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DESIGNhabitat 2: Studies in Prefab Affordable Housing

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DESIGNhabitat 2.0 + 2.1: Two Case Studies in Prefab Affordable Housing

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ABSTRACT

Sparked by a surge of attention in the design press early in this decade, modular production has emerged as a topic of design research and exploration in a number of academy-based design/build studios across the US. These studios typically involve production of the modular components of the student-designed homes in a setting intended to simulate the conditions of a modular production facility, transport of the units to the project site, and on-site completion by the students and faculty. The design research objectives of these projects have included exploration of alternative materials and modular production strategies, ways to achieve higher energy performance, and explorations of the inherent design flexibility associated with modular construction.

Building on the precedent of these studios, the DESIGNHabitat 2 Initiative has been designed to see if the lessons of the "simulated factory" could translate to the marketplace of for-profit modular production. Working with two of the country's largest modular housing producers, the students and faculty of the DESIGNhabitat 2 Initiative have designed two modular homes for Habitat for Humanity in the Katrina-affected region of west Alabama. These homes have been used to test the viability of modular production as a solution to the labor shortages currently limiting Habitat's ability to respond to the tremendous need for high-quality, energy efficient, and affordable housing in the Gulf Coast region.

The first DESIGNhabitat 2 Home, completed in 2006, featured a hybrid approach of factory-produced components and site-built sections, and earned state and national AIA awards for design. The second home, DESIGNhabitat 2.1, is currently under construction. DESIGNhabitat 2.1 incorporates the lessons of the first cycle of design, construction, and analysis. More specifically, it is designed to test a different mix of factory and site-built components against the cost and on-site labor results of the first home.

This paper will examine the lessons learned from the two cycles of design, production, and construction of the DESIGNhabitat 2 Initiative, including the viability of modular construction as a means of realizing high-quality affordable housing. The paper will also reflect on the student learning outcomes associated with the DESIGNhabitat Initiative and the challenges of incorporating the design strategies associated with prefabrication into a curriculum grounded in a tradition of hands-on construction.

Introduction

Auburn's School of Architecture began working with Habitat for Humanity in 2001. This partnership evolved into the DESIGNhabitat program; a research focused, service learning program designed to apply the energy and talents of the school to the challenge of designing and constructing high quality affordable housing in Alabama and across the region. In the first round of collaboration with Habitat (DESIGNhabitat 1) begun in 2001 and completed in 2002, students designed and constructed a new prototype home aimed at improving the cultural and climate "fit" of Habitat homes when they were built in early-20th Century neighborhoods common to communities across the state[1].

In response to a 2003 request from Habitat to study how small, rural Habitat affiliates could build more homes with fewer on-site volunteer resources, a student/faculty team began to study the potentials and limitations of incorporating prefabricated construction strategies into the Habitat home-building process. This study considered a broad range of factory-based strategies -- from panelized framing and SIPS panels to HUD-code units – and weighed the benefits of speed and resource efficiency against the cost and "Habitat culture" implications. The results of this study (completed in 2004) concluded that the best balance of benefits to cost would likely come from utilizing a

hybrid of modular construction and site-built strategies. In the summer and fall of 2004, Auburn architecture faculty members David Hinson and Stacy Norman began planning a research-driven design/build studio aimed at testing the conclusions of the 2004 study.

DESIGNhabitat 2: Design Brief

Working in partnership with Habitat's state-wide coordinator and an east Alabama Habitat affiliate, the goal of the DESIGNhabitat 2 Initiative was to test the viability of factory-based modular construction as a means for Habitat affiliates to build homes when faced with limited volunteer-builder resources.

The first step in the project was to study the lessons learned from the design research and exploration already completed in a number of academy-based design/build studios across the US.[2] This effort was structured as a fall semester research seminar. The examples studied by the students typically involved production of the modular components of the student-designed homes in a setting intended to simulate the conditions of a modular production facility, transportation of the units to the project site, followed by on-site completion of the modular home by the students and faculty.

The students identified the next step in this line of investigation as the challenge of moving these design explorations from a simulated factory to a real one. Consequently, the DESIGNhabitat 2 team recruited one of the largest modular home producers in the US, Palm Harbor Homes, as a project partner and began to intensively study Palm Harbor's production process and the associated design opportunities and constraints.

Less than a month after the DESIGNhabitat 2 project began, hurricanes Katrina and Rita slammed into the Gulf coast. Overnight, the conditions underpinning the focus of the project – the need to build high-quality Habitat homes with few volunteer resources – became the reality for hundreds of affiliates across Texas, Louisiana, Mississippi, and Alabama.

The DESIGNhabitat 2 team was soon contacted by Habitat for Humanity International and, by the spring of 2006, the team had agreed to construct the test house for a newly formed Habitat affiliate in Hale County, Alabama -- one of the Alabama counties where Katrina had displaced a significant number of families.

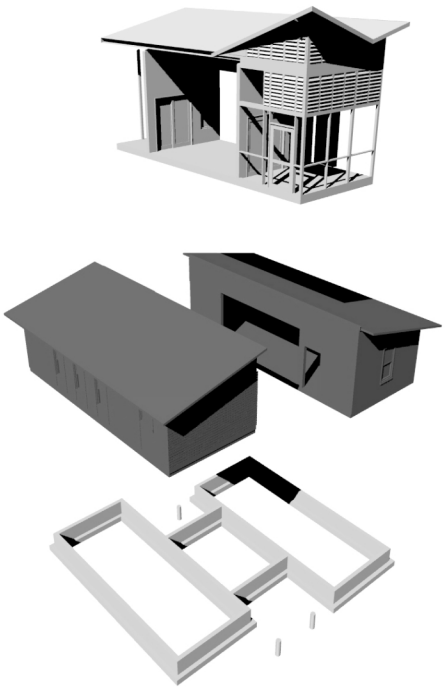

Fig. 1. DESIGNhabitat 2 Axon

Fig. 2. DESIGNhabitat 2 View from Street

DESIGNhabitat 2: Design Response

Faced with the challenge of designing and constructing the project in a short time frame, the team began the spring semester with a month-long charrette designed to generate five alternative prototype home proposals – each of which incorporated and illustrated the lessons

of the fall research seminar. In mid-February, these proposals were presented to a panel of project advisors (Habitat leadership, modular industry representatives, and Auburn faculty) who selected one of the schemes to advance to design development and construction.

The selected scheme was chosen by the advisors because of its energy conserving design features, the clarity of its plan and because the scheme offered the most clearly identifiable site built features (the central connecting space and porches) – an important consideration in the non-profit's volunteer builder-centered culture. This 1152 SF scheme included three bedrooms, and one bath.

The three-box scheme had an approximately 2:1 factory-to-site-built floor area ratio. The factory-produced modules included the bedrooms, the single bath, a laundry closet and the dining area and kitchen. The central connecting space would serve as the living area and accommodated the circulation between each of the program spaces.

Strategies for optimizing energy performance focused on solar orientation, cross ventilation, appropriate insulation and radiant barrier metal roofing.

The DESIGNHabitat 2 House became an exercise in distributed construction sites, from the factory in Boaz, AL to the CNC shop at Auburn University School of Architecture, culminating at the construction site in Greensboro, AL. As the modules began their respective journey through the factory, a small team of students were on-site assisting in the foundations and block work, while at the same time the cabinetry for the home was being cut, assembled, and finished by another group of students on campus in Auburn. Once the modules were delivered to the site and set, a two-week blitz build began.

Unique to the selected scheme was the center bay section that would require a considerable amount of site fabrication (a "plus" in the eyes of the Habitat veterans eager to incorporate ample "sweat equity" opportunities). Site work would include framing, foam insulation, setting windows and doors, electrical and HVAC, as well as drywall and painting.

Over the course of the next two weeks, the team (averaging 10 students and 2 faculty members) brought the project very near to completion, finishing the center bay section, the front and rear porches, the cedar rainscreen and all but about 10% of the fiber cement siding. It would require weekend volunteers and the mechanical and electrical subcontractors another 4-6 weeks to complete the home.

Post-Construction Analysis

One of the key lessons learned on the day the modules arrived is that the on-site work can be increased dramatically as a consequence of problems that arise in the factory production phase — particularly when working with a tightly constrained construction schedule.

For instance, it became apparent in the factory that some of the window sizes did not match the rough openings. The rough openings were repaired in the factory and the windows shipped loose. This created a significant impact on-site, requiring time to set windows and complete drywall.

Another lesson arose from the choice to separate the two factory-built modules by a site-built section. This meant that, rather than being able to capitalize on the ability of the factory to complete all of the electrical wiring, a substantial amount of electrical wiring had to be performed on site.[3]

The success of the DESIGNhabitat 2 project notwithstanding, the experience left many questions still to be pursued relative to the potentials of the factory-based approach. Chief among these is the challenge of finding the optimal balance between site and factory-constructed components of the home, and the challenge of further stretching the design quality potential of the modular construction process.

Of the five prototype design proposals developed by the team, the design constructed in DESIGNhabitat 2 represented the highest proportion of site-built elements (one third of the home). Could the on-site man-hours be reduced even further if more of the home was factory built? Would the cost premium rise proportionally, or does the logic of the factory-based economic model allow that extra area to be built at only slightly higher cost?

Does the production logic of the modular process generate its own unique set of design po-

tentials — potentials not inherent in the design/cost equation of site-built homes?

DESIGNhabitat 2.1: Design Brief

These questions became the starting point for a second phase of the DESIGNhabitat Initiative – the DESIGNhabitat 2.1 House. Working with a team of six students, Hinson and Norman began planning the design and construction of a second modular home in the fall of 2007. Working with a new modular producer, and with the Hale County Habitat affiliate, it was agreed that the second modular house project would be designed to answer some of the questions raised by DESIGNhabitat 2.0; in particular the question of what was the optimal mix of factory versus site-built components?

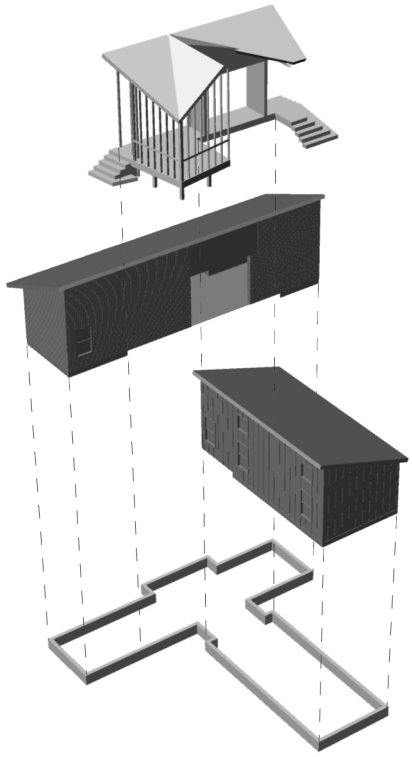

Fig. 3. DESIGNhabitat 2.1 Axon

Fig. 4. DESIGNhabitat 2.1 View from Street

DESIGNhabitat 2.1: Design Response

The student team began this second round by revisiting the schemes developed in 2006 to see if the unbuilt schemes offered a viable starting point for the second house. Two of the unbuilt schemes were determined to be good vehicles for pursuing the goals that framed this second round and the best features of each were incorporated into a new design, christened the DESIGNhabitat 2.1 House.

The 2.1 design featured a 2-Box design in a T configuration. In this scheme all of the conditioned space would be constructed in the factory, with on-site construction limited to foundations, front and rear porches, roofing and cladding. As with the first home, electrical and plumbing connections, along with HVAC system installation, would be performed by licensed professionals. The DESIGNhabit2.1 House was a 3-bedroom two bath comprised of approximately 1172 SF. The T-Bone scheme provided for the collective functions of the home (living area, dining area, and kitchen) to be at the intersection of the two boxes. The more private functions, (bedrooms and baths) gravitated to the ends of each box.

While the 2.0 house featured relatively simple factory-produced elements (and a more complex, site-built center bay); many more of the design features of the DESIGNhabitat 2.1 house would rest on what the students could achieve via the factory-produced modules. Consequently, translating the DESIGNhabitat 2.1 scheme into units that could be factory-produced and transported to the site would require a more complex level of pre-production coordination between the students and the

modular producer. Working with the modular producer to understand all the fabrication and assembly details — from the hinged roof and hinged attic walls to the eaves and marriage line details — became the focus of the team's efforts over the course of the spring of 2008. They also planned out an intensive two-week site construction phase designed to utilize the short interval between semesters to mobilize a team of students to help the team complete the project.

While the team was successful in translating almost all of their design goals into the factory-constructed modules, the amount of time required to work through these details and get the units into production exceeded the schedule by nearly six weeks. While this may seem like a modest delay by industry standards, it had the unfortunate effect of pushing the on-site construction phase beyond the window of time planned by the students. Consequently, rather than having a team of 12 to 15 students working intensively for two weeks, only small groups of students have been available to work on the project at any given time over the three months since the modules were set. While progress has been steady, as this paper goes to print, the exterior work is still several weekends away from being complete.

We can, however, begin to project some conclusions relative to the questions that framed this second round of design and construction:

DESIGNhabitat 2.0 + 2.1: Lessons Learned

DESIGNhabitat 2.0 featured 943 SF of factory produced conditioned area and 209 SF of site built conditioned area. The front and rear porches totaled an additional 200 SF. The signature design features of the house, including the vaulted central space and the distinctive "breeze catcher" front porch, were all built on-site utilizing conventional framing techniques.

In contrast, 100% of the conditioned area in the DESIGNhabitat 2.1 house was constructed in the factory, although some interior finishing was required to achieve the vaulted ceiling in the main living area. The site-constructed elements included the front porch and the section of roof required to join the two modules at the attic level. Other differences in the two designs included an additional bath in the 2.1 house, factory-installed cabinets (they were student-built in the 2.0 house), and a more complex module setting procedure for the DESIGNhabitat 2.1 house (in the 2.1 design, the crane was required to lift the hinged roofs).

Both houses featured site-installed metal roofs, and a cladding scheme that blends fiber-cement siding and a cedar rain screen to express each component of the composition.

As expected, the DESIGNhabitat 2.1 house is projected to cost more than DESIGNhabitat 2.0 ($75/SF vs. $68/SF) primarily because the second house relies on a "for profit" production process to build more of the home. In order to more closely understand how the differences in the "blend" on modular and site-built elements impacted the project cost, we can isolate the elements of the cost history for each home that were not influenced by the choice of approach (such as site work, foundations, electrical, plumbing, HVAC).

In this analysis, the combination of the modular component costs and the cost of site-constructed elements for the DESIGNhabitat 2.0 amount to approximately $48/SF. The same combination of elements on the DESIGNhabitat 2.1 house cost $58/SF. This helps frame the "premium" associated with increasing the area of factory-built SF from 65% to 100% at $10/SF. From another angle, we increased the factory-produced area by 35%, at an increase in cost of about 21%. While this analysis does not account for all the differences between the two designs (such as the extra bath, kitchen elements, complexity of site-built elements, etc.), it does give some perspective on the cost consequence of shifting from a blend of factory and site-built elements to an emphasis on maximizing the factory-produced area.

The other element of the "hypothesis" of DESIGNhabitat 2.1 was that the shift to more factory-produced area would be offset by a reduction in the on-site volunteer hours required to complete the house. Unfortunately, the delay in delivery of the modules threw the on-site construction phase outside of the planned window, and the team lost the ability to structure the volunteer work effort in a manner comparable to the approach utilized on the DESIGNhabitat 2.0 house.

Conclusion

The two homes constructed via the DESIGNhabitat 2 initiative provide insight into how non-profit affordable housing groups, like Habi-

tat for Humanity, can respond to the challenge of building high-quality homes when on-site volunteers are in scarce supply. They also help to answer some of the more specific questions that arise from the specific context of Habitat's approach, such as:

- Can factory-based production be reconciled with Habitat's volunteer-builder culture and its need for "sweat equity" work by prospective homeowners?

Our experience suggests that utilizing factory-produced components is far from an "all or nothing" decision. By adjusting the mix of elements completed in the factory versus completed on site, affiliates can tune their approach to match the human resources they have available.

- Can a factory-based, modular home realize high quality with regard to both design and energy-performance?

The DESIGNhabitat 2 Initiative illustrates that the choice of a factory-produced, modular construction approach does not require a lowering of design aspiration. It does, however, require designers to devote time to understanding the differences between conventional "stick-framed" construction, and the processes and transportation limitations modular producers have to accommodate.

While this paper has not focused on the energy-performance strategies integrated into both homes, our experience suggests that both site-built and factory-produced strategies employ similar energy performance strategies. The principal difference between factory-based and site-based construction is not in the performance of the end product, but in the amazing resource efficiency of the factory floor compared to the typical job site.

- When is factory-based, modular construction a viable alternative to Habitat's traditional approach?

The DESIGNhabitat 2 Initiative has been framed by the Habitat for Humanity cost model, so conclusions regarding cost must be understood within this context. When analyzing costs for Habitat homes, the standard process is to tally up the cost of the materials (including the value of in-kind donations), and to add the costs for "professional" labor (HVAC, plumbers, and electricians). All other volunteer labor is left out of the equation. Compared with this process, the principal disadvantage of factory-based construction is the labor and profit associated with the factory constructed components.

To establish a definitive understanding of the difference in cost (and time) between a site-built home and a modular home, we would need to construct an identical design via both methods. While we've not been able to do this, our analysis of the cost history for these two DESIGNhabitat homes suggests that this "modular premium" is approximately $12 to $20 per SF, depending on whether an affiliate chooses a hybrid of modular and site-built elements (such as in House 2.0) or a fully factory-produced approach (as in House 2.1)[4].

As expected, our experience makes it clear that modular construction cannot compete on a cost basis with homes built entirely with free labor. However, when that labor pool is not available — such as in the recent period following the 2005 Gulf Coast hurricanes — the DESIGNhabitat 2 Initiative illustrates that Habitat affiliates can use this approach to build high-quality, high-performance homes, provided they can find the resources to compensate for the labor costs built into the factory produced components.

Notes

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[1] For an overview of the DESIGNhabitat 1 Project see Hinson, David W. *"Community Centered Design/Build Studios: Connecting the Past and the Future of Architectural Education"* Proceedings of the 2002 ACSA Technology and Housing Conference, Portland, OR

[2] The work of Daniel Rockhill and his students at the University of Kansas and the work of John Quale and his students at the University of Virginia exemplify the excellent modular design research underway in architecture schools. The work of these design/build studios provided a valuable source of pre-design insight to the DESIGNhabitat team.

[3] For a comprehensive look at the DESIGNhabitat 2 project, see **DESIGNhabitat 2: Studies in Pre-Fab Affordable Housing**, co-authored by David Hinson and Stacy Norman, published by the School of Architecture, Auburn University, 2008 (ISBN 978-1-60585-934-7)

[4] Habitat affiliates in Alabama are currently (2008) building a conventionally designed Habitat home for about $48 to $50 per SF, utilizing volunteers to construct the home from the foundations up.

The two DESIGNhabitat 2 homes have been completed for $60 per SF (2.0) and $71 per SF (2.1). Since 2006, Habitat has utilized factory-based, modular production to build a significant number of homes across the Katrina-affected areas of the Gulf Coast and, while we do not have a complete cost history for these projects, we do know that the costs have ranged between $75 per SF and $100 per SF.

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