

DESIGN OF MODULAR FLOATING BRIDGE

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Abstract

The robust nature of floating bridges allows it to be used as solutions for water body crossing across a range of distances, and the design of the bridge can be modified to suit its purpose accordingly. However, as floating bridges tend towards lengths greater than 1000m, the scope of materials and designs to use narrows greatly while deployment also takes a longer time. In order to optimise deployment time and cost, innovative designs will need to be implemented, especially with longer floating bridges in mind. Drawing on proven techniques and technologies used in other maritime fields, this paper will look at novel design of an unmanned, modular floating bridge as a solution to long floating bridges which can be deployed in the fastest time possible.

Introduction

Floating bridges have been around since 2000 BC, when wooden bridges were used to help the army cross bodies of water where bridges were not present. Although once used as makeshift solutions during wartime, modern floating bridges are cost-effective structures for water bodies of unusual depths and very soft bottoms where conventional bridges are impractical ^[1]

Modern floating bridges have 3 main components:

1. Pontoons (upon which the deck of the bridge lies)
2. Anchors (to minimise movement of pontoons due to environment conditions)
3. Ramps (to allow loads to safely move onto or away from the bridge)

Floating bridges and their components can be modified according to design requirements and location. The longest floating bridge in the world - the Evergreen Point Floating Bridge - is 2310m long and has 77 pontoons, 772 concrete columns and 331 concrete girders.



Photo 1: Evergreen Point Floating Bridge (atlasobscura.com)

It is a permanent bridge meant to allow traffic to flow between Seattle to its residential eastern suburbs across Lake Washington ^[2]. In contrast, the M3G is a manned amphibious vehicle that can be joined up to form a modular floating bridge which can be used for wet gap crossing. This report will focus on the design of an unmanned, modular floating bridge as a solution to the longer floating bridges (greater than 1000m) which can be deployed in the fastest time possible.

Comparisons with the Evergreen Point Floating Bridge

The requirements of this bridge necessitate innovative design features. The Evergreen Point Floating Bridge in Seattle, USA is the longest floating bridge in the world, with a length of 2310 m. The floating bridge is laid atop 77 concrete pontoons that float above the water and are secured by 58 anchors to the lake bottom. Of the pontoons, 21 are longitudinal pontoons that support the deck and structure and are 360 by 75 by 28 feet (109.7 m × 22.9 m × 8.5 m) and weigh 11,000 short tons (10,000 t); 54 smaller supplemental pontoons, weighing 2,500 short tons (2,300 t), are used to stabilise the weight of the bridge; and two "cross" pontoons, weighing 10,100 short tons (9,200 t), are located at each end of the floating span, which connect the deck to fixed bridges and approaches using hinges to move up to 24 inches (61 cm) for fluctuations in lake water levels moving the pontoons.^[2]

The Evergreen Point Floating Bridge (EPFB) is one of the few bridges that can serve as a comparison for this report's floating bridge due to its comparable length of 2000m and its pontoon-based structure. However, the EPFB's pontoons are made of concrete and anchors are set up across the length of the bridge, which entails a longer set-up time and higher expenditure.

The M3G Amphibious vehicle is used around the world to cross water gaps. It can function individually as floating platforms or be joined with other M3Gs to function as pontoons in a floating bridge.^[3] Individual M3G vehicles are joined by ramps to form continuous bridges to cross water gaps. While these do not stretch for distances greater than 150m, the M3G vehicle bridge's modular nature can be emulated to create an unmanned floating bridge of length 2000m.



Photo 2: Use of M3Gs in an exercise between the UK and Germany (GDELS.com)

Transportation and Anchoring

To reduce the manpower needed to construct the modular bridge, individual modules can be moved into position and held in position through dynamic positioning. This eliminates the need for tugboats and anchors to hold the individual modules in place.

Each module in the bridge is subjected to forces from wind, waves and currents from the environment. The response to these forces, i.e., its changes in position, heading and speed, is measured by the position-reference systems by the position, the gyrocompass and the vertical reference sensors. Wind speed and direction are measured by the wind sensors.

Traditionally used in seagoing vessels, a dynamic positioning system can control the position and heading of a vessel by using thrusters that are constantly active and automatically balance the environmental forces (wind, waves, current etc.). Environmental forces tend to move the vessel off the desired position while the automatically controlled thrust balances those forces and keeps the vessel in position. (Mehrzadi et al., 2020)^[4]

While there are various dynamic positioning systems that can be used, the most commonly used is a Proportional - Integral - Derivative System. The system determines the difference between the vessel's measured (actual) position and the desired position, and then finds the forces that the thrusters must generate to reduce the deviation as much as feasible. The algorithms used also determine the thrust needed to offset the forces of wind, wave, and water current acting on the vessel.

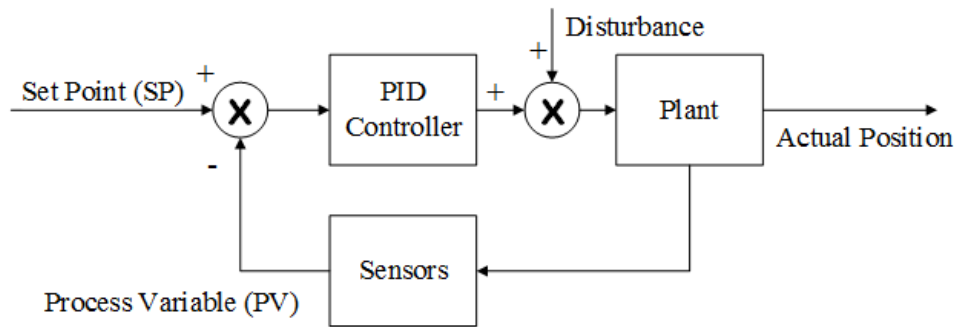


Figure 1: Proportional – Integral – Derivative System Block Diagram (Ali et al, 2015)^[5]

As for the thrusters, they need to be manoeuvrable in 3 degrees of freedom - surge, yaw and sway- to counteract environmental forces. The thrusters will be controlled in accordance with the information obtained by the gyrocompasses and vertical reference sensors. In the development of control algorithms for individual modules, one of the important tasks is the automation of the process of controlling the surface vessel's motion for the entire voyage, starting from the departure port, and ending at the destination port (Manngard et al, 2019)^[6].

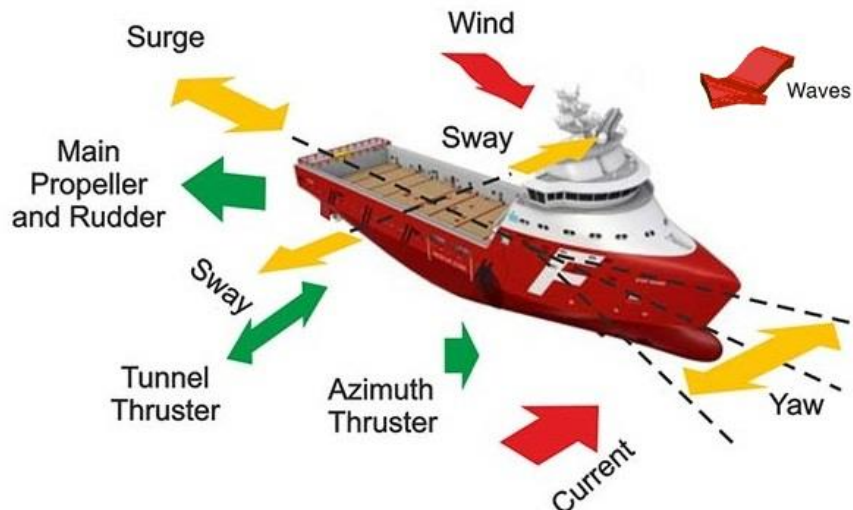


Figure 2: Surge – Sway – Yaw acting on a vessel (offshoreengineering.com)

In this case, the desired route of the system consists of several different-type segments, and thus it may be necessary to use different controllers at different path stages.

Individual Components:

Constructing a whole bridge of 2000m and transporting it to the required location will increase deployment cost significantly as more thrusters or tugboats must be used. Preparing modules and transporting these to the location is more cost effective, and in case of emergency, can allow control systems to adjust to the sea state and environmental conditions more efficiently. As such, modules need to be constructed and transported separately, and assembled linked together at location.

Most of the bridge will consist of floating platforms held in place by azimuth thrusters using the dynamic positioning system. This will involve connecting all the individual platforms retrofitted with azimuth thrusters with ramps. A pin and roller connection would negate any

significant changes in the height of the platform while floating and allow vehicles moving across the bridge to move without being significantly affected by the changes in angle of the ramp (J. Sim, personal communications, 4 December 2022).

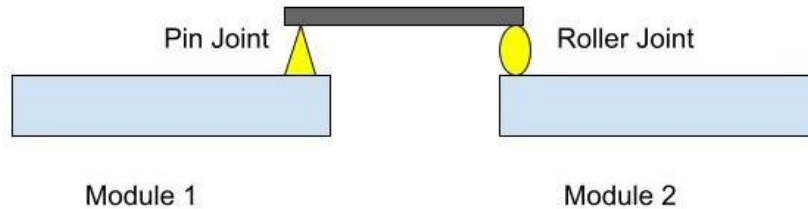


Figure 2: Ramp connection between modules

Hence, the floating modules will be connected in a manner as shown in figure 2.

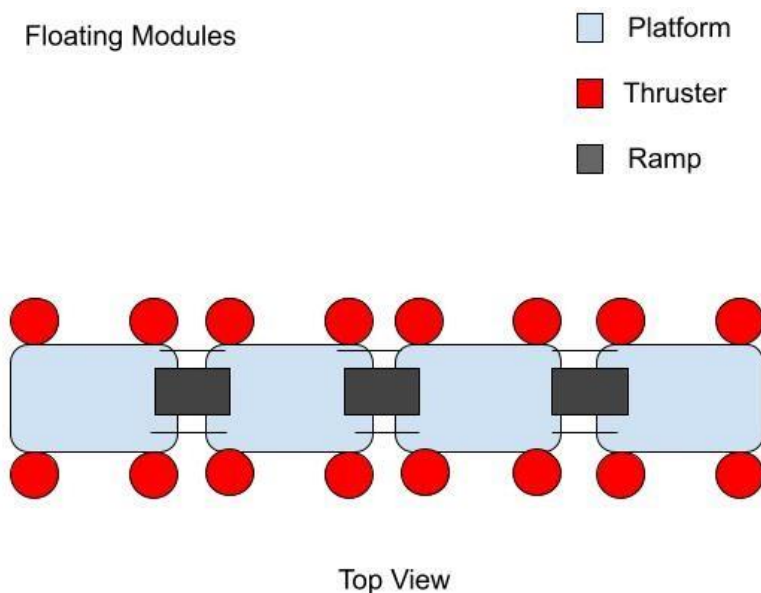


Figure 3: Connected Floating Module Design

The ramps for the approach and departure to and from the bridge are fixed ramps, so that vehicles can safely manoeuvre onto the first module. This is due to the minimal change in the angle of the fixed ramp due to the oscillation of the first module.

In order to ensure the bridge stays stable, in addition to the thrusters keeping each module in position, the modules closest to the land embankment need to be held in position firmly. Various anchor systems can be used, however, a system similar to the Mulberry harbour spud installation could be the most applicable and feasible, as these allow the modules to be

anchored quickly (Hsu et al, 2007)^[7] and can be transported easily (compared to other retrofitted anchors)(Cox et al, 1996)^[8].

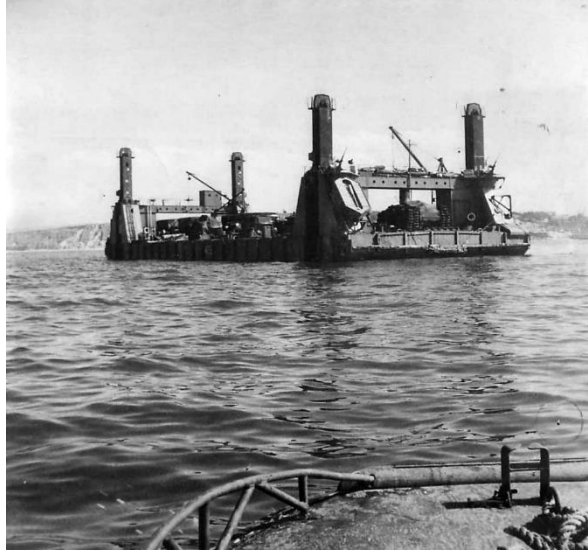


Photo 3: Mulberry Harbour Spud Installation (worldwarphotos.info)

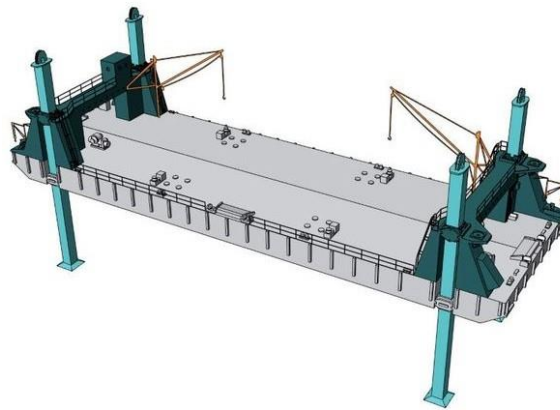


Photo 4: 3D Model of Mulberry Harbour Spud Installation (avrmodel.com)

With reference to photo 2, spud anchors (commercially used during dredging to stabilise platforms offshore) can be used to hold the modules closest to embankments in place. These spuds can be retrofitted onto the modules and transported to the required location to be placed in position.

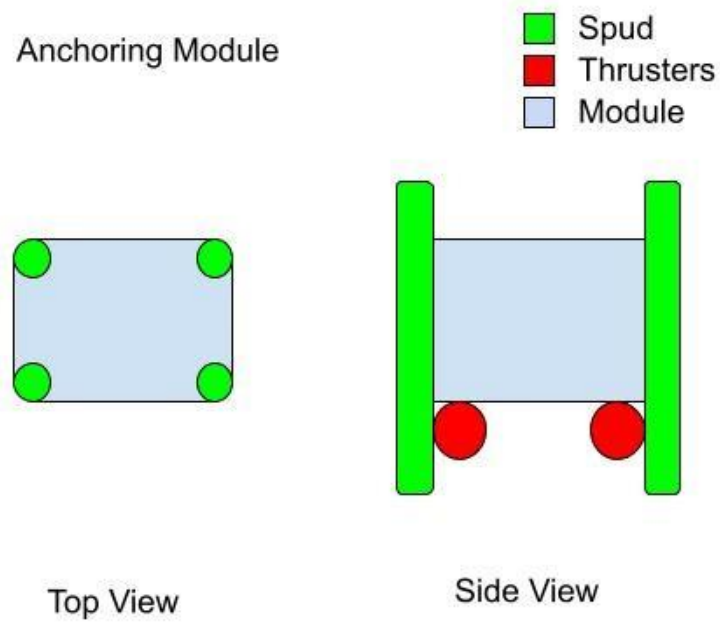


Figure 4: Anchoring Module Design

The final structure is represented in figure 4.

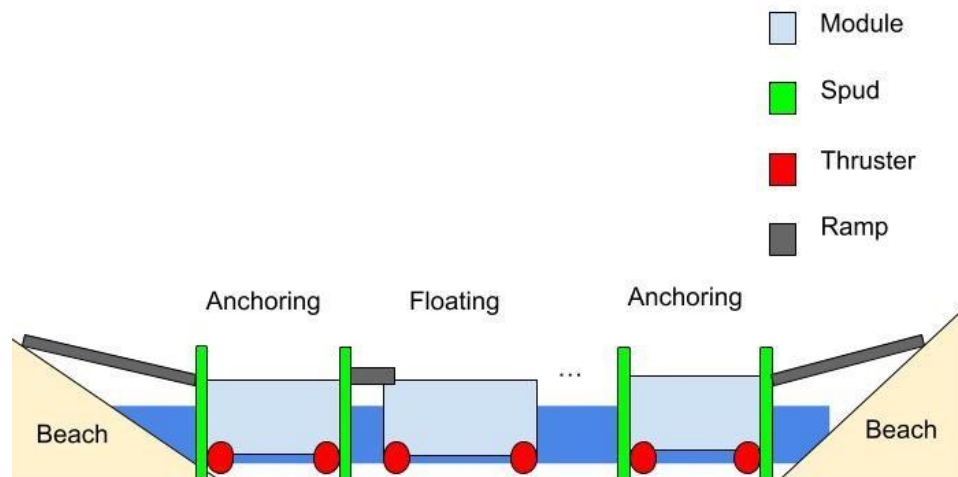


Figure 5: Model of proposed unmanned floating bridge

Conclusion and Future Work

The design of this unmanned floating bridge has prioritised the deployment time of the bridge. Its sustainability and feasibility, while considered, have not been explored at depth.

Furthermore, though the bridge uses proven technologies from various maritime fields, the use of azimuth thrusters in holding together pontoons and spuds and anchoring to stabilise the bridge, still need to undergo seakeeping and rigorous testing. This unmanned, modular, floating bridge needs to undergo proper experimentation before its design can be deemed viable.

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