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Amphibiating Prefabricated Housing

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Abstract

The presentation will focus on the adaptation of prefabricated model houses into amphibious houses. It will present a range of prefabricated model typologies and their adaptations in amphibious housing as well as a few amphibious prefabricated key case studies: Old River Landing in Louisiana; United States; Cow Bay Cottage in Nova Scotia, Canada; and Pinaymootang Community in Manitoba, Canada.

Keywords: Amphibious Housing; Prefabricated Housing; Buoyancy System; Flood Plain; Amphibious Retrofit; Buoyant Foundation

1.0 Introduction to Prefabricated Housing

The increased popularity of prefabricated homes in the mid-1900's changed the way that we understand the process of home construction. Suddenly, a house was no longer limited to the status of a static object, and its building process could be removed from the costs and complications of on-site construction in preference to mass manufacturing, either in part or as a whole. Much of its popularity is due to its cost savings in material and labour, as well as the simplicity of its process from conception to complete construction. Prefabricated housing is divided into several categories defined by the level of completion of the manufactured product and its assembly method. This paper will discuss only panelized structures and manufactured homes, as they are most relevant to small-scale residential construction.

1.1 Nomenclature

Panelized structures: an assembly of prefabricated components that do not enclose usable space. They form a considerable percentage of the final building envelope prior to shipment in compact form.
**definition from Schoenborn, Case Study Approach to Identifying the Constraints and Barriers to Design Innovation for Modular Construction*

Manufactured housing: factory-built housing unit constructed with a permanent chassis to assure the initial and/or continued transportability of the home.
**definition from Schoenborn, Case Study Approach to Identifying the Constraints and Barriers to Design Innovation for Modular Construction*

Amphibiating: The authors recognize that "Amphibiating" is a word that is not in the Standard English language lexicon. This term was coined by Elizabeth English in 2013 to describe the process of providing an amphibious

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foundation to an existing structure.

1.2 Why Choose Prefabricated Housing

There are many appealing factors that encourage homeowners and developers to opt for prefabricated housing rather than traditional construction. A significant factor in many circumstances is the relative low cost of prefabricated construction. While the scope of prefabricated homes ranges from mobile homes to very sizeable permanent housing, the reduction of on-site labour in most cases greatly reduces the cost of building a new house. In remote locations, where labour is sparse and/or expensive, premanufactured houses allow the construction of a house to take place by fewer individuals who only require a general understanding of foundations and assembly instructions, rather than bringing in various tradesmen from surrounding cities.

In addition to the substantial reduction of labour, the time frame from when the house is chosen to finished construction is substantially less than traditional house construction. Since the majority of the construction process takes place in a factory setting, it is not at the mercy of factors such as seasonal climates or weather conditions, which frequently delay the completion of projects. Also, since many of these houses are mass-manufactured models, whether for panelized structures or manufactured homes, often a substantial part, if not the entire manufactured product will already have been constructed even before it is purchased, allowing the transportation and/or assembly of the product to begin immediately.

Aforementioned advantages of premanufactured housing, namely its low cost, efficacy for remote locations and timely construction, entail that many of these houses, as is the case with our three case studies, find themselves in floodplains. Many examples of houses on remote floodplains, such as several fishing camps in Old River Landing in Louisiana, United States, and Cow Bay Cottage in Nova Scotia, Canada, function only as seasonal dwellings. These secondary dwellings generally necessitate a low-cost housing solution, something difficult to achieve without prefabricated housing, considering limited access to labour and materials in remote locations. In the case of Pinaymootang in Manitoba, Canada, manufactured housing was chosen by a government agency to subsidize housing for an indigenous community that was displaced by an induced flood, and was in urgent need of housing.

1.3 Key Considerations for Amphibious Prefabricated Housing

The controlled manufacturing process and assembly of prefabricated homes make them good choices for sites that are destined to face environmental hardships. As prefabricated houses are designed to be strong enough to compensate for the effects of transportation, strategies like replacing nails with screws, adding glue to joints, and using up to 30% more lumber than conventional housing add to the ultimate structural integrity of the house. In fact, after Hurricane Andrew in Dade Country Florida in 1992, the Federal Emergency Management Agency (FEMA) released a report indicating that prefabricated and masonry homes had fared better than other construction methods. While this additional structure makes the house more resistant to harsh environmental conditions, it should also be noted that these reinforcements add to the total weight of the structure, requiring an amphibious foundation system with additional buoyancy.

The distribution of weight in premanufactured and panelized housing is also very important to consider when designing a buoyancy system, or when choosing a model knowing that it will be retrofitted with a buoyancy system. Kitchens and bathrooms often contain objects that impose concentrated live loads, for example, stone countertops and baths filled with water. The ideal weight distribution for a buoyancy system would organize these bits of programme with a symmetrical load distribution, in order create a horizontal alignment of the building's center of gravity and center of buoyancy. However, in a conscious endeavour to simplify manufacturing processes, premanufactured and panelized models often group rooms with water requirements (i.e. kitchens and bathrooms) along the same wall. Uneven weight distribution as such requires significant calculation and compensation in the arrangement of the buoyancy system. In Figure 1 is an example of a premanufactured house in which the bathroom and kitchen are all placed along the northern wall. In this scenario, if the buoyancy blocks were to be evenly distributed beneath the floor structure, the centre of gravity would shift substantially towards the loaded edge of the building while the centre buoyancy would only shift relatively little in the same direction. This displacement, since the centres are not vertically aligned, would create a moment arm between the two centres, causing the house to rotate in a flood condition. In order to compensate for this moment, the buoyant system would have to be designed with varied distribution, adding cost and complexity to the amphibious foundation design and house assembly.

1.4 Amphibious Foundation Systems – Panelized vs. Manufactured

Figure 1. floor plan for premanufactured home.
Source: Palm Harbor Homes

As the construction processes and assemblies of modular, and manufactured homes differ from one another, so do their process and strategy for rendering them amphibious. In order to add a buoyancy system to a manufactured home, since it is an enclosed unit with a permanent chassis, only a minimal layer of structure below the floor to resist uplift during flood conditions is added to the underside of the house, and only if needed. The buoyancy blocks are then secured underneath. Also, vertical guidance posts will be near the corners on the outside of the building envelope, so as to not create unnecessary openings in the enclosure (Figure 2a). This assembly would then typically be placed on shallow foundations. The process is quite different for panelized houses, as you are given a kit of parts to assemble on site. More often than not, these kits do not come with specifications for foundations, and sometimes even exclude the floor structure as a whole, allowing for many design options in terms of both foundation and buoyancy system. While the foundation systems can vary from pile foundations to shallow foundations or a crawl space, generally speaking, the amphibious floor assembly will consist of a few key elements: a floor structure designed purposely for both gravity loads and uplift, a thin load-transfer layer to distribute uplift forces evenly across the substructure, and buoyancy blocks underneath. The unresolved floor design allows the option to pass vertical guidance posts through the floor structure and hide them inside the building (Figure 2b).

1.5 Case Studies

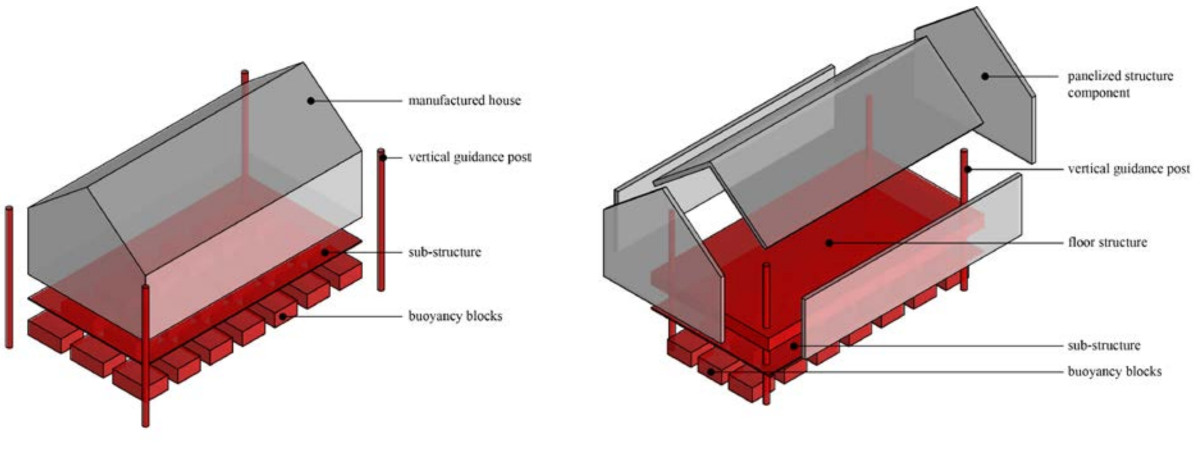

Figure 2. (a) manufactured house amphibious system components; (b) panelized structure amphibious system components.
* *System components not to scale. Foundations not shown.*
Source: Elizabeth English

1.5.1 CASE STUDY A – Old River Landing, Louisiana, United States

Figures 3a, 3b. Amphibious houses in Old River Landing
Source: Elizabeth English

Old River Landing, located in Pointe Coupee Parish, Louisiana in the United States, is an excellent example of the retrofitting manufactured housing with amphibious foundations. The community, tucked away in rural south Louisiana and known as one of the best fishing spots in Pointe Coupee Parish, has clusters of amphibious housing that have been floating above annual spring floods reliably for over 30 years.

The community consists largely of fishing camps and seasonal dwellings. As these secondary residences are located in a remote area, many owners opt to bring in manufactured houses and mobile homes as a relatively simple and inexpensive housing solution, due to minimized labour costs and other costs associated with remote construction. Amongst the manufactured homes, several have been retrofitted with amphibious foundations (Figure 3), following the example of one house in particular, which had proven to be successfully rendered amphibious by a local resident. The houses, which are often unoccupied, are protected from annual flooding by amphibious foundations whether residents are present at the time of the flood or not.

The amphibious solutions are designed to be as effective and low-cost as possible. When necessary, the undersides of the manufactured houses are retrofitted with a steel frame, under which are fastened blocks of extruded polystyrene for buoyancy. The houses are permanently elevated 3 to 4 feet above ground level to give room for the buoyancy blocks. Vertical guidance posts attached to the steel frame at all four corners keep the house from moving laterally, allowing the houses to move only up and down with water levels and coming back to their initial position.

1.5.2 CASE STUDY B – Cow Bay Cottage, Nova Scotia, Canada

Cow Bay Cottage is located on the Cow Bay Trail in Nova Scotia, Canada. The site, which is located 2 km inshore of the mouth of the Cole Harbour inlet located on a flood plain and floods up to 1m with severe storms occurring every several years, largely protected from waves coming from the open Atlantic Ocean. Before it was demolished, a seasonal cottage occupied the site, which had hitherto been damaged by flooded and rebuilt on two separate occasions (Figure 4). Rather than lift the house on stilts, the owner has chosen to install a panelised house with an amphibious foundation system.

The house is to be assembled by the owner himself, a fact that informs many of the design decisions for the house. The need for the house to be constructed by a single person influenced the owner's decision to choose a panelised model with simple assembly instructions, and to choose a screw-pile foundation system, which is much easier to install alone than poured concrete foundations. The panelised model selected also does not include the floor assembly, allowing the floor system to be designed from the beginning, alongside an engineer, as a holistic amphibious system

Figure 4. Original Cow Bay Cottage (static structure) in mild flood condition.
Source: Bob Taylor, GSCA

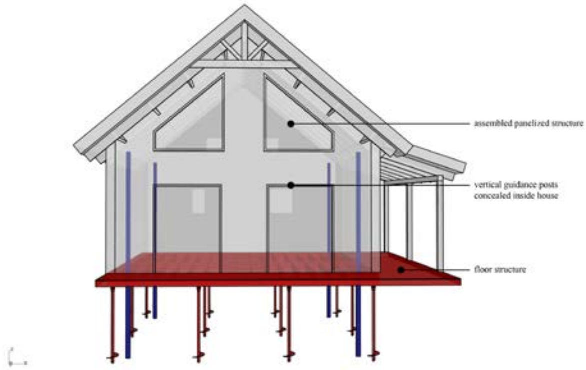

Figure 5. Amphibious Panelized Cow Bay Cottage Assembly
* *System components not to scale. Buoyancy Blocks not shown.*
Source: Lia Tramontini

rather than a post-construction retrofit.

The floor assembly consists of a wood frame, under which is fastened marine plywood to distribute the load from the buoyancy blocks beneath. The buoyancy blocks, which are modular commercial foam-filled dock floats, are arranged beneath the structure evenly between the foundation piles and vertical guidance posts. Since the model came with an unresolved floor structure, the design team has chosen to locate the vertical guidance posts in the inside corners of the house, so as to not have them visible from the exterior. (Figure 5)

1.5.3 CASE STUDY C – Pinaymootang Community, Manitoba, Canada

Pinaymootang is one of the small indigenous communities that make up the central Manitoba Interlake First Nations Reserves. In this area, the provincial government's water diversions divert excess water from Lake Winnipeg to Lake St. Martin at flow rates that cause flooding, but don't allow the water to flow out towards Lake Manitoba. This system, which is designed to mitigate floods on behalf of the larger, non-indigenous populations exacerbates regular flood rates, causes extreme flooding in the Lake St. Martin reserve and the surrounding agricultural land. This regularly forces the communities to evacuate to protect their own health and safety. The Pinaymootang community was evacuated after a flood in 2011 and most residents have not returned.

At a nearby decommissioned military base, the government brought in 68 manufactured homes for members of the Interlake Tribal Council Bands to inhabit. These houses were subsequently abandoned by inhabitants in favour of a new community constructed closer to their original site located on higher ground. The proposal for this project suggests transporting the manufactured homes from the military base to Lake St. Martin (Figure 6), and installing them on amphibious foundations. Transporting these otherwise unused houses from the military base to the Lake St. Martin Reserve is a significantly smaller expense than building new houses, and is made possible by the

Figure 6. (a) existing manufactured homes on military base; (b) pony-wall foundation system for existing manufactured homes
Source: Elizabeth English

manufactured nature of the dwellings. The process for this transition is designed to be implemented in simple steps, so that residents of the Interlake Reserves Tribal Council Bands can learn this simple and easily replicable process. This will build local capacities to help ensure its future implementation across the affected reserves, by passing the knowledge to other Band members. The proposal suggests accomplishing the project in phases, beginning with two prototypes. First, site work will be executed and the foundations prepared. This will take place in August, while the ground is not frozen, allowing the foundations and guideposts to easily be installed. The foundations will be set into the ground, and the structural sub-frame will be assembled without the application of any buoyant elements. Vertical guidance posts will be installed outside the perimeter of the foundation at all four corners. Once the foundations are complete, the two prototype manufactured houses would be transported from the military base to Pinaymootang, and subsequently outfitted with buoyancy blocks. Once the houses are fixed, they will be connected to their various utilities, rendering them fully functioning dwellings. The two prototypes will be studied closely for the remainder of the year, particularly in their performance during spring floods. Necessary adjustments will be made to the design to ensure that the highest degree of functionality is achieved in the subsequent construction of the rest of the amphibious houses in the Pinaymootang community.

1.6 Conclusion

The use of prefabricated houses, whether panelized or manufactured, presents many benefits that often make them excellent candidates for buoyant foundation systems. They are suitable both from project conception and as post-assembly retrofits. As a panelized structure means that the structure is not fully assembled and the manufactured product does not enclose a solid space, this system allows a larger degree of flexibility in the design of the amphibious system, particularly in the placement of the vertical guidance posts and the composition of the floor structure. Manufactured homes, on the other hand, have more restricted possibilities for the aforementioned design items, and are generally treated as retrofit designs, as they are fully enclosed and constructed with a permanent chassis. When choosing between panelized and manufactured model for an application with a buoyant foundation system, while their relative low-cost makes then a particularly enticing and increasingly popular choice, it is the desired aesthetic, level of assembly, and ease of transportation that are key to deciding which option is most suitable to the project.

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