Very Large Floating Structure and its Application: An Overview

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Abstract: Introduction to the world of very large floating structures (VLFS) that have been gradually appearing in the waters is largely due to a severe shortage of land and the skyrocketing land costs in recent times. VLFS provide an exciting and environmentally friendly solution for land creation from the sea as opposed to the traditional land reclamation method. Its application are mainly for construction of floating bridges, floating fuel storage facilities, floating airports, floating piers and docks, floating hotels floating stadia, and even floating cities have triggered extensive research studies in the past three decades.

Keywords: Hydroelasticity, very large floating structure, Mooring system, Breakwater, Mega float

Introduction

Since population and civic development are spreading in land scare island countries, it needs to create land artificially. Land reclamation programmes is a well known man-made process to build artificial land. Many countries like Japan, Singapore, China, Indonesia, Netherlands, UAE etc are famous for reclaiming land from the seabed, riverbed, lake etc. But land reclamation has its limitation. It is suitable when the water depth is shallow (less than 20 m). When the water depth is large and the seabed is extremely soft, land reclamation is no longer cost effective or even feasible. Also in earthquake prone countries there is possibility of devastating the construction of reclaimed land. City planer and marine engineers started thinking of alternative solution. Then those architects proposed the concept of ocean space utilization using a floating structure.

Classification

According to geometry current VLFS designs fall into two categories: **semi-submersible** type, and **pontoon** type. Semi-submersible type floating structures have a raised platform above the sea level using column tubes or ballast structural elements. It is mainly deployed in high seas with large waves while it maintains a constant buoyancy force to minimize the effects of waves. Floating platforms used for drilling and production of oil and gas are typical examples of semi- submersible-type VLFSs. They are fixed in place by column tubes, piles, or other bracing systems.

pontoon-type floating structures lie on the sea bed like a giant mat floating on water and is intended for deployment in calm waters such as a cove, a lagoon or a harbor. It is simply constructed by box elements. It is extensively used for its high stability, low manufacturing cost and easy maintenance and repair. These structures have a large surface area and a relatively small depth. They behave elastically under wave action.

By location VLFSs are classified into two category, namely coastal VLFS and offshore VLFS. Large pontoon-type floating structures being termed often Mega-Floats by Japanese engineers is an example of coastal VLFS whereas mobile offshore base (MOB) is an example of offshore VLFS.

Mega floats have some basic features, namely

a) As a rule they must have at least one of its length dimensions greater than 60 m, horizontally they can be from 500 to 5,000 metres in length and 100 to 1,000 metres in width, with typical thickness of 2 to 10 metres.

b) Very large pontoon type floating structure,

c) mooring facility to keep the floating structure in place,

d) an access bridge or floating road to get to the floating structure from shore,

e) a breakwater (usually needed if the significant wave height is greater than 4 m) for reducing wave forces impacting the floating structure.

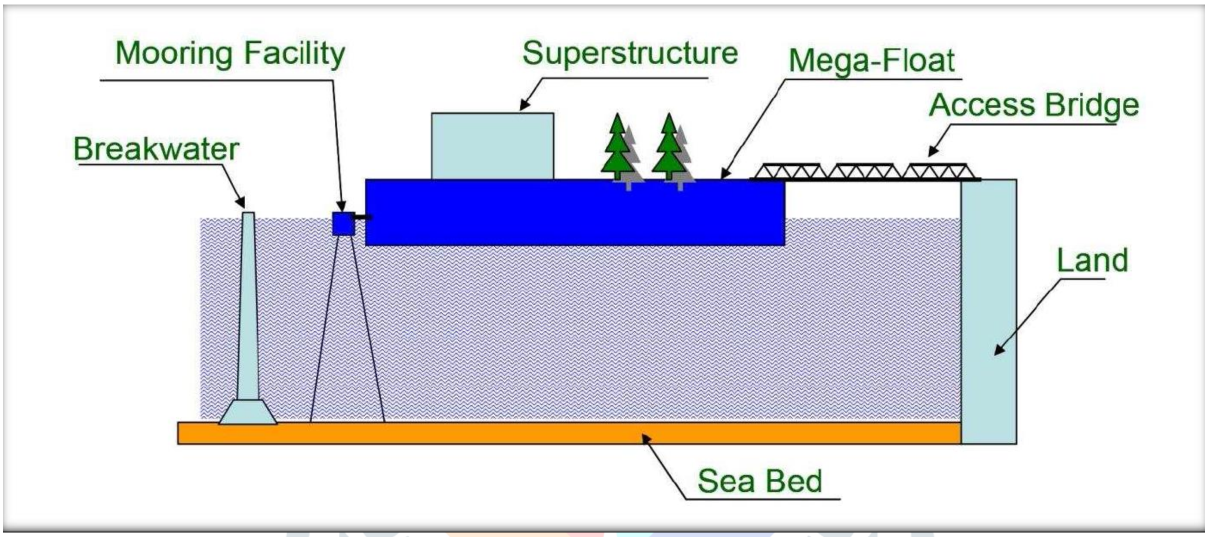

Fig. 1: Diagram of a Mega Float System

The Office of Naval Research, US, has been conducting studies on the technical feasibility and costs of building a mobile offshore base. A mobile offshore base is a self-propelled, modular, floating platform that could be assembled into lengths on the order of one mile to provide logistic support of US military operations where fixed bases are not available. We may be seeing these huge mobile offshore bases in the oceans in the future.

Mooring System

It is an important part for designing a very large floating structures since they keep in position so that the facilities installed on the floating structure can be reliably operated and to prevent the structure from drifting away under critical sea conditions and storms. A freely drifting very large floating structure may lead to not only damage to the surrounding facilities but also the loss of human life if it collides with ships. A mooring system is made up of an anchor, connectors and mooring line, and is utilized to keep a floating platform stationary in all water depth. There are different types of mooring system such as the dolphin-guideframe system, mooring by cable and chain, tension leg method and pier/quay wall method used according to floating structures.

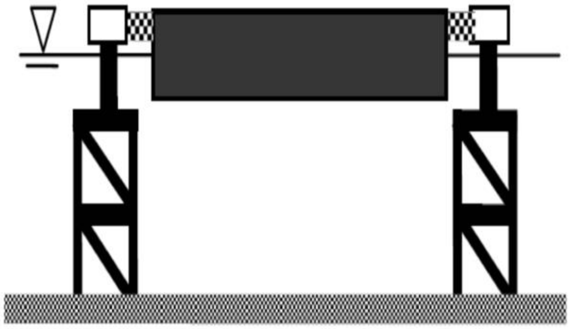

Fig 2: Dolphin Frameguide Method

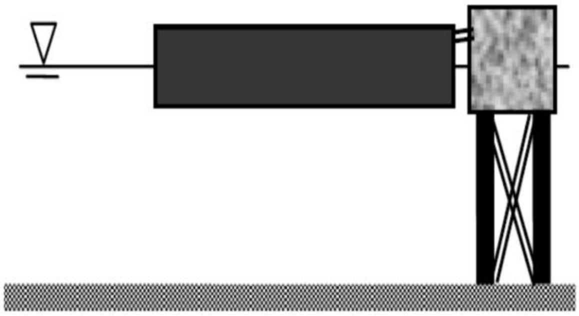

Fig 3: Pier/Quay Wall Method

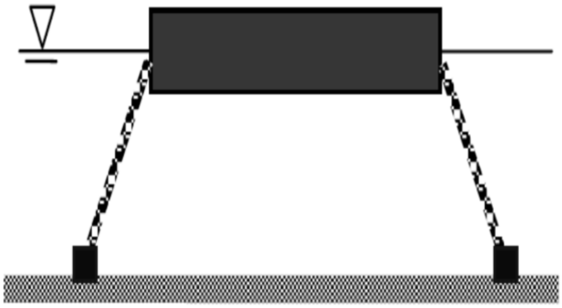

Fig 4a: Chain/Cable Method

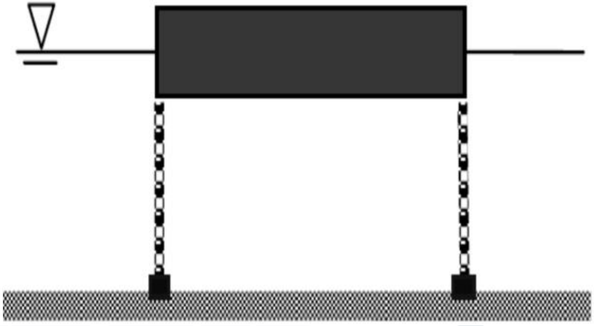

Fig 4b: Tension Leg Method

The proportion of the cost of mooring equipment of VLFS is comparatively small with respect to the total cost. Chain/Cable Method and Tension Leg Method uses chains, wire ropes, synthetic ropes, chemical fiber ropes, steel pipe piles, and hollow pillar links. These mooring systems are used for VLFS operating in deep sea such as the tension leg floating wind farm and the floating salmon farm. However, the motions of a floating structure become large when the length of mooring line is rather long. Especially in deep seas, the tension leg system (see Fig 4b) is adopted to which the pretension is applied to the mooring line in order to restrain heaving motion. In such a station keeping system, it is difficult to restrain the horizontal motion and usually the mooring lines experience significant tension forces.

Application of VLFS

Floating Bridge

The idea of developing floating structures is not new to the world. During 480 BC King Xerxes of Persia used two pairs of floating bridges constructed on boats, leading his army across the Hellespont. In 1874, a 124-m long floating wooden railroad bridge was constructed over the Mississippi River in Wisconsin and it was repeatedly rebuilt and finally abandoned. Brookfield Floating Bridge is still in service and it is the seventh replacement structure of a 98-m long wooden floating bridge (Lwin 2000). In 1912, the Galata steel floating bridge was built across Istanbul's Golden Horn where the water depth is 41 m. The 457-m long bridge consists of 50 steel pontoons connected to each other by hinges. However, in 1992, soon after a new bridge was erected just beside the original bridge, a fire broke out and the old Galata floating bridge was burned down (Maruyama *et al.* 1998). Other floating bridges include Seattle's three Lake Washington Bridges, i.e. (i) the 2018-m long Lacey V. Murrow Bridge which uses concrete pontoon girders and opened in 1940, (ii) the 2310-m long Evergreen Point Bridge completed in 1963, and (iii) the 1771-m long Homer Hadley Bridge in 1989; the 1988-m long Hood Canal Bridge built in 1963; the Canadian 640-m long Kelowna Floating (concrete) Bridge which was opened to traffic in 1958, the Hawaiian's 457-m long Ford Island Bridge which was completed in 1998. A more recent floating bridge of 300m long is the one over the Dubai creek. More recent floating bridges built from 1990s include the two famous

Norwegian floating bridges: 845-m long Bergsoysund Floating Bridge built in 1992 near Kristiansund over a fjord depth of 320 m and the 1246-m long Nordhordland Floating Bridge built in 1994 at Salhus over a fjord depth of 500 m. Both bridges are horizontally curved (in the form of funicular curves) to better resist the wave, the water current and wind forces. An interesting pedestrian floating bridge is the 94-m long West India Quay Footbridge which was constructed in 1997.

An outstanding floating bridge that was built at the turn of the millennium is the 410-m long Yumemai Bridge. The bridge is constructed across a water channel, and it floats on two hollow steel pontoons (each of dimensions 58 m x 58 m x 8 m). The bridge can be swung around a pivot axis near one end of the girder when a passage way for very large ships in the channel is needed.

Floating Airport

From 1995 to 2001, the Japanese constructed and studied the performance of the Mega-Float (a 1 km long floating test runway in Tokyo bay, see Figure 5) in order to develop and investigate the soundness of the VLFS technology for use as a floating airport. After conducting several real aircraft landings Japanese Ministry concluded that floating runaways' hydro-elastic response would not affect aircraft operations and VLFS is indeed feasible for floating airports. This

Structure has been dismantled and is no longer in use. Achmad Yani International Airport is the first floating airport in the world constructed in 2018. Only the passenger terminal and apron are floating.

Fig. 5: Mega-Float at Tokyo Bay, Japan

Floating oil Storage

Very large floating structures have been used for storing fuel. Constructed like flat tankers (box-shaped) parked side by side, they form an ideal oil storage facility, keeping the explosive, inflammable fluid from populated areas on land. Japan has two major floating oil storage systems. One oil storage facility is located in Shirashima with a capacity of 5.6 million kilolitres while the other is at Kamigoto with a capacity of 4.4 million kilolitres.

The Shell floating LNG plant was constructed to process and liquify offshore natural gas into liquified natural gas for transport and storage. The Shell project was scheduled to begin processing gas in 2016. In December 2018, Shell announced that the wells have been opened and the plant was ready to begin the initial phase of production. In June 2019, it reached a significant milestone, shipping its first liquefied natural gas cargo to customers in Asia.

Other Floating Structures

Singapore has built the world's largest floating performance stage at the Marina Bay and is planning to construct a mega floating fuel storage facility (FFSF) off Pulau Sebarok to cater for the increasing demand for oil storage capacity.

South Korea has also initiated a number of VLFS projects. Construction is underway to build three floating islands (named as Viva, Vista and Terra) on the Han River for entertainment and convention centres. The VLFS team of the Samsung Heavy Industries is working on a floating cruise terminal for Seoul which also houses hotel rooms and CIQ (customs, immigration and quarantine), and a floating mobile quay system.

Another example of floating structure is The Hotel Haegumgang and King Pacific lodge Princess royal Island. Hotel Haegumgang is a floating hotel that began operations in Queensland, Australia, was moved to Vietnam, and is currently docked at Mount Kumgang on the east coast of North Korea.

Japan has a number of floating emergency rescue bases parked in the Tokyo Bay, Ise Bay and Osaka Bay since they are ideal application in earthquake prone countries like Japan.

A floating structure consisting of two sections was constructed in 1978 in Brazil. One section of the structure is built for a pulp plant (230 m x 45 m x 14.5 m) while the other section is for a power plant (220 m x 45 m x 14.5 m). It was towed to its site at Munguba as a floating structure but was installed in its location on piled foundations.

In 1979, Bangladesh purchased from Japan a 60.4 m x 46.6 m x 4 m floating power plant. The power plant is located at Khulna, Bangladesh.

In 1981, Saudi Arabia built a 70 m x 40 m x 20.5 m floating desalination plant and towed to its site where it was sunk into position and rests on the seabed.

In 1981, Argentina constructed a 89 m x 22.5 m x 6 m floating polyethylene plant at Bahia Blance.

In 1985, Jamaica acquired a 45 m x 30.4 m x 10 m floating power plant. This plant was built in Japanese shipyards and towed to Jamaica and moored by a dolphin-rubber fender system.

In 1985 Bethlehem Marine Construction Group built the 124 m x 109 m floating dock in Texas Shipyard.

At Ujina Port, Hiroshima there is a floating pier of dimensions 150 m x 30 m x 4 m. Vancouver has also a floating pier designed for car ferries.

The sustainable engineering science barge is constructed by the New York Sun Works Center on the Hudson River in Manhattan to demonstrate that urban agriculture on floating structure is possible without causing damage to the environment. In salmon producing countries such as Norway, USA, Canada and Chile, marine salmon farms are constructed to ensure continuous supply of fresh fish.

A 70 MW floating solar power station was established in Kagoshima Prefecture, Japan in 2013.

On 8 April 2016, the first stage of the rocket that launched the **Dragon CRS-8** spacecraft, successfully landed on the **autonomous spaceport drone ship** named *Of Course I Still Love You*, the first successful landing of a rocket booster on a floating platform.

On July 14, 2021, Singapore made a beautiful history when it officially opened the world's largest floating solar farm. The project (which started in August 2020) was initially planned to be 10 years in the making but it was shorted completed in less than a year. In india the largest floating solar power plant is established by National Thermal Power Corporation (NTPC) in Ramagundam of Telengana State.

After more than three years of construction and a three week towing operation supported by a dozen ships, Russian gas company Novatek achieved a major milestone during August'23 with the arrival of the first production line of its flagship Arctic LNG 2 project on the largest floating structure in the world with a length of 332 m, a width of 154 m and a weight of 640,000 tons at the Gydan peninsula in the Russian Arctic.

In Lusail, Qatar, HSB MARINE built world's largest artificial floating concrete island. For the 2022 FIFA World Cup opening ceremony, they successfully delivered this structure with a total area of 2000 sq. mts and a weight of 2500 tons. This floating structure can rise and fall according to the water level.

SayBoat in Nelahozeves, Czech Republic, **Wa Sauna** structure in Lake Union in Seattle, US, **Drie Streken** floating structure in the Northern Netherlands, **Floating House by Morphosis** - the net-zero 945-square-foot house in New Orleans' Lower Ninth Ward and **Archipelago Cinema** on Thailand's Kudu Island among the top cinema theatres in the whole world are some examples of floating architecture.

Some Advantages

Below are the following advantages to build VLFSs.
i) They are easy and fast to construct.
ii) VLFS's can be easily transported, expanded and removed.
iii) They are cost effective when water depth is large.
iv) They do not disrupt ocean current.
v) They are immune to seismic shock.
vi) They do not damage marine eco system.
vii) The use of water space rather than land space results in a reduction in the overall rate of deforestation.
viii) their location in coastal waters provides scenic body of water all around, making them suitable for developments associated with leisure and water sport activities.
ix) their positions with respect to the water surface are constant and thus facilitate small boats and ships to come alongside when used as piers and berths.

Conclusion

Very Large Floating Structure (VLFS) is a unique concept of ocean structures primary because of their unprecedented length, displacement cost and associated hydroelastic response. A summary of the applications, research and development of the VLFS is presented here. Technology utilized in the project must be well proven or reliable to reduce risk of massive investment of resources. VLFS has little or no history of performance. Methods used for mitigating the hydroelastic responses include the bottom-founded and floating breakwaters, air cushion, submerged and oscillating water column (owc) anti-motion devices and the hybrid type anti-motion devices.

Future research studies on VLFS may include (a) the effect of variable water depth and/or wave shortcrestedness on hydroelastic response of VLFS equipped with anti-motion devices, (b) on-sea experiment for validation of the effectiveness of anti-motion devices in real environmental conditions, and (c) the effect of slowly varying drift forces on the hydroelastic response of VLFS equipped with anti-motion devices.

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