The Monumental Water Celebration: A Construction Proposal of Building on Water and Carving Water Edges

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Abstract:
Building-on-water is the trend of the 21st century for waterfront cities. In fact, being a waterfront city is an added value for the city, which, in turn, increases the value of its lands and real-estates. Therefore, architects, designers, and governors encourage the concept of building-on-water to create iconic identity to the waterfront cities. Nevertheless, some architectural proposals of buildings-on-water remain on papers due to several constrains, such as, cost, regulations, structure, constructability, and transportation. Jeddah is a Middle Eastern waterfront city, located at the center of the Red Sea at the west shore of the Kingdom of Saudi Arabia (KSA). It is the largest seaport in the Middle East and North African regions. Moreover, the city is acknowledged as the gate to Mecca, the Muslims' destination for pilgrimage and Umra; accordingly, Jeddah gained its uniqueness to be one of the most imperative cities on the Red Sea. Since then, building on the Red Sea water is developed as an element of contemporary architecture to enrich the concept of Jeddah water-celebration; to be one of the iconic cities of Saudi Arabia. In fact, the 2030 vision of KSA aims to transform Jeddah city to be the tourists' destination that attracts visitors from all over the world to participate in that celebration. The celebration of building-on-water techniques are mainly dominated by two methods; building on an artificial island, such as Burj Al-Arab, Dubai, United Arab of Emirates (UAE); and building-on-land then shift the structure to water, such as Troll-A Platform Oil Rigs, North Sea. The objective of this study is to introduce a third construction method to build-on- water by arguing the following questions: How buildings on water can be integrated into the land while maintaining the character of being in the middle of the water? How to transform the existing building condition to accommodate water? How to reduce and avoid construction on water issues and concerns? And finally, how to utilize and control shore edges in term of public zones versus private zones?

Keywords:
Construction on Waterfront Cities
Building-on-water
Water Celebration
Iconic City
Construction Methods.

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Introduction:
Waterfront cities are the cities located at the shore edge facing the coast. They are also referred to as shore cities and coastal cities. Throughout history, people have resided waterfront cities in order to transport easily from a place to another and for fishing, an easy source of food. Over time, these cities have developed and added more values to their countries through seaports, which are the driving factor for the economy in waterfront cities. Nowadays, waterfront cities are not only economic cities, they are the beauty gates to their countries.
Onshore cities have developed unique identities of themselves. Of these identities is building-on-water. It is an approach that has never been impossible to apply, however, the cost, regulations, structure, constructability, and transportation are the major challenges to this concept. Regardless of these issues, governments, developers, and architects encourage the concept of building-on-water to celebrate the uniqueness of being a waterfront city and to create icons that represent those cities.
In fact, the approach of building-on-water is developed to recognize the cities. The city history, behavior, and culture often be reflected on architectural buildings and designed objects in waterfront cities. For instance, Burj Al-Arab is an icon of Dubai, UAE that reflects the importance of sailing ships as part of the city history. Sydney Opera House is the symbol of Sydney City, Australia that represents sea shells. Statues of Liberty in New York city, USA, mirrors the concept of freedom. King Fahad Fountain, the world's tallest fountain, is an icon of Jeddah,

Saudi Arabia that reflects the culture of the traditional Arabian censer. The common geographical factor between these cities is their locations as waterfront cities; while the common concept is to honor history, behavior, or culture through building icons on-water.
Jeddah is a Middle Eastern waterfront city, located at the center of the Red Sea at the west shore of KSA. The city is recognized by the rich concept of celebrating water as an element of contemporary architecture and urban design. In fact, the concept of building-on-water in Jeddah started in 1980 as a result of the city development and urban expansion. Since then, carving water edges and constructions-on-water turned into a character that reflects the city identity and prioritized as building-on-land. Regardless of cost, man-hours, transportation, and utilization of public versus private zones caused by building-on-water, the 2030 vision of KSA aims to transform Jeddah to be the tourists' destination by urging on-water projects, which attract visitors from all over the world.
Construction-on-water technique in Jeddah is mainly expressed through building on an artificial man-maid island. On the other hand, construction-on-water, worldwide, is mainly implemented by two methods; building on an artificial island (ex. Burj Al-Arab), and building-on-land then shift the structure to water (ex. Troll-A Platform Oil Rigs, North Sea). This study illustrates a third construction method of building-on-water that reduces and avoids the potential issues due to cost, man-hours, transportation, and utilization of public versus private zones.

Jeddah City and The Red Sea Shore

Jeddah, a 3000-year-old city, located at the center of the east cost of the Red Sea, an inlet branch of the Indian Ocean and the geographical connection between Asia and Africa. Between 1970 and 1980, Jeddah witnessed a tremendously urban incensement as a result of the oil boom. The second urban expansion was between 1980 and 1990; proportionally with the transportation and infrastructure development. From 1990 to 2007, Jeddah experienced the first water landfill that determined and characterized the Red Sea water-edge pattern of the city (Figure-1).

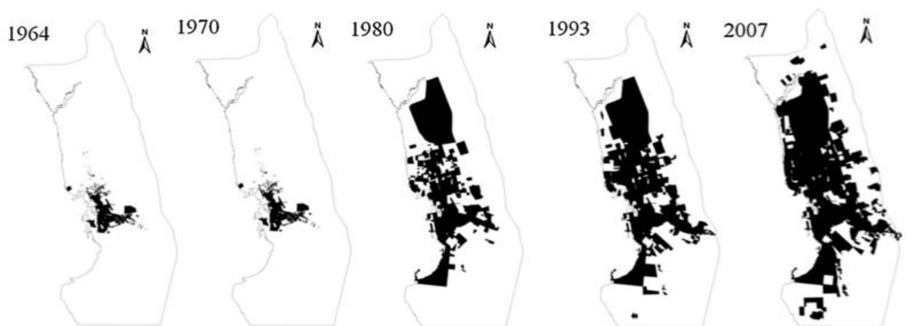


Figure-1: Urban and Spatial Expansion of Jeddah City from 1964 to 2007. (M. Aljoufie et aL. / Cities 31 (2013) 57-68

The Red Sea is named after the red sea corals, which canvas the seabed. The deepest point of the Red Sea is at 2,211 meters below the ground level and the water tides range between -1m to 1.5 m as maximum (Figure-2). The Red Sea is considered to be the festival hall of Jeddah. To declare the waterfront pride, the city announced the building-on-water approach in 1980. The first two structures on the Red Sea in Jeddah were completed in 1985; King Fahad Fountain and Al-Rahma Mosque, also known as the Floating Mosque. In 1990, the approach was implemented to build more structures on-water. Jeddah Lighthouse, the harbor and seaport control tower, which was constructed to be the tallest lighthouse in the world. In 2002, on-water resorts were built on an artificial islands off-the-shore to carve the water-edges and monument the waterfront (Figure-3).

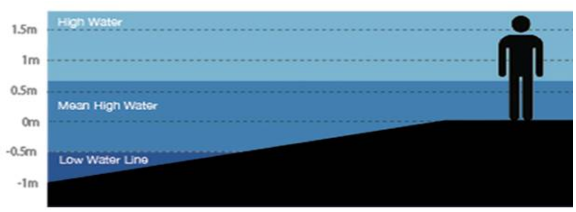


Figure-2: Red Sea Water Tied, highest and lowest tied of Jeddah City

Figure-3: Building-on-water concept in Jeddah city started in 1985.

Jeddah Waterfront Forms and Edge

The waterfront of Jeddah assists several programs, such as, industrial, commercial, residential, and tourisms. The multiple land uses, functions, and zonings, which take place at the same water shore, the water-edges and forms behave dynamically based on the characteristics of the function, space, architectural scale, and water level. Accordingly, analyzing the waterfront of Jeddah declares nine categories in participation between land and water (Figure 4), (Table 1-A):

1. The Double T.
2. The Whale Tail.
3. The Sored.
4. The Pies.
5. The Curve.
6. The Wave
7. The Creek.
8. The Hocks.
9. The Fingers.

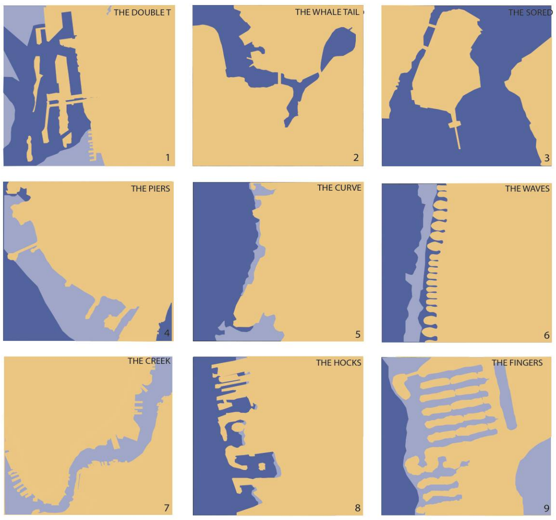


Figure-4: Jeddah City Waterfront forms and edges.

Figure-5: Burj Al-Arab, Dubai, UAE.

The common factor between these edges is integrating water within the land to increase the advantages of being on-water. for instance, being on-water or in a waterfront area increases the real-estate value, maximizes water view, promotes accessibility and connections between land and water, and creates different opportunities for the dwellers in term of jobs, trades, and resources. Thus, waterfront edge is the targeted area to be formed and carved differently and generously in Jeddah. **Dominated Methods of Building-on-water in Different Waterfront Cities Around the World:**

1. **Building on Water Case Study I: Burj Al-Arab, Dubai, UAE.**

Dubai is a waterfront city located at the west coast of the Arabian Gulf in UAE. The city vision is to create an iconic global center for tourism, trade, and finance. Therefore, Sheikh Mohammed bin Rashid Al-Maktoum, the vice president of UAE decided to introduce an architectural building to be the city icon of Dubai, Burj Al-Arab. (Figure-5)

Since the city is located at the shore, building on the water of the Arabian Gulf was the best option. In response to the vice president desire, Tom Write, the architect of Atkins, a global architecture and engineering firm, proposed to construct a tall building-on-water that represent the historical sailing ships. The tower was built on an artificial man-made island, following the procedure on (Figure-6):

Table-1: Conclusion Analysis of Waterfront Forms and Edges Categories in Jeddah

NO.	NAME	DATE	FUNCTION	FORM	FORM RESPOND	WATER LEVEL	ARCHITECTURE SCALE	PHYSICAL CHARACTERISTICS
1	JEDDAH ISLAMIC PORT	646	INDUSTRIAL	DOUBLE T	SUPPORT GLOBAL CONNECTIONS AMD SEA-LINES.	DEEP/ FOR SHIPS NOT SWIMMING	MONUMENTAL DECKS	HARD CONCRETE STRUCTURE AND STONE ELEMENTS
2	CENTRAL FISH MARKET	1890	COMMERCIAL	WHALE TAIL	ALLOW FISHING BOATS TO GET INTO SHALLOW WATER TO UNLOAD FISHES	SHALLOW WATER/ NOT FOR SWIMMING	SMALL INDIVIDUAL BOAT DECKS	HARD CONCRETE SAND BEACH FOR FISHING BOATS
3	KING FAHAD PALACE AND FOUNTAIN	1980	RESIDENTIAL	SORED	THE WATER HAS BEEN USED AS AN INSULATION ELEMENT FOR ISOLATION AND PRIVACY	DEEP/ NOT FOR SHIPS OR BOATS AND NOT SWIMMING	MONUMENTAL BUILDINGS (PALACE)	THERE IS ONLY ONE WAY TO GET TO THE ISLAND, THROUGH UNDERWATER INFRASTRUCTURE
4	AIR FORCE BASE	1980	INDUSTRIAL	PIERS	PIERS PLAYS THE ROLE OF THE RUNWAYS FOR THE FLIGHTS TO TAKE OFF. ALSO ITS HAS THE PRIVATE TAKE OFF PIERS FOR THE KING'S HOLLOWCAPTRE	SHALLOW/ NOT FOR SWIMMING SMALL BOATS ARE ALLOWED	GARAGES FOR THE AIRPLANES AND PRIVATE COMPOUNDS FOR THE WORKERS	HARD SCAPE (PIERS) ARE EXTENDED TOWARD THE WATER
5	DESALINATION	1973	INDUSTRIAL	CURVE	ALLOWS WATER TO BE SUCKED IN TO THE FACTOR.	SHALLOW/ NOT FOR SWIMMING BOATS ARE NOT ALLOWED	MONUMENTAL WATER PIPES STORAGES, AND FACTORS	SMOOTH EDGE
6	CORNICH	1980	TOURISM	T WAVES	CELEBRATING THE EDGE, FUN, ENTERTAINMENT, AND ART.	SHALLOW/ NOT FOR SWIMMING BOATS ARE NOT ALLOWED	LOW EDGES PARALLEL TO HIGH RISE BUILDINGS	HARD SCAPE ISLANDS EXTENDED TO THE WATER EDGE TO INCREASE AIR FLOW
7	OBHOR	1992	TOURISM	CREEK	CELEBRATING THE EDGE, FUN, ENTERTAINMENT, ART, AND MOSTLY WATER ACTIVITIES AND SPORTS	SHALLOW/ FOR SWIMMING AND BOATS	SMALL HOUSES	PIERS ALL THE WAY TO HAVE THE BOATS AND SHIPS PARKED THERE.
8	NORTH OBHOR	646	RESIDENTIAL/ TOURISM	HOCKS	PRIVACY AND SAFETY	SHALLOW/ FOR SWIMMING AND BOATS	PALACES	LUXURIOUS AREA
9	DURRAT AL-AROUS	1996	TOURISM/ RECREATION	THE FINGERS	MAXIMIZE THE WATER VIEW IN ALL SIDES	SHALLOW/ FOR SWIMMING AND BOATS	SMALL HOUSES	LUXURIOUS RECREATION-AREA

A. Constructing The Island: a temporary basin built for excavation and concrete pouring. Piles are driven and tied to the temporary basin walls. (Figure-6A)

B. Foundation: Perimeter of island layered with concrete sponge -like blocks to prevent erosion. A total of 250 piles, each 45m long and 1.5 diameter thickness are driven into the ground to facilitate friction with the underlying and sand substrates. (Figure-6B)

C. A basement that is nine meters in height is constructed and is flush with the top level of the island. (Figure-6C)

D. Foundation is completed and the construction of the superstructure is able to commence. (Figure-6D)

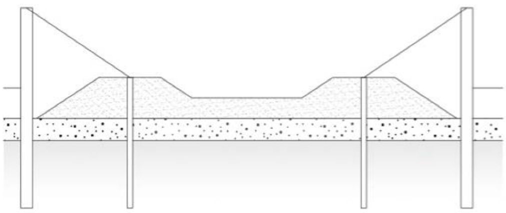


Figure-6A

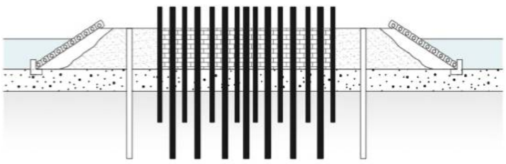


Figure-6B

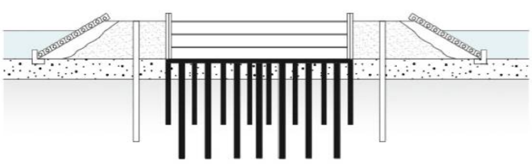


Figure-6C

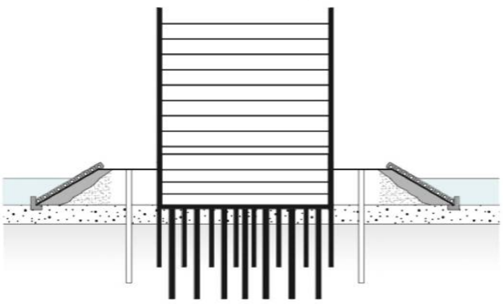


Figure-6D

The longitudinal sections of Burj Al-Arab show the relationship of the built out foundations in comparison to the shore land and the bridge that connects the land to the island. The building sits on a built-up land, to be formed from the sea sand below and the foundations of the building, which are embedded deep into the sand of the sea floor. The connected bridge was constructed before the vertical structure to transport the building equipment and materials to the construction site (Figure-7). The main matter with building-on-an-island is the transportation of the construction equipment and materials that requires more man-hours, coast, and time in addition to the construction ships and platforms used to put up the vertical structure.

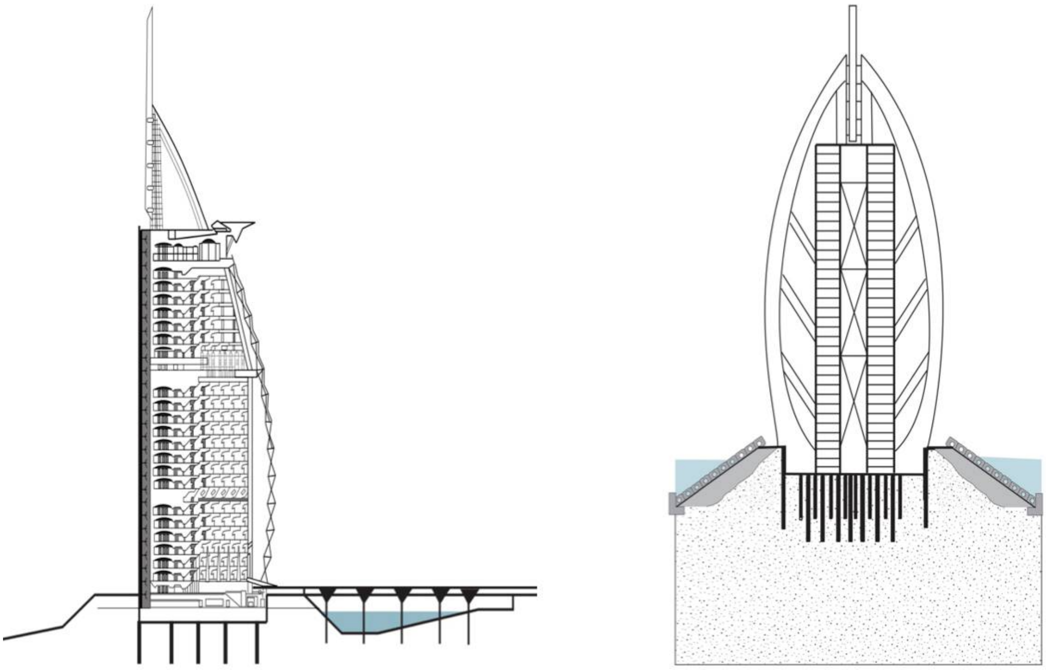


Figure-7: Longitudinal Sections of Bur Al-Arab

2. Building on Water Case Study II: Troll-A Platform, North Sea

Figure-8: Troll-A Platform, North Sea

Troll-A is a platform used for the extraction of gas and oil in the North Sea off the Western coast of Norway It is known as the “Skyscraper at Sea” (Figure-8). Like many other platforms, Troll-A was constructed on land and brought down to the site of the oil field. In this case, the formwork and 6-feet-thick concrete walls of the legs are poured while being surrounded by the vacuum barrel foundations. These vacuum barrels are also called skirt suction foundations because they are composed of cylindrical concrete drums that are embedded into the sea floor and anchored through a process of hydro-static pressure. When the mid points of the concrete legs are reached, a concrete belt is cast around them for stability and the structure is prepared to be transported. The legs are towed from the temporary dry-dock, where they are then moved into deeper waters. Thus, the construction procedure of Troll-A is considered one of the most difficult and complicated techniques to build-on-water as it passes through eight stages:

A. Foundations: Foundation construction inland. Each leg uses a group of six 40- meters tall vacuum-anchors holding it fixed in the mud of the sea floor. (Figure-9A)

B. Lower Legs: The walls of Troll A's legs are over 1-meter-thick made of steel rein- forced concrete formed in one continuous pour. (Figure-9B)

C. Bracing: a "Chord shortener", a reinforced concrete box interconnecting the legs, joins the four legs. It has the function of damping out unwanted potentially destructive wave-leg resonances by retuning the leg natural frequencies. (Figure-9C)

D. Upper Legs: Additional stability (lateral) and gravity loads reinforced by a mid- point bracing. (Figure-9D)

E. Moving Off Land: After 4 legs are completely formed and dried, the structure is towed to a fjord, a deep-water formation with low wave frequency. (Figure-9E)

F. Moving to Sea: The structure continues to be towed further out into the ocean and away from land. (Figure-9F)

G. Platform: The Platform (modular construction at a nearby dock) is attached and welded to the legs. (Figure-9G)

H. Submerged: Finally, the entire structure is submerged under water, dropped further and further into it reaches the ground floor of the ocean. (Figure-9H)

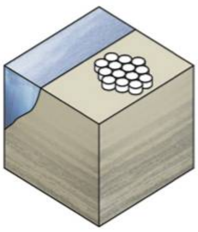


Figure-9A

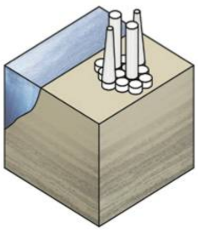


Figure-9B

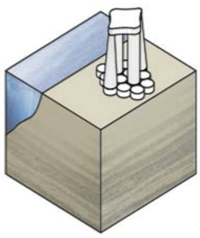


Figure-9C

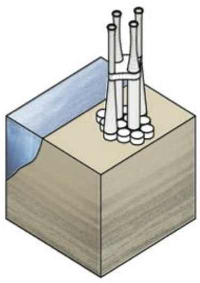
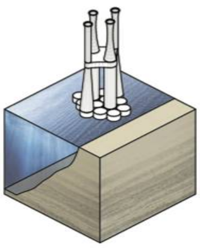


Figure-9D



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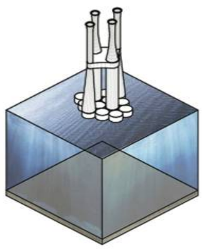

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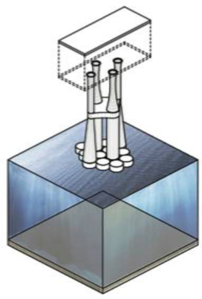

Figure-9G

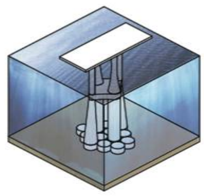

Figure-9H

This massive method of construction is considered one of the most expensive as a results of the tremendous effort, process, and equipment needed to be constructed and transported to water. Furthermore, when the oil extracting process is over, the structure is left on the sea bed and new one is constructed for another oil-extracting field.

Construction-on-Water Proposal

Throughout the era of building-on-water, architects and engineers dominated two construction methods to build-on-water. The first technique, which is the most common, is building an artificial landfill island on the water, construct the foundation piles, connecting the island to the land through a bridge to supply the island, then constructing the vertical structure; as explained in Burj Al-Arab, Dubai, UAE (Figure-10). The second technique is constructing the foundations on land then shift them to water; diving the foundations to the sea ground; and finally, constructing the vertical structure; as explained in Troll-A platform, Oil Rigs Towers (Figure-11). The theories of the two previous methods depend on the fact of being on-water first, then starting the construction, which demands the use of giant construction ships to transport heavy equipment, materials, and machineries to be on-water in order to be able to build the vertical structure.

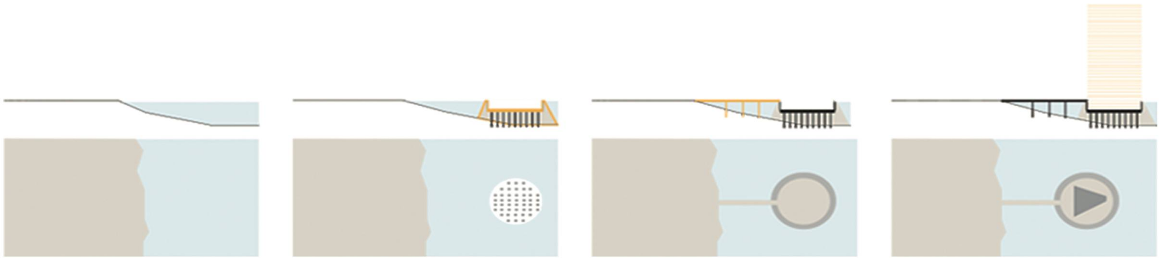

Figure-10: Burj Al-Arab Construction Process

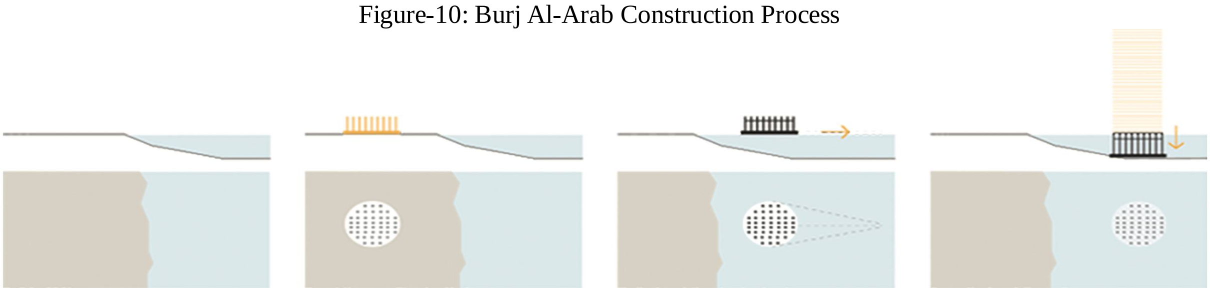

Figure-11: Troll-A Platform Construction Process

On the other hand, the third construction proposal technique of building-on-water, which is presented on this paper, depends on the theory of starting the construction process on-land, then carving the land to be on-water. This construction process requires a site near the shore to construct the foundations, podium, and vertical structure, then inviting the water to the site as a final phase of the construction process. The construction phases mainly characterized and illustrated in four main stages:

1. Foundation:

Considering a total excavation of 42 meters below the ground level to be divided into four sections. The first section, which is just below ground level, is considering the highest tide of the Red Sea water, which is 2 meters. The second section is 12 meters, which will be covered by the water. The third section is 24 meters, the total height of the basement, which is the massive horizontal structure. The fourth section is 4 meters, the thickness of the foundation mat. When reaching the 42-meter grade below the ground level, foundation piles will be taking a place on 55-meter depth, below the 42 meters. At this stage the foundations are completed and qualified to host the horizontal structure. (Figure-12A)

2. Constructing The Basement:

To connect the land with the vertical structure, a massive horizontal basement is constructed. The basement act as a podium to the building. At 24 meters down, bearing-wall systems are constructed to perform as a ground bathtub that protects the basement from soil pressure and side loads. In addition, several layers of isolations are implemented to shield and preserve the basement. The 24 meters is the total height of six floors under the ground. The remained of 14 meters from the top of the basement to the actual ground level will be occupied as a construction field surface for the vertical structure. (Figure-12B)

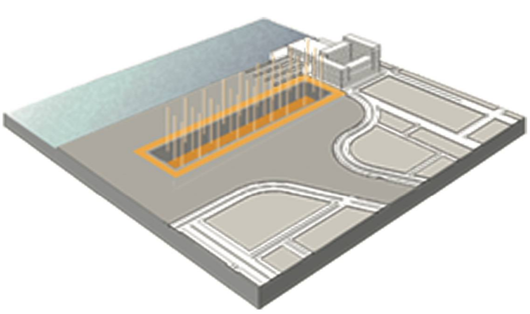

Figure-12A

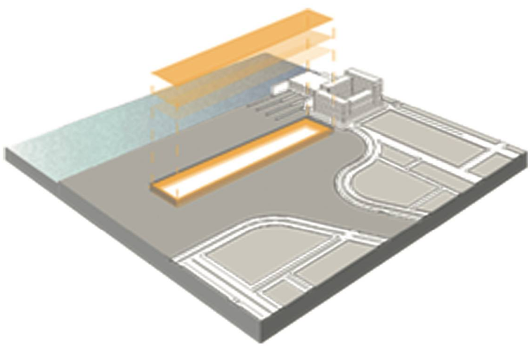

Figure-12B

3. Vertical Structure:

At this stage, the construction site is remained on land, where construction process follows the traditional building-on-land method. The advantages of constructing on-land reduces the man-hours, coat, time, and accessibility. (Figure-12C)

4. Carving the Land:

This phase announces the process of being on-water. Carving the ground is about taking out the land and soil around the vertical structure and over the massive horizontal structure, which is the basement. This process has to start from the water-edge backward to the land to invite the water and let it surrounds and covers the structure to be on-water. The outcome is a floating vertical structure on-water yet connected to the land through the massive basement. (Figure-12D)

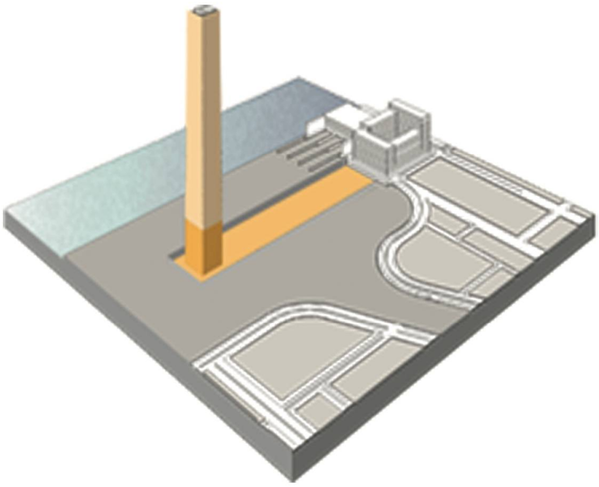

Figure-12C

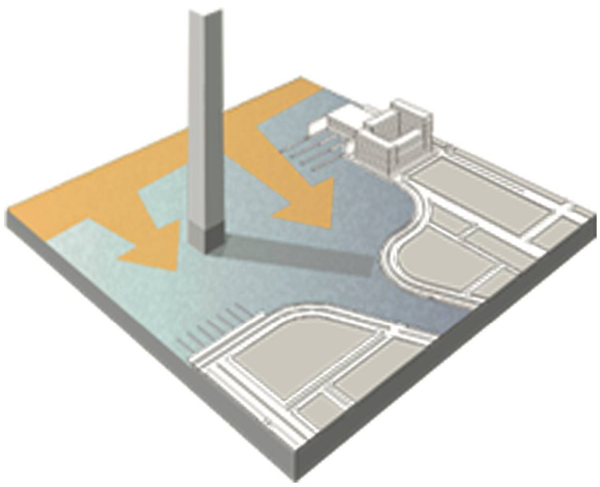

Figure-12D

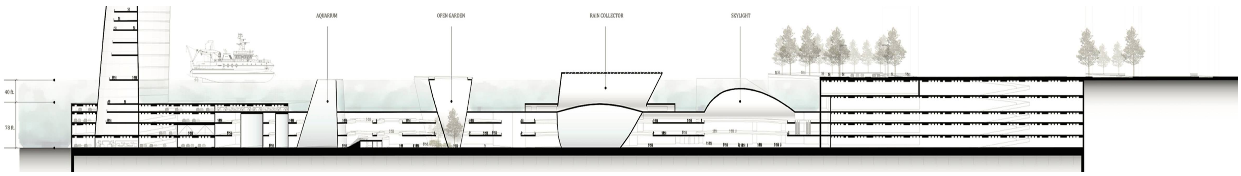

Figure-13: Longitudinal Section of the Proposed Construction Process, Horizontal Massive Structure.

The proposed construction technique of building-on-water is actually a construction system on land, simply like any other construction process, land excavation, foundations, then vertical structure. The massive horizontal structure is the basement is the element that integrates the vertical structure system within the land, yet maintaining the exact characteristics of being-on-water. Therefore, the concluding excessive phase of the suggested construction technique is the phase that defined the building-on-water process, carving the land and inviting the water to the site, to be recognized as a vertical structure floating on water. (Figure-13)

The advantages of this construction method are:

1. Cost Reduction: On-water construction machineries and equipment are substituted by on-land construction equipment and machineries.
2. Accessibility: accessing the site and transporting material will be through land not through ships or water.
3. Man-hours: Building-on-water demands a tremendous number of workers and laborers to work on-land and on-water. the proposed technique reduces the number of laborers by limiting the work efforts to on-land field only.
4. Utilization of Public-Private Usage of Zones: One of the main arguments facing the on-water-buildings is limiting the zone to private usage. The proposed construction method is about utilizing the waterfront to be used as a public zone and not only limited to the on-water-buildings.

Conclusion

The approach of building-on-water is a behavior developed to recognize the uniqueness of waterfront cities. It is a concept transformed into theory, and implemented as a technique. Regardless of the concerns, matters, challenges and consequences accompanied with the building-on-water concept, waterfront cities are persisting the celebration of water through architecture and urban design.

Jeddah is one of the leading cities in adapting the concept of building-on-water. The approach is implemented toward the city character and vision in celebrating water, which is one of the main reasons led to develop the approach of building-on-water.

The dominated building-on-water methods have proven their success achieving the desire of creating icons and celebrate water all over the world; however, they have not overcome the resultant side-effects. Therefore, developing construction-on-water methods to resolve the cost, regulations, structure, constructability, and transportation issues is the key of success for this approach.

The construction proposal of building-on-land and carving the ground to invite the water is a backward process of being on-water first by building an island, then constructing the building. The bottom line of all construction-on-water methods is to be on-water. The construction process, on the other hand, is the turning point to resolve the encountered issues. Thus, the proposal of carving the land to invite water is an alternative of integrating architecture, land, and water to be recognized as a building-on-water characterized by building-on-land.

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