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Una reseña sobre las estructuras flotantes y el papel de la ingeniería

An overview on floating structures and the role of engineering

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Resumen

En este artículo se presenta una breve historia de las estructuras flotantes, que enlaza en con las recientes opciones que ofrecen los desarrollos offshore. Posteriormente se analiza el papel de los ingenieros, destacando cómo en este tipo de estructuras se plasma la idea de diseño en el cual ingeniería y arquitectura se encuentran en un convivio de funcionalidad y belleza. El papel de los ingenieros se traslada, por tanto, a la actualidad, donde la falta de espacio y las exigencias ambientales de reducción del uso del suelo empujan a encontrar alternativas como las estructuras flotantes. En un escenario complejo donde el arte de la ingeniería se enfrenta a los desafíos del medio marino, influyéndose mutuamente, el artículo analiza cuál es el nuevo papel de los ingenieros. A partir de las enseñanzas sobre la filosofía de las estructuras y, en particular, de las ideas de Eduardo Torroja Miret, el artículo analiza los desafíos para el diseño de estructuras flotantes en un entorno complejo y resalta la importancia del diseño conceptual en el perfil del ingeniero, consciente de la complejidad y multiculturalidad del nuevo contexto en el que se desenvuelve.

Palabras clave: estructuras flotantes, impacto ambiental, papel de la ingeniería

Abstract

This article presents a brief history of floating structures, and their links with recent opportunities given by offshore developments. The role of engineering designers is then analysed too, highlighting how these types of structures resemble the idea of design where engineering and architecture meet in a convivium of functionality and beauty. The role of designers is therefore transported to the present day, where the lack of space on land and the environmental requirements of reduction for land use demands finding alternatives such as floating structures. In a complex scenario where the art of engineering meets the challenges of the marine environment, influencing each other, the article discusses which is the new role of engineers. Drawing from the teachings on the philosophy of structures and, in particular, from the essence of Eduardo Torroja Miret's work, the article analyses the challenges for the design of floating structures in a complex environment and uses the basic theory of conceptual design to outline a new necessary profile of a designer, aware of the complexity and multiculturalism of the new context in which he operates.

Keywords: floating structures, environmental impact, engineering role

1. INTRODUCTION

Floating structures have been an alternative to ground-based structures since ancient times, with a long tradition as temporary solutions.

Their design demand engineers to optimize structural design, and require a combination of structural behaviour intuition and advanced structural analysis. Typically extreme actions combined with structural shapes have led to proposals where the essence and beauty of the Engineering, as a whole design.

Nowadays, technological development, especially in the offshore field, has brought new possibilities for floating structures, such as permanent structures. In addition, the recent environmental policies push for a reduction in the use of land. This has brought a flourish of proposals for different types of floating structures in different fields such as transportation, housing, energy, and food production. In this new horizon of possibilities, the enthusiasm must be calmed by a new awareness of the role of engineering which, in the complexity of today's panorama, calls for a new role for the designer.

2. BRIEF HISTORY OF FLOATING STRUCTURES

Building on the water has always been a necessity. Starting from floating houses (Figure 1), as an ancient way of inhabitant protection, or where communities lived on fishing activities, multiple examples around the world show how floating constructions for civil use have changed to adapt to different needs.

Figure 1: Fisherman's Wharf, Victoria, BC, Canada - Ronin, Unsplash

New reasons, among them climate challenges, imply a technological effort in areas such as the Netherlands, to build large floating settlements.

The development of floating structures involves several fields, depending on the needs to be met. Floating bridges have served as a temporary solution, especially for military purposes, as the historical Xerxes's floating boat bridge which was used during the second Persian invasion of Greece in 480 BC (Tavana and Khanjani 2013), and then became an alternative for permanent constructions since around 1940, for example with the Hobart bridge in 1943 (Lee and Wood 1981). 1940 is also the construction year of Lake Washington Floating Bridge, closed in 1989, in Seattle, US.

Since then, other floating bridges have been constructed around the world. Among them, are the two Norwegian floating bridges Bergsøysund (1992) and Nordhordland (1994), in Figure 2.

Figure 2: Nordhordland bridge – Aas Jakobsen

Floating docks are also military solutions turned into permanent use. Mulberry Harbour, used during the Second World War by the British, is an example of a military application (Landis 1997). Among the permanent constructions of this type, the floating container terminal at Valdez, Alaska, built in 1982, is the largest of its kind and is an example of how concrete is a promising material for use in this exposed environment.

Concrete durability has been successfully evidenced also in offshore applications (Fernandes et al. 2008) and, in the last 50 years, new solutions have been developed both for material properties and their technological applications. For instance, elements connecting the tension leg platforms to the seabed, called tethers, were installed for the first time in the '80s in the UK continental shelf in the Hutton oil field (Mercier et al. 1982) and then in several other installations.

The technological advances in marine operations necessary for the installation of these constructions and the maturity of newly developed technologies, such as seabed connection systems (tethers), led to the development of several studies for deep-water crossings (Minoretti and Olsen 2020). Around 2014, after the first study for crossing the Sognefjord (Skorpa 2010), Norway started a series of studies and tests to cross the deep and large fjords along its west coast, along the E39 route from Kristiansand to Trondheim (Minoretti and Bakken 2016).

Among the structures proposed, floating bridges, hybrid suspension bridges on tension leg platforms and submerged floating tube bridges (SFTB) have been evaluated. Actual proposals for submerged floating tube bridges origins in an old conceptual design from the end of the 19th century (Minoretti and Olsen 2020). The tube structure is submerged but floating at a defined position below the water level. For long crossings, the structure needs to be vertically stabilized by floating pontoons or tethers, connecting the structure to the seabed (Minoretti et al 2019).

In this solution, the submerged structure takes advantage of the buoyancy to counterbalance the vertical loads (that is why it is also named ‘Archimedes bridge’) and concurrently lowers the main sea load on the structure just with the submergence. In a vision where the structure takes advantage of the natural laws, the SFTB recalls the solutions where the project equation marries the simplicity and correctness of nature (Livio 2017). Nevertheless, this crossing solution has been proposed several times in the last century, for different applications (Fib bul.96 2020) in lakes and sea crossings, but it has not been built yet.

Hybrid existing solutions are the Statpipe shore approach SFTB, a twin rectangular 670 meters SFTB built in 1982 in Kalstø, Norway, to protect two gas pipelines, and the Söderströmstunnel (Figure 3) in Stockholm, Sweden. This is a subsea tunnel built in 2015 that relies on groups of piles for the foundations, due to the poor soil characteristics, and therefore having a static behaviour as an SFTB on columns support.

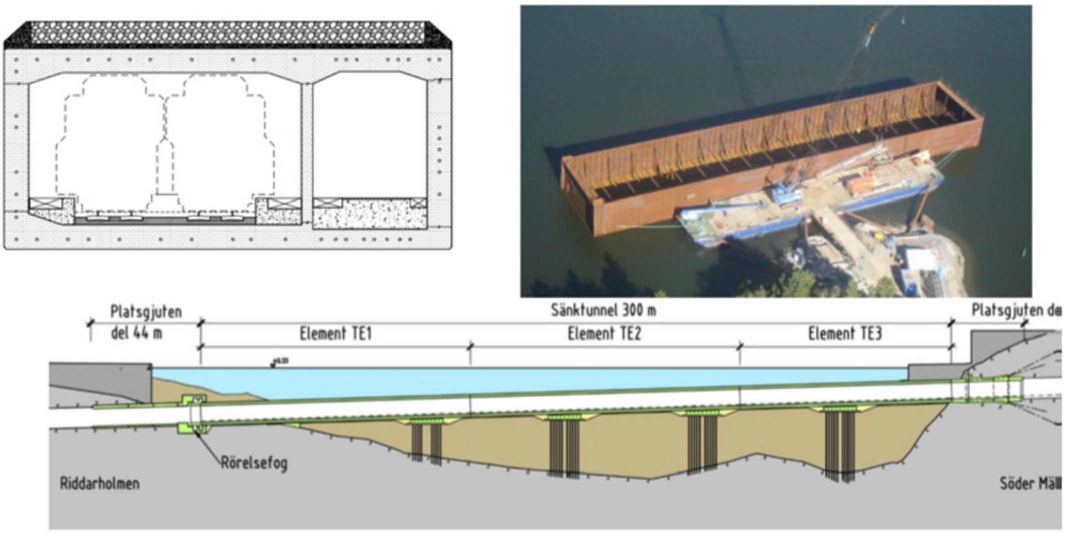

Figure 3: Söderströmstunnel - cross-section, concrete casting afloat and longitudinal section, Trafikkverket

Other types of floating structures have been developed and implemented, such as floating facilities (restaurants, stages, airports) and floating production installations (for energy production - Figure 4 - or food production). Technology is allowing us to broaden our horizons and the designers are working to implement new solutions.

THE ROLE OF ENGINEERING

Certainly, the high technical specialization required in the design of these constructions, combined with their functionality in the past linked almost predominantly to the industrial sector, has attracted many engineers to the ranks of designers of floating structures. Furthermore, floating structures are among those types of constructions where the design of the structure simultaneously defines the aesthetics of the construction. As with bridge structures, technique and aesthetics come together in the design of floating structures, and the role of engineers as designers enter the dimension of beauty’s rigor defined by Pier Luigi Nervi (Leslie 2017).

Figure 4: Walden Floating PV, National Renewable Energy Lab

The role of structural engineers has been distinguished by the general role of designer only in the last 150 years (Shteto, 2021) and, before that, the structure and the architecture had undistinguished roles within the process of creation.

Floating structures are among those structures where the structural design has a general design role, because, once defined, it shapes also the main architecture and defines, with a major role, the aesthetic of the construction. Along this process, to answer to the defined need, engineers conceive a functional solution to withstand the local specific load conditions, shaping contemporary the aesthetical function of the structure at the same time. To say it with Eduardo Torroja's words, in floating structures, the structural part answers all the equations required for the project (Torroja et al.1958).

Borrowing Torroja's words again, structural intuition becomes of paramount importance, as the conceptual design leads the way for the solution's success.

The role of conceptual design has gained more and more importance, recognizing the essential role of designers in the front-end phase, in the scientific and technical communities. For this reason, the International Federation for Structural Concrete (Fib) has been organizing, since 2019, the Fib Symposium of Conceptual Design of Concrete Structures. The Symposium, by an initiative of Prof. Hugo Corres Peiretti, took place for the first event at the Torroja Institute in Madrid, with the vision of bringing together the different professionals around the reflection on the role of conceptual design and the importance of sharing knowledge with new young generations. Again through input from Prof. Corres, in his role as president of the Fib, the Fib YMG (Young Member Group) was created (Figure 5). Four years later, the Symposia slogan invited the young members on a reflection on the future: 'The challenges ahead are more serious than before, therefore future conceptual designers must be better than the existing ones'.

Figure 5: Prof. Corres with YMG of Fib

3. THE NEW CHALLENGES

Future challenges are for sure important and urgent.

Sea levels rising (source https://climate.nasa.gov/vital-signs/sea-level) are putting pressure on several nations, which can no longer rely on protective solutions that are now technically reaching their limit and economically unsustainable. In addition, exhausted areas (Wang and Wang, 2015) are pressing to find new solutions, that could be flexible to accommodate future changes in space and fast to build. There is a need to make available areas near existing settlements or to return lands to nature in areas that are now saturated, reconstructing a habitat that was erased in times of little awareness of environmental impact. In the governmental plans for construction expansion, the imperative reduction of produced emissions and of land use darkens the horizon, threatening with stagnation in the construction sector. Along the coastal areas, land has become more expensive, bringing a need to relocate logistic installations and production plants.

For these reasons, water has been seen as a new expansion area, both for relocating facilities near the shore or to extend the existing ones (Figure 6), or for new energy production installations, but also for civil and transportation purposes.

Figure 6: Sorenga seawater pool, Oslo - Dr. Techn. Olav Olsen

Floating structures present in addition several favourable characteristics (Fib bull. 91). They are flexible and they could be conceived as modular for future change. They are in principle resistant to earthquakes as they are base-isolated, and they are not exposed to risks for sea-level rising. They could reduce the noise impact in the surroundings for the population in-land and they require a use of land limited to eventual areas of connection with land or to anchorages or foundations.

On the other hand, floating structures could have to withstand harsh environmental conditions, especially if the structure is exposed to open sea. Particular challenging situations, like a tsunami or subsea landslides, could compromise the integrity of the structure and therefore the design of these structures requires a very high technical level and an excellent knowledge of local design situations. Situations where the buoyancy of the structure is compromised must be considered by experienced designers and, in the design, robustness and redundancy must be used wisely.

However, the success or failure of floating structures is not only a matter of structural response to design conditions. Operating in the sea (or lake) environment, the structure must be conceived taking into consideration the local environmental characteristics of the area, in terms of biological marine life, and must be designed considering the possible benefits that the structure could generate for the local environment, in addition to minimizing the possible negative impact on the surroundings.

Floating concrete installations could provide new colonization areas for local species but could also be areas for invasive and indigenous species that could compromise the survival of local species. In addition, the release of material from the concrete surface could endanger local species in the long term, so careful testing especially in the use of new materials should be planned. The presence of floating structures and artificial lighting could represent a barrier to migration for some species or attract them in the proximity of the light source. Floating structures connecting different habitats, such as floating bridges, could represent a favourable connection for the spreading of species, with positive or negative consequences. The effect of noise produced during the construction, installation and the life of the structures, should be evaluated also in terms of effects on marine species. Specific studies (Follestad et al. 2022; Multiconsult 2023) demonstrated the importance of involving environmental experts from the early stage of the design, to build a knowledge of the local environment and work on the environmental challenges to transform them into opportunities, whenever possible.

As an example, for the study of an SFTB on the Bjørnafjord crossing, in Norway (Minoretti et al. 2016), the pontoons were studied as floating green islands (Figure 7), able not only to guarantee the structural performance needed but also to create a shelter for the nesting of local species.

The environment therefore becomes a new equation in the perspective of the design, with a multiplicity of competence needed to bring into the general picture at the base of a successful design concept.

Figure 7: study for an SFTB with pontoons for the Bjørnafjord crossing in Norway, Statens vegvesen

4. THE NEW ROLE OF ENGINEERING

The new conceptual design is more difficult than before, as the Fib symposium stated in 2023. Starting from bridging engineering and architecture, the new designers need to be aware of the complexity of the environment we operate in.

Floating structures can be a real opportunity if we just do not make the same mistake made with land-based constructions, where the indiscriminate construction has ignored the socio-environmental implications and has led us to today's desperate and often unsuccessful attempts to remedy past mistakes.

The new conceptual design starts from the knowledge of the project's needs and of the local characteristics where the project will operate, embracing a multidisciplinary perspective and recognizing the need for the involvement of a range of experts from various disciplines. Among them, environmental experts, who must be involved from the early stages of the project, to transform the environmental challenges into possibilities and provide long-term value to the construction. Lasting value is the bearer of true sustainability

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