UHPC – ALLOWING FOR THE DEVELOPMENT OF FLOAT HOMES IN ONTARIO

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Abstract:

Based on the growing concern of increased water levels due to climate change, an interest in developing float homes has arisen. Examining case studies shown in British Columbia, where float home developments are common, it can be noted that float homes can be a successful investment. In British Columbia, the standard base construction is made of Styrofoam encased with reinforced concrete. This assures that the homes will not sink due to the deterioration of the reinforcement in the concrete.

The European standard is to have open hull areas with which the home is built upon. It is critical to design an open hull base to improve the usage of space within the home. By incorporating an open hull there is additional storage space, room for mechanical equipment, and improved ballast in the structure.

This paper aims to document the development of an Ultra High Performance Concrete (UHPC) prototype for the float foundations. Working in partnership with FDN Engineering, the objective of Facca Incorporated is to design and develop a foundation based on European examples. Facca Incorporated currently owns marina property that they intend to make into a float home community. The objective is to construct a prototype in 2019 and subject it to the ice conditions in Ontario, Canada.

This paper will examine the history of float home construction and how UHPC can alleviate many of the problems the float homes are subject to.

Keywords:

Float Homes; Climate Change; Ontario; Ultra High Performance Concrete; Technology; Flooding; Alternative Housing

1. Introduction

The development of floating homes throughout Europe, British Columbia and Seattle has opened a market previously uncharted. The objective of this paper is to observe and analyze the potential reasons why floating homes might be successful in the province of Ontario, Canada. This paper will look at how modern technology can make floating communities a reality through the use of Ultra High Performance Concrete (UHPC). Looking at the history of floating home bases and analyzing their positives and negatives, this paper seeks to establish UHPC as the preferred float home construction base material.

This paper will examine the impact climate change will have on the elimination of land through rising water levels. With the cost of housing in large metropolis set to continually increase, with the right technology floating homes will provide adaptive alternative housing. Through studies and testing, this paper will outline the path that developers will need to take to properly implement floating homes within Ontario using UHPC floating bases.

2. Background

2.1. History of Float Bases

2.1.1. Log Float Base Construction

Floating homes have had an extensive and sometimes difficult history. When Western North America was being settled, the main industries were logging and fishing. Typically, these workers were paid very little for their work. In Seattle, these workers opted to live in floating homes so that they could live mortgage and rent free. Due to their low income and lack of funds, these shacks were typically put together using scraps of wood. The construction of these homes and mooring made them more susceptible to being destroyed by storms of heavy snow loads (Blecha, 2010).

In the late 1880's in British Columbia, logging companies began harvesting wood. As roads were too difficult to construct, it made the most sense to make camps on floats. The homes could then be moved along the coast following the wood harvest (Sandy, 2018).

Log float home base construction can provide good strength, it is a resilient substance, it is affordable and easily accessible, and it does not easily transmit vibrations (Newcomb, 1974). According to "The Wonderful World of Houseboating," log float base construction requires yearly painting and is typically more fire prone than other substances. In a paper written by Michael Pedneault, he notes that, "logs are not recommended for floatation because of their susceptibility to becoming waterlogged and/or becoming infested by torredo worms in a salt-water environment" (Pedneault, 1977).

2.1.2. Concrete Float Base Construction

According to Pedneault's paper, one of the materials recommended for use by the Greater Vancouver Floating Homes Cooperative is concrete. Concrete float bases are typically more resistant to perforations or damage cause by trauma to the base. This material has a long life span with only minimal maintenance required. Furthermore, concrete is more resistant to chemicals (Pedneault, 1977). At the time of this thesis' publication, concrete was considered one of the more expensive options, which remains true today.

Concrete is the preferred building material in a marine environment. Concrete provides mass for stability, rigidity for strength and durability, and is a long-term solution. The concrete bases contain structural reinforcement which as a positive helps the base achieve the required engineered load requirements for wind, wave and snow for individual locations. Concrete is typically maintenance free, which is an important difference between this type of base and wood constructed base (IMFS, 2013).

Alternately reinforced concrete is susceptible to corrosion, which produces a risk of sinking (IMFS, 2013). To mitigate this risk, it is included in the "Standards for Float Homes and Live-Aboard Vessels in Victoria Harbour" that, "Where solid flotation devices are not used, adequate pumps or a manifold pumping system shall be maintained in proper working order, with accessible sounding pipes and suctions provided for each compartment" and that, "A Float Home with a flotation device other than solid flotation shall be equipped with a bilge alarm system with detectors in each compartment with audible internal and external visual alarm indicators in the Float Home" (Transport Canada, 2001).

International Marine Floatation Systems Inc. (IMFS) provides an example of a common float base in communities and Vancouver and Seattle. See Figure 1 and Figure 2. It should be noted that any data gathered from IMFS holds the potential for bias as they are a for profit company who seeks to gain from the increased use of concrete float bases.

Figure 1 – Concrete Floating Foundation with EPS Foam (Jostrom, 2013)

Figure 2 – Concrete Floating Foundation with EPS Foam (Peters, 2013)

2.3 Climate Change – Water Levels

When researching the need for floating homes, it is critical to examine the impacts of climate change. According to the National Ocean Service of the United States Department of Commerce, the global sea levels are rising approximately 3.2mm (1/8 inches) per year (National Ocean Service, 2008). The global sea level projections increase for the year 2100, based on 1.5°C (34.7°F) of global warming, sea levels will rise from between 0.26m to 0.77m (10 to 30 inches). Table 1 below shows a compilations of sea level increase projections at 1.5°C and 2°C (34.7°F and 35.6°F) for the year 2100. The data is shown in centimeters, with Representative Concentration Pathway (RCP)2.6 scenarios shown. The Upper and Lower limits are shown at confidence levels of 17-84% and 5-95%. (IPCC, 2018).

Table 1 – Projected sea level increase in 2100 (units in cm) (IPCC, 2018).

Study	Baseline	RCP2.6		1.5°C		2°C	
		67%	90%	67%	90%	67%	90%
ARS	1986-2005	28-61					
Kopp et al. (2014)	2000	37-65	29-82				
Jevrejeva et al. (2016)	1986-2005		29-58				
Kopp et al. (2016)	2000	28-51	24-61				
Mengel et al. (2016)	1986-2005	28-56					
Nauels et al. (2017)	1986-2005	35-56					
Goodwin et al. (2017)	1986-2005		31-59				
			45-70				
			45-72				
Schaeffer et al. (2012)	2000		52-96		54-99		56-105
Schleussner et al. (2016b)	2000			26-53		36-65	
Bittermann et al. (2017)	2000				29-46		39-61
Jackson et al. (2018)	1986-2005			30-58	20-67	35-64	24-74
				40-77	28-93	47-93	32-117
Sanderson et al. (2017)					50-80		60-90
Nicholls et al. (2018)	1986-2005				24-54		31-65
Rasmussen et al. (2018)	2000			35-64	28-82	39-76	28-96
Goodwin et al. (2018)	1986-2005				26-62		30-69

2.4. Cost of Housing

2.4.1 Cost of Housing & Population Increase

As the world population continually increases, the accessibility of housing will decrease. The United Nations predicts that the World population will reach 9.7 billion by 2050 (United Nations, 2015). Large cities will in turn continue to increase. For example, in 2015 in New York City the average price of hosing increased by 12%. As seen in Table 2, the number of residences under construction continues to not meet the demand for housing. In the rental market, it is projected that the current number of rental units being constructed will alleviate some of the current rental difficulties New York is facing (U.S. Department of Housing and Urban Development, 2015). In the examination of this information, a need for floating homes can be identified through the future housing crisis that is imminent.

Table 2 – Housing Demand in New York City (2015-2018)

	New York City HMA		Bronx Submarkter		Brooklyn Submarket	
	Sales Units	Rental Units	Sales Units	Rental Units	Sales Units	Rental Units
Total Demand	16,000	50,175	650	9,350	7,300	17,200
Under Construction	4,095	47,970	30	2,650	580	22,750
	Manhattan Submarket		Queens Submarket		Staten Island Submarket	
	Sales Units	Rental Units	Sales Units	Rental Units	Sales Units	Rental Units
Total Demand	2,850	9,775	4,200	12,200	1,000	1,650
Under Construction	2,975	10,500	300	11,500	210	570

Looking at a ten-year projection, the costs of upgrading from a condo to a house in Toronto and Vancouver will increase drastically, see Figure 3 and 4 (Tencer & Ferraras, 2017).

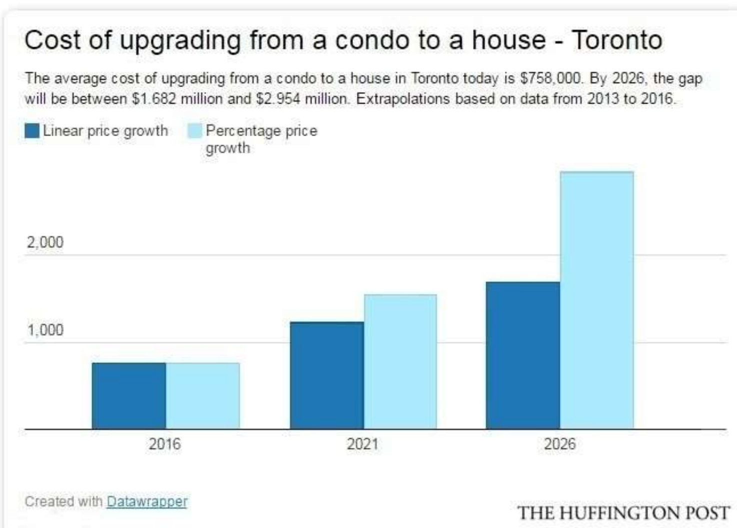

Figure 3 – Cost of Upgrading from a Condo to a House – Toronto (Tencer & Ferraras, 2017)

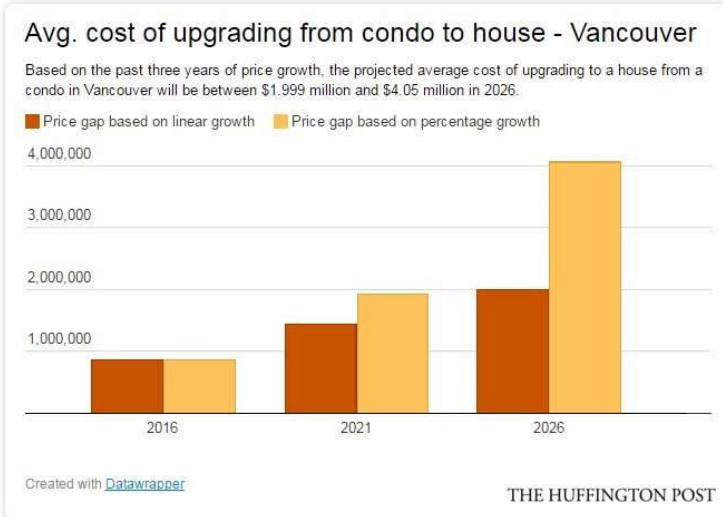

Figure 4 – Cost of Upgrading from a Condo to a House – Vancouver (Tencer & Ferraras, 2017)

2.5 Why Use UHPC?

UHPC is the material of the future. With an incredibly long-life span of theoretically 600 years, low permeability and high strength, it provides the solution to many common problems floating homes currently face. According to a document from the US Department of Transportation, UHPC has a "discontinuous pore structure that reduces liquid ingress, significantly enhancing durability compared to conventional concrete" (Graybeal, 2019). Building with UHPC allows homeowners the confidence that their home will remain afloat for a long time.

Further, due to the high strength and low permeability of UHPC, the walls of the floating home base can be significantly thinner and lighter, than normal concrete. With a lighter base, UHPC addresses issues that current homeowners have with buoyancy and listing.

3. Testing Methods

Facca Incorporated is working on two prototype bases. The bases will be designed as two separate modules for convenient delivery. A proposed bolted connection between the two will be created and tested. The initial trials will have the walls and base poured in one piece. The top will be poured as one slab separately then attached to the base. See Figure 5 for a 3D image of the proposed prototype. It should be noted that the pink rigid insulation shown in Figure 6 is strictly for insulation and heat loss purposes. The insulation is not for added buoyancy, unlike the insultation added to the floating bases in British Columbia.

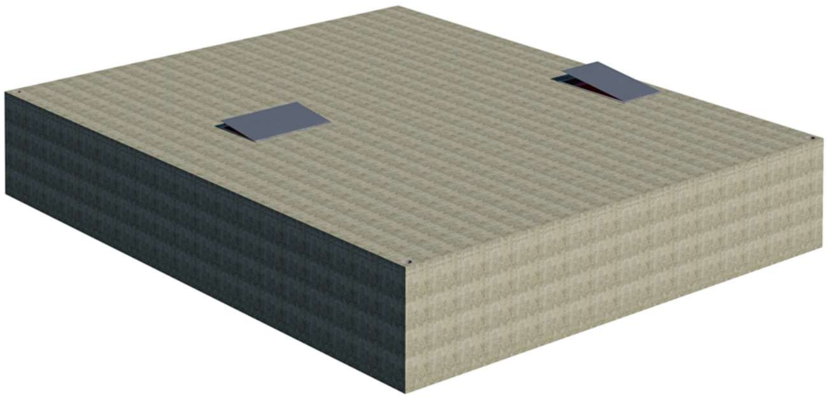

Figure 5 – Exterior of Concrete Floating Base

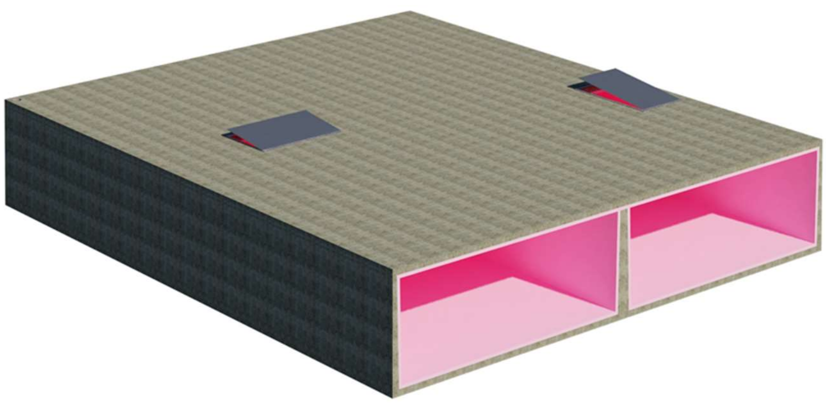

Figure 6 – Section of Concrete Floating Base

4. Results

The first prototype was constructed at a tenth of actual size. The Styrofoam was built as part of the form to ease the removal from the forms.

The second prototype was constructed without insulation as part of the form to compare the form stripping process.

The prototypes were constructed and stripped to ensure the base could be properly removed from this formwork technique. The UHPC base was placed upside down to insure the least number of air voids possible would form in the walls and base. Figure 7 shows the outer layer with its forms removed. Figure 8 shows the fully stripped concrete base.

Figure 7 – UHPC Base Before Removing from Centre Forms

Figure 8 – Stripped UHPC Floating Base Prototype

5. Discussion

After the completion of this prototype it was concluded that more testing is required. Specifically, testing using an alternative material to steel fibres, such as polyvinyl alcohol (PVA) fibers. Performing testing on how the float bases reaction to the continuous freeze thaw cycles and then monitoring the bases' reaction is recommended. Testing is currently being completed and further photographs and data will be presented at the conference.

6. Conclusions

Through the comparison of wood construction float bases, concrete constructed float bases and UHPC constructed float bases, it can be stated that UHPC provides the most advantageous floating home base material. Float bases constructed out of UHPC provide a more durable, denser and more buoyant base. Through the research gathered on climate change and increasing housing prices, the demand for more floating homes can be established. As recommended in the discussion, to properly implement floating homes in the province of Ontario, more tests should be conducted. Specifically, the use of PVA's instead of steel fibres and a study on the effects of a freeze thaw cycle on a UHPC float base. These tests will be completed prior to the conference and their data shared there. It can be concluded that float bases using UHPC are the best option for successful implementation of floating homes with in Ontario.

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8. Acknowledgements

Thank you to Philip Loh and Don Gardonio for their guidance and support with the writing of this paper.