so as to provide two similarly sized spaces with different qualities.

Material Efficiency – Modular Dimensions

In addition to the overall footprint of the project being 8' x 16' the height and dimensions of the prefabricated panels was determined in order to conform with standard material dimensions. The prefabricated wall panels where actually 4' wide by 8' high on the high side of the shed roof and 7'-4" high on the low side. This arrangement provided that no wall dimension would be over 8 feet. The roof panels were built in modules of 2' x 10' so they would create a 1 foot overhang on all sides. Final wall and roof panel dimensions well also driven by their weight considering that assembly was to be executed without heavy equipment.

Energy Efficiency – Passive Design

All windows were equipped with a shutter or other sun shading device appropriate to it solar orientation. The porch was located on the west side to provide additional shading to the west wall of the enclosure. A layer of 1½" rigid insulation was applied continuously over walls and roof therefore limiting thermal bridging.

Natural Light Access

Windows were emphasized on the north and south side of the structure. North windows were the largest in surface and located just above a countertop which was to be used as a desk. Windows on the south were horizontal in shape and able to function as a light shelf. The window located in the east wall was vertical in shape and equipped with an operable shutter designed to act as a sun shading device when opened perpendicular to the surface of the exterior wall.

Photovoltaic Solar System

The shape selected for the roof was a shed sloping towards the south taking into account solar panel orientation. A determining factor for the design of the shed roof was the necessity to span the width of the structure with a single prefabricated panel in order to simplify construction and assembly.

Flexible Space Planning

The interior space was designed to function both as an office and sleeping area. The desk surface placed against the north wall could pivot downward and the space would then function as a meeting room. Another panel could also pivot down on the east wall and be used as a meeting table. A bed on wheels would be moved on the floor from its storage position against one of the wall to provide sleeping arrangements.

PROCESS

The Office/Studio project was structured in the following phases; design, prefabrication and assembly.

DESIGN

The goal of the design phase was for students to identify the technical requirements of using a panelized system and develop a design scheme which would successfully integrate all construction components. The design phase was carried out by 3rd-year students in the context of a Materials and Methods course.

Initially students developed a variety of design propositions for a small prefabricated structure. They produced dimensioned plans, elevations, sections and an axonometric view. These propositions ended up presenting a variety of sizes, layouts and roof shapes but did not always take into account the necessity for these elements to be prefabricated with standard material sizes and assembled without special equipment. Given the first series of design propositions developed by students the overall size of the project was then defined as an 8’ x 16’ rectangle with an 8’ x 8’ porch and 8’ x 8’ office/studio. It was also decided that the roof shape be a shed with a 1:12 pitch to simplify construction and allow for easy installation of the photovoltaic system.

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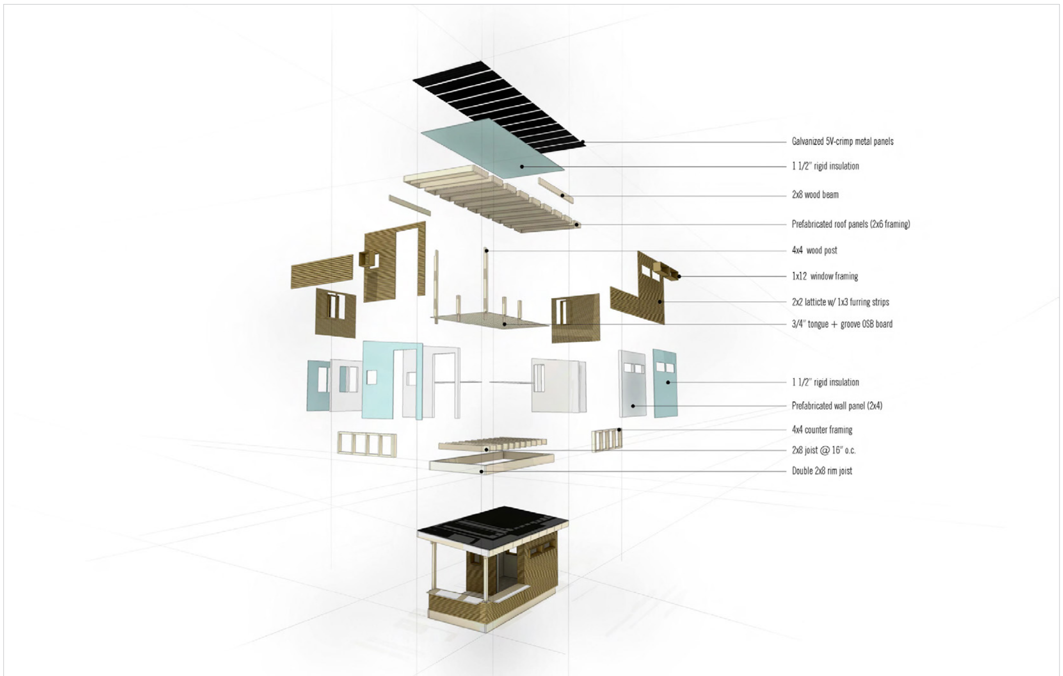

Figure 1: exploded view of building components

A second iteration of the design was then produced by students which presented major improvements over the first draft. All design propositions were reviewed and successful components from a number of designs were combined to define the final building. Up to that point in time the documents produced were typical architectural drawings aimed at describing the shape and dimensions of the structure but not its modes of assembly.

Once the design was finalized students developed a set of construction documents describing each prefabricated panel and building component along with its mode of assembly. The drawings produced included plans and elevations of the overall structure and individual panels, two sections and an exploded axonometric view presenting the overall assembly and connectors.

PREFABRICATION

The goal of the prefabrication phase was to build all wall and roof panels with a high level of precision in a controlled and safe work environment.

All prefabricated panels were built in the shop at the School of Architecture. Students were assigned a team and worked in the shop at set times set aside from regular class hours. The wall panels built in 4 foot wide sections were constructed with 2 x 4 framing and ½” OSB sheathing placed on the outside. Rigid insulation was placed on the exterior side of the panel over the OSB sheathing. The dimensions of the modular panels assumed assembly to be executed by two people.

Door and window openings where precut in all wall panels. In addition to conforming to the overall dimensions of the structure, the 2' x 10' roof panels were sized so one person could lift them while another person would receive them and install them. Roof panels where constructed using a 2 x 6 framing system covered with ½" OSB sheathing and rigid insulation. Assembly of all prefabricated panel components was achieved using screws rather than nails to allow for future disassembly.

ASSEMBLY

As planned, assembly was carried out by 2 people as a way to verify the assumptions made during the design phase with regards to panel size and weight.

Prior to the assembly of the prefabricated panels students built a floor system composed of ¾" tongue and groove OSB boards screwed onto 2x8 floor joists at 16 inches on center.

The perimeter of the floor was built with two 2x8 on which heavy duty casters were installed in order to move the structure during and after construction.

Once the floor system was installed, wall panels were screwed directly onto the floor sheathing and rim joists. Temporary bracing was used to ensure safety during the assembly of the wall panels. Following the wall panel assembly, two 4x4 posts were notched at the bottom and bolted onto the floor structure. 2x8 beams were then installed to support the roof structure above the covered porch. Roof panels were finally anchored to the top of the walls and beams to complete the basic structure. The overall assembly of the overall structure took approximately five hours.

The phases of design, prefabrication and assembly were completed during the course of a single semester in the spring of 2014. The installation of the exterior cladding, roof panels and interior built-ins is currently being carried out by graduate students. We expect the project to be completed in the spring 2015 with the installation of wiring, lighting and connection to a small solar array.

EXTERIOR CLADDING

The exterior cladding installed over the prefab walls consists of a horizontal wood lattice system installed over vertical furring strips. The pieces of lattice are 2x2's obtained by ripping a standard 2x4 wood stud, therefore minimizing waste. The air space between the exterior face of the wall and the back side of the lattice is ¾" and each horizontal lattice board is spaced ½" vertically. All window openings were framed with 1x12 boards in order to visually define the perimeter of the window, create a sun shading device/light shelf and provide a surface to terminate the horizontal wood lattice. The system used for the roof is a 5v crimp galvanized panel installed over the rigid insulation.

OBSERVATIONS

When the project assignment was presented to students there was a clear emphasis on the fact that they were expected to integrate construction methods within their design proposition. The first design iteration did not prove very successful with regards to construction informing design. This may have been due in part to the lack of construction knowledge and experience of the majority of the students enrolled in the course. Another factor contributing to the difficulties encountered by students may be related to the delivery method of the original assignment which was presented verbally and graphically. Even though the pedagogical goals were clearly laid out in the assignment students struggled with the concept of basing their

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Figure 2: prefab panel construction

Figure 3: structure assembly

Figure 4: exterior cladding system

design on a set of specific materials and construction methods. In that regard a preliminary and short hands-on exercise may have helped clarify the expected outcome of the design phase.

A more structured and detailed set of design guidelines was then developed with the definition of overall dimensions and the decision to use a shed roof for practical reasons. The refinement of the program seemed helpful to the majority of the students. Following the relative failure of the first design attempt students were much more successful at incorporating construction processes in the second design iteration.

The environment in which students worked at the SA+ET, a large and fully equipped shop, provided a setting that proved safe and conducive to team work. Due in part to good work conditions the overall craftsmanship of the construction was relatively high which proved key to the assembly of the prefab modules. The majority of the students involved in the project did not have prior construction experience and this project became an opportunity to demonstrate that building skills and knowhow can only be acquired through the physical act of making.

Another positive outcome to be noted about prefabrication was the fact that it allowed a large number of students to work at the same time on a number of building components, therefore increasing efficiency and production output.

The assembly phase of any prefab project is usually preceded by a bit of anxiety and anticipation as the validity of design and construction quality are about to be tested. The actual assembly of all prefabricated panels was successful and validated the overall design and construction planning although the installation of the roof panels proved a bit harder than expected and required the help of a 3rd crew member at certain times. Assembly of the structure was completed by a crew of 2 people in 5 hours.

CONCLUSION

Prefabrication continues to gain ground in the construction industry with its many positive contributions in terms of quality control, cost, efficiency and sustainability. In that context it seems appropriate to expose students to a mode of project delivery which presents a number of promises in the current challenge to build better and more efficient buildings in a safer work environment.

Because of their size and weight structural insulated panels offer a flexible system that does not necessarily require the use of heavy equipment. In that regard this type of prefabricated system has proven it can deliver high quality and energy efficient buildings to even remote rural areas that may lack particular design and construction expertise.

The end goal of this prefab design-build project was to engage students with the means of construction in order for them to understand the importance of connecting design with specific materials and construction processes as the latter can be both limiting and inspiring. The intense coordination required between design and construction in projects involving some level of prefabrication makes such projects both challenging and rewarding for students. As such prefabrication can prove valuable within design-build curricula and in the ongoing efforts to bridge the structural gap between design and construction.

ENDNOTES

1. Moe & Smith, *Building Systems: Design technology & Society*, 2012, Routeledge

2. Knaack, *Prefabricated Systems*, 2012, Birkhauser

3. Kieran & Timberlake, *Refabricating Architecture*, 2003, McGraw Hill