Prototypes in Manufactured Housing with SIPs

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Abstract

This paper studies a possible innovation in manufacturing techniques for prefabricated houses. First, the paper focuses on a proposed hybrid condition between Structural Insulated Panels (SIPs) and that of the conventional manufactured home. Advantages offered by each method of construction are selected and discussed with the goals of increased energy efficiency and structural properties and decreased construction time and cost. Second, a prototype design (by the author with a team) is presented; this prototype, which was recognized as a finalist in a regional competition for Hurricane Katrina survivors' housing, becomes a means to explore the hybrid construction condition, in which spatial, logistical and technical details are encountered.

I

As is well known to those familiar with the industry, manufactured housing does not fall under local jurisdictions for building standards. Rather, manufactured housing is regulated by national standards and guidelines determined by the US Department of Housing and Urban Development (HUD) in 1974, Part 3280: Manufactured Home Construction and Safety Standards of the Code of Federal Regulations. By 1997, a report had already been published to identify energy savings and structural and safety benefits of integrating SIPs construction in manufactured housing. The report highlights the possible areas to be further studied in relationship to HUD codes: fire resistance, wind resistance, structural testing, ventilation standards, and transportation effect.[1] In all above areas, foam panel initial data suggests that SIPs construction would perform efficiently and economically compared to conventional construction methods of manufactured homes. Historically, manufactured housing has played a critical role in the provision of housing; it has intervened to provide affordable housing and has provided homes quickly in times of catastrophe. In the last eight years, new manufactured homes represent a fluctuating value of between 10-20 percent[2] of the total new single family housing units built. By some accounts, manufactured housing represents over 30% of the new single-family homes built in the US.[3] Efficient construction methods under factory conditions allow for many advantages: affordability (small, single-wide home, 600-800 sq. ft., economic construction can sell for as little as $24,000[4]) very little construction expertise needed on site, close oversight of all labor and materials costs, lack of construction constraints due to weather, and professional supervision of all building phases. SIPs use can save up to two-thirds of the framing labor time for walls and roofs, with no significant impact on other construction performance areas observed in a case study of two Habitat for Humanity homes.[5] SIPs construction also carries specific and important advantages. SIPs assemblies have been determined to reduce heat transfer because of fewer thermal bridges. SIPs constructed homes can be as much as 12% more energy efficient than homes built to the 2004 International Residential Code (IRC).[6] SIPs, because of the lightweight, malleable characteristics, accommodate wiring chases. Integrated wire chases for walls can be easily accessed through the interior walls. Relocation of the HVAC duct work from the underside of the manufactured home, in the "under belly," to ceiling boxed plenum can allow HVAC to be completed in the factory and not on site. Therefore this step also reduces labor costs, and labor complexity. Ultimately, SIPs technology can be made more sustainable easily with new materials replacing oriented strand board (OSB) emitting volatile organic compounds (VOCs). Varying studies conclude that commonly used OSB does emit low levels of formaldehyde, close to 0.1 parts per million (PPM).[7]

Some of the possible replacement materials can be structural cement insulated panels (SCIPs) or soy based, recycled boards (bio-SIPs).[8] SIPs can come in larger dimensions that also allow for quick assembly. Reports suggest the integration of SIPs can greatly reduce the dimensional lumber needed to

construct a home by as much as 25 percent due to the use of 2x6s 24 inches on center versus the use of 2x4s 18 inches on center, which is the typical factory method today.[9] There has been little exploration in the industry to carry out investigations of this potential. Reasons for this may be speculated upon generally and range from an unfamiliarity on the part of the plumbing and electrical trades with SIPs installation to a general inertia in the industry which eschews an immediate increase in costs, regardless of long term savings and benefits. Some of the factors can be the required evaluations and adjustment of HUD regulations to manufactured homes.

Nevertheless, the core of HUD's report remains to be evaluated and the advantages of the hybrid construction still stand; a combination of these two manufacturing building practices would allow for specific advantages in the construction of new, affordable homes: 1) energy efficient construction, 2) improved structural characteristics (high wind resistance), 3) increased ease of construction (factory conditions with close professional supervision of all technical aspects), 4) readily adaptable to larger and/or complex family unit structures (due to its continuous load bearing wall constructions capabilities), 5) increased possibilities for the design of alternative spatial configurations (SIPs allow for roof configurations that may be higher in height, and allow for the walls to join readily creating varied floor plan configurations).

II

The paper seeks to evaluate a design proposal in the Regional Texas Grow Home competition for Katrina victims of Port Arthur, Texas, a finalist among 100 entrants. The recognized design entry takes into account the criteria for the competition, while combining SIPs construction in modular manufactured housing, in order to create a sustainable, affordable, incrementally additive, contextual response to housing needs brought on by catastrophes. Series of construction details: representing existing industrial standards along with new erection methods for roof construction are presented. The floor plan studies address the need for varied family structure, the ease of additional living area to the overall housing coherency in conjunction with construction ease. The scheme addresses the raised foundation condition in consideration of the fair housing act, ADA and new definitions of universal[10] and visitability[11] design implications.

The call for the competition was predicated on the conditions existing after Hurricane Rita in the area of Port Arthur, Texas, 2007/spring 2008. The largest statewide architectural competition held to that time is the Texas Grow Home design competition. The competition sought to find solutions for cottage designs of a size and style that would become the models for many other homes to be built in Texas. The goals of the competition are to provide permanent, affordable housing solutions capable of rapid development in the wake of a disaster, houses that are architecturally and contextually appropriate to the existing Texas Gulf Coast neighborhoods. The designs were to incorporate a two-bedroom, one-bath house, somewhat larger than the Katrina Cottage,[12] that could serve as a permanent, conventional home for an elderly household or other small family. The base module is to be designed to easily accommodate a planned addition that, when added to the core module, could expand the house to a traditional three-bedroom, two-bath home.

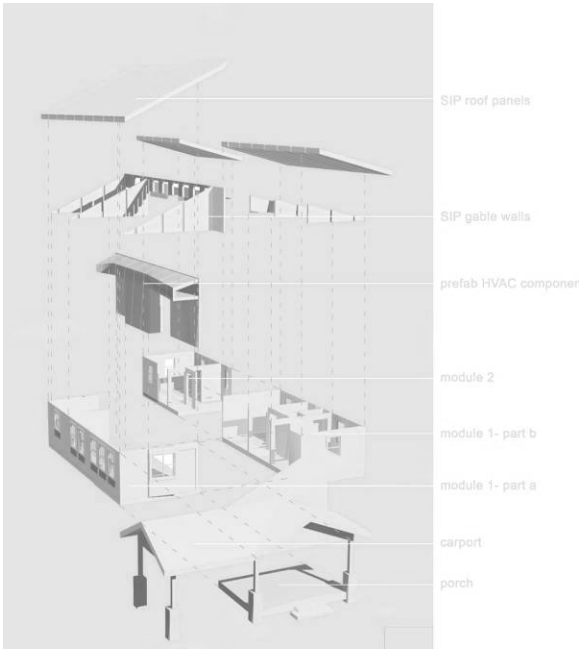
The factor of convertability into larger permanent homes was one of the larger lessons learned from other recent disaster driven housing solutions. The complete (two module) affordable house is limited to approximately 1,100 SF. The core module is to contain a living area, kitchen area, two bedrooms and one bathroom. The core module (which may consist of one or more component parts) should be able to stand alone. The core module should have the ability to connect to a second module (comprised of one or more component parts) providing one additional bedroom and one bathroom. The design should incorporate two minor variations, thereby adding variety to neighborhoods in which the houses are to be located, Port Arthur, Texas as a case study. The total cost of construction (excluding the foundation) was limited. It was not to exceed $54,000 for the core module and $23,000 for the add-on module. In relation to other housing competitions held for earlier disasters, the figures for construction and purchase were much higher. This represents a reduction in cost of each home of a quarter to a fifth in price from other disaster driven design solutions.

The conditions of the competition stipulated that the design be built off-site from an area

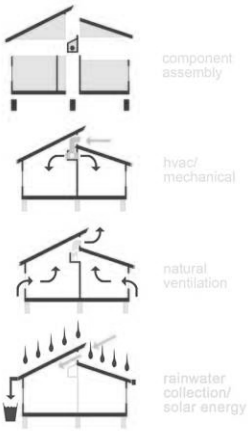
impacted by a natural disaster, and then moved to a permanent location within the disaster region, and erected with minimal on-site labor. The competition solutions sought to use industrialized modular fabrication methods. As such, requirements for transport were limited. The designed components must conform to the limits of standard ground transportation with a maximum 13'-6" height, 14'-0" width and 80'-0" length.

III The Design

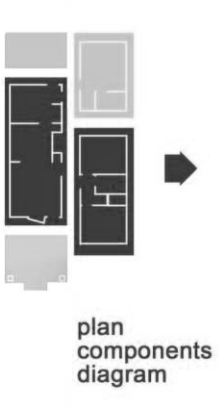
The team had chosen early to investigate the use of SIPs as a structural and insulation solution for this housing problem. Texas represents one of the states with the most number of manufactured housing fabrication locations: modeling modular, single, double, triple and even quadruple wides throughout the state. The energy efficiency that could be derived by the use of SIPs could readily qualify the house design for an Energy Star label. The possibility again to integrate the heating system into the interior of the house through isolated ductwork channels, further insulating the system, was an advantage to the design. The notion of marrying SIPs construction with that of manufactured housing made much sense, though many papers and reports previously cited attest to many benefits for both industries. The manufactured housing industry has worked in conjunction with Manufactured Housing Research Alliance with the US Department of Housing and Urban Development Affordable Housing Research and Technology Division to create a study of the manufactured housing fabrication process, to streamline even further the factory end of production.[13] This report cites the major causes of cost and delay in construction as due to the external prefabrication of steel or metal wall sections and roof[14] and wiring requirements that caused the electricians to pull and push through segments of the construction.[15] One of the most important areas to improve is thermal envelope performance.[16] Construction of manufactured homes using SIPs would directly address some the major concerns highlighted in the report. The spanning capacity of the wall and roof sections with SIPs would be more stable and durable through the transport process as well. The design of the house is premised on very common Texas bungalows built as affordable housing just during and after the Second World War. These houses were often inspired by the many mail-order floor plans available to prospective home owners early in the 20th century. The houses are designed as a one story structure, most of the living spaces are centered around the large living space, low pitch roof lines and many horizontal elements, connected rooms with no or little hallways taking up space, with efficient floor plan, with the amenity of many built in features like cabinets, shelves, and seats. Particular to Texas, the feature of a front porch is amenable to shaded outdoor living. The design of the Texas Grow Home entry was based on such ideas. The house design dimensions are challenged by the transport dimensions. The design takes into account lateral bracing necessary while the house is split during transport and brought together again on site. The spine becomes a critical place for various elements. The introduction of built in cabinets, cavity for ductwork, located at the splice help to reinforce the construction during travel.



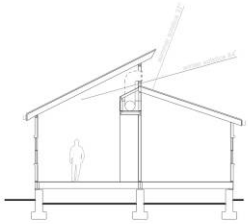
The SIPs are used for the exterior walls, raised flooring and pitched roofs that are angled. An important design aspect was to create the greatest height allowable through the careful study of the slopes. The slopes were determined by transport limits, the diagonal being the maximum length in the transport volume. Normally in manufactured housing, the roof lines and interior spaces are compromised by the limit in height achievable during transport.

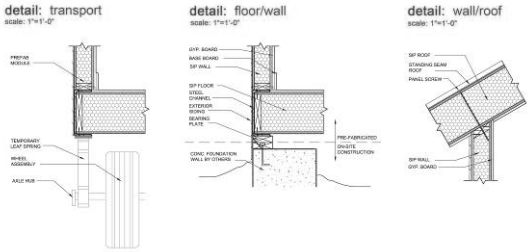


The design was to offset the roofline so in order to vent hot air during the summer, passively cooling the compact house scheme. Underneath the clerestory, the ductwork is integrated into the wall cabinets to further insulate and centralize the output. The design allows for the minimal length of ductwork to feed both vertical halves of the floor plan. The two base modules in plan also sit offset from each other.



This was purposefully created in order to make space for the third module that could be added later, also to create the option for a covered porch with carport. The indentation in the floor plan then makes possible for the entry and exit to exist along the house versus being abruptly placed on the façade. The back area is then able to also absorb the ramp to make the house accessible, because of the necessary concrete foundation on grade and crawl space below, the house was not able to be planned on grade.





The marriage of existing technologies in SIPs with affordable housing could be a method for addressing some of the critical issues in housing today, particularly related to the need for quick assembly, the ability to passively cool, and overall an energy efficient dwelling unit. With minor adjustments to using healthful materials as part of the sandwich construction, SIPs could offer overlapping benefits to the manufactured housing industry: reduction in

dimensional lumber use, factory condition oversight of labor and skills, construction time reduced due to interior working environment, high values for insulation with limited thermal breaks. Reconfiguring existing norms and practices in the building industry of manufactured homes could allow for an affordable option possible for many Americans to own a home.

Notes

[1] Lee, AD, DW Schrock, SA Flintoft, "The Federal Manufactured Home Construction and Safety Standards—Implication for Foam Panel Construction," *Pacific Northwest National Laboratory for the US Department of Housing and Development*, 1997, pp. 5-13.

[2] Manufactured Housing Institute, "Manufactured Homes Shipment and Site Built Housing Starts and Homes Sold, (1980-2007)," *Data source, Institute of Building Technology and Safety (shipments)*, Dept. of Commerce and Bureau of Census (Housing Starts and Homes Sold), 2008.

[3] Lee, AD, DW Schrock, SA Flintoft, (1997) p. 2.

[4] The cost of the manufactured home as quoted on www.mh-quote.com, September 08, 2008. The Stafford Act can grant through FEMA directly to an individual up to $26,100.

[5] Mullens, MA, M. Arif,"Structural Insulated Panels: Impact on the Residential Construction Process," *Journal of Construction Engineering and Management*, American Socity of Civil Engineers, July 2006, pp. 786-794.

[6] Thomas-Rees, S., S. Chandra, S. Barkazsi, D. Chasar, C. Colon, "Improved Specifications for Federally Procured Ruggedized Manufactured Homes for Disaster Relief in Hot/Humid Climates," Florida Solar Energy Center, Washington DC: US Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Program, September 2006, p.4.

[7] The EPA (Environmental Protection Agency) considers this a threshold for irritation. Actual readings of over 500 mobile homes read from 0.01 to 0.46 PPM, the average resident was exposed to 9.9 ppm-hour, which over the week is more twice the weekly 20 ppm-hour federal worker exposure standard.

8 Bio-SIP is patented by CU Professor Julee Herdt's work with the U.S. Department of Agriculture's Forest Products Laboratory.

Scott, Jim. "CU-Boulder Researchers Using Solid Waste For New 'Green' Building Panel Materials," *News Center, University of Colorado, Boulder*, March 17, 2008.

[9] Thomas-Rees, S., S. Chandra, S. Barkazsi, D. Chasar, C. Colon, (September 2006) p. 3.

[10] "Universal design is a relatively new paradigm that emerged from 'barrier-free' or 'accessible design' and 'assistive technology.'" "Universal Design." Wikipedia, The Free Encyclopedia. 08 September 2008, 10:55 UTC. Wikimedia Foundation, Inc. 13 August 2008. < http://en.wikipedia.org/wiki/Universal_design >.

[11] "A house is visitable when it meets three basic requirements: one zero-step entrance, doors with 32 inches of clear passage space, one bathroom on the main floor you can get into in a wheelchair." "Visitability." Visitability. 08 September 2008, 11:05 UTC. Ragged Edge Online. < http://www.visitability.org/ >.

[12] Creole-style Katrina Cottage is incompatible with many Texas neighborhoods and rural communities devastated by Rita as stated in the competition brief regarding the difference between other new forms of housing pertaining to recent catastrophes. Initial cost estimates for Katrina Cottages were ranging from $65,000-$85,000.

[13]United States. Department of Housing and Urban Development Affordable Housing Research and Technology Division, *Getting Lean: Assessing the Benefits of Lean Production in Factory Built Housing*, Manufactured Housing Research Alliance, New York, NY, December 2005.

[14] Ibid., p. 30.

[15] Ibid., p. 24.

[16] Ibid., p. 34.