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A Case Study on the Construction of Dubai's Palm Jumeirah

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A B S T R A C T

The aim of this report is to introduce the conception of mega project called Palm Jumeirah. This island is shaped like a palm tree, capped by a crescent. The Palm Jumeirah is an artificial island located in Dubai, United Arab Emirates, which was created through the process of land reclamation. The idea for its construction was developed during an economic collapse in Dubai following financial problems and slowing property markets. Aiming to the increased tourism and luxury lifestyle of the city, the creation of the Palm Jumeirah began in June 2001. The land reclamation started in the same year. It was designed largely to combat the problem of limited development space, especially beachfront properties. The palm shape of the island was decided on as it provided significant beachfront area, while remaining culturally relevant and symbolic. The crescent shape over it is the breakwater, constructed for the protection of the structure. The Palm Jumeirah is part of a larger series of developments called the Palm Islands, including Palm Jebel Ali and Palm Deira, which, when completed, will together increase Dubai's shoreline by a total of 520 kilometres, thereby increasing beaches in the city of Dubai. These islands are a new step to mankind to develop land on water and find more resources, especially land for the increasing population. This report emphasizes the risks during the execution of this project. It will also analyze the mega project, discussing the ways in which it was planned, implemented, created, the problems it had to face with and the future consequences of it.

Keywords: Land reclamation, Breakwater, Coastline extension, Risks, Planning, Implementation and Consequences.

1. Introduction

Dubai - a bustling cosmopolitan city and the home to 2.1 million people, is located in the United Arab Emirates (UAE). In the last couple of decades, Dubai's oil industry has fueled massive growth and change in the city. Dubai is one of the wealthiest places in the world with luxury that offers unmatched extravagance. The oil industry is almost entirely responsible for keeping the country afloat, generating a significant portion of its revenue. Due to the widespread reliance on oil in the nation, the economy is predicted to suffer greatly once oil runs out. The crown prince of Dubai – Shiekh Muhammad came up with an idea to save his country. He aimed to turn Dubai into a world class luxury and holiday resort. Dubai experiences sunshine year-round. It attracts five million tourists annually, but the prince wanted more than fifteen million. The coastline of Dubai is only 72 kilometers, which is not enough to accommodate 15 million tourists. A plan was devised to build an artificial palm tree-shaped island off the coast of Dubai which would increase the coastline hence increasing the number of beaches. The idea of the Palm Jumeirah was first dreamt up in the 1990s as a means of adding more land to the country's development space. The Palm Jumeirah is an artificial island in Dubai, United Arab Emirates on which major residential and commercial infrastructure is constructed. The island is in the shape of a palm tree, topped with a crescent shaped structure, having many luxury hotels, exclusive residential beach side villas, extravagant apartments, marinas, water theme parks, restaurants, shopping malls, sports facilities, health spas, residential, leisure, recreational and entertainment centres. It consists of a 1.5km long main trunk and 17 fronds, providing a large portion of residential and commercial space. The fronds contain a variety of beachfront villas, while the trunk contains hotels, apartments, condos, shopping malls and other commercial properties. The breakwater contains a mix of luxury hotels, resorts, condos and villas. This island is a new step to mankind in developing land on water and finding extra resources for the increasing population. The main advantage would be the expansion of the livable area.

2. Construction Process

The Palm Jumeirah - covering 560 hectares, has taken up 5 square kilometres and adds 78.6 kilometers to the country's existing coastline. It was a marvel of modern construction engineering, but the project did not come without challenges. Building the island required maintaining a delicate balance between the needs of nature and the needs of the city, all within set deadlines. The Island was to be made of natural materials namely rock and sand. An immense amount i.e. 94 million cu.m. of sand and 5.5 million cu.m. of rock was used which was to be placed in precisely the right location. Sand and rocks were collected from 16 quarries across United Arab Emirates and 6 nautical miles out in the gulf sea bed. The sand had to be coarse, dense and resistant to wave impact. Some of the machinery used was Barges - a long flat-bottomed boat; float boats, Tugboats - used for towing larger boats and ships, Dredges- an apparatus to scoop mud, Vibro-compactors, Heavy land based machines like cranes, bulldozers, etc. The entire construction process was essentially divided into three phases.

- Phase 1 : Construction of Breakwater
- Phase 2 : Construction of Palm Island
- Phase 3 : Infrastructural Development on the Island

In a span of 2 years, the whole city was built. It can sustain a population of at least 220,000. There was an extensive review of the studies conducted from years of research, trial and errors, survey, assessment and analysis which helped in forming the backbone of this project. Now that the Palm Jumeirah has been built, experts hope that it will inspire other similar projects throughout Dubai and the rest of the world. The knowledge of what is needed to build an artificial island and preventing it from washing away could help in determining more efficient and effective construction methods. Knowing how to quantify and eliminate the post-construction impacts, will pave the way for improvising future designs. With advances in engineering, ambitious projects such as the Palm Jumeirah can continue to grow and evolve.

2.1. Land Reclamation

Land reclamation is a technique used to create new land from existing water bodies, typically, but not always, coastal. The land reclaimed in this way is known as reclaimed ground or landfill. Land reclamation projects can create new space for development and infrastructure. Human activities necessitated the creation of new land for agriculture and production of food before industrialization. In South China, farmers reclaimed paddy fields by enclosing an area with a stone wall on the sea shore near river mouth or river delta. The species of rice that grow on these grounds are more salt tolerant. Fish ponds are a great example of land reclamation. In cities with heavy population, fish ponds are an efficient use of small, compact spaces. They also offer very good pre-processed food in the form of fish, insects, and plants. These ponds are gentle on the environment and help give farmers extra produce. Note that other countries have re-enacted land reclamation on smaller scales, but there had never been an attempt to reclaim land this large.

2.2. Breakwater

The main purpose of the breakwater is to protect the beaches of the island against the incursion of waves. The breakwater of Palm Jumeirah has a width of 200 meters in cross section and a length of 11 kilometers. To build it, the lowest layer consisted of sand and rocks weighing up to one ton in weight were placed on top of it followed by two more layers of rocks weighing 6 tons each. This layer of sand was 7.4 meters thick. The huge rocks of irregular shape and size are interlocked among themselves providing rigidity to the wall and are about 7 meters in height. Furthermore, there are two large openings, each 328 feet wide, on either sides of the breakwater for water circulation in order to eliminate stagnation in the 16 narrow channels between the 17 fronds. The water renewal time is the time taken for complete turnover of all the water in a waterbody. Water renewal time in this case is estimated to be around 13 days. By having water circulate around the fronds and open sea, marine life will be supported. It also aids in supply of oxygen and the pollution removal. Tidal flows around the crescent are crucial to prevent water stagnation. A retaining wall was built in between the crescent and the fronds and a layer of rock was placed in front of it to reduce the quantity of overtopping water. In an attempt to create a natural reef, this was created from mountain blasted rock instead of concrete slabs which is expensive and also difficult to source. “That is 550ha of artificial reef which will have marine life. Since its completion, the diversity of life is amazing; a whole host of different fish species have returned to the area and a pod of dolphins has even paid regular visits”, said Chris O'Donnell, the CEO of Nakheel.

3. Challenges

Sand doesn't tend to hold together well, so an island made out of sand would need to be anchored in place somehow. The most worrying problem was how to keep the sand from washing away. This problem was very tricky because many factors had to be taken into account, including the strength of the storms, height of the waves and tides etc. Hence, a crescent shaped breakwater structure was designed, to protect the fronds from storms and waves of high intensity. The islands would be made of an insane amount of terraformed sand sourced from the 3 nearby arid sea beds, (60 nautical miles out of sea in the gulf) whereas the breakwater made of mostly rock and sand, with more rock than sand. There were some challenges with dumping this sand layer that had to be addressed, such as the fact that it would be done when the sea was at its calmest for ensuring stability. Then, some huge rocks were placed

atop the already existing sand layer to raise the structure above the sea level. The crescent was raised from approximately 4 meters below to approximately 4 meters above the sea. Local quarries supplied the rock, which was then transported to the site on barges and put in place by heavy equipment. In just a matter of hours, the rocks were immediately shipped to the construction site, aboard barges. 40,000 tons of rock per day was being placed to construct the structure as quickly as possible. The rocks were placed with great finesse, so as to ensure the interlocking with adjacent rocks. Once the rocks had been placed, finding the right type of sand for the construction of fronds was the abutting challenge. While the UAE has an abundant supply of desert sand, it was determined to not be suitable for the project as it was too fine and flaky. The sand was taken from the sea and used for construction, not from Dubai deserts. This is because the sand from the sea is more environmentally friendly and sustainable, more stable in terms of seismic and geotechnical terms and has the fertile, organic content that allows marine life to grow. The sand was sprayed using dredging ships at very high speeds of around 10m/s in an arc shape, allowing the sand to reach areas where the ships couldn't physically manoeuvre. This process is known as "rainbowing". Because the curve of The Palm's shape was so complex, it made it difficult to place the sand precisely in the desired areas. This was a problem because there were no fixed points of land to survey from, so they needed something else for locating the precise positions of where the sand needed to be placed. With DGPS (Differential Global Positioning System), the engineers could accurately verify their placement, to an accuracy of 1 centi-metre. The method in which this was done is, five men carry the gadgets on their backs as they walk around the island. The system locates the five men via GPS, and once they are located, it measures the precise height and position of the deposited sand. The engineers rely on the coordinates of these anchor points to determine exactly where they need to make additional deposits. Once the sand was placed, it was essential to compact or settle it before building on it. This is typically a natural phenomenon, which, in reality takes millions of years, but in this case, obviously it had to be done artificially. Vibro-compaction was used to compact the sand and to strengthen it into a firm base for construction.

4. Advantages of Palm Island

1. Tourism for the country increased, which added to its economy.
2. The engineers were able to build a structure that was free from concrete construction. This is beneficial to the environment because it is eco-friendly and attracts various new marine life.
3. The invention of land reclamation solved the problem of where to build near sea shore areas.
4. The structure can provide extra land for the construction of villas, flats, parks, shopping malls, and other facilities.
5. It improves the visual appeal of the shoreline.

The success of The Palm Jumeirah was the first step in developing sustainable islands and a new approach to mankind. The world population is increasing by about 83 million people per year. And that has led to concerns as to how the next generations will be able to sustain themselves. This project proves that land reclamation is now possible and that area can be used for housing.

5. Consequences

It will take years to fully understand what influences the Palm Jumeirah has had. The impacts of the construction of the Palm Jumeirah can be observed now, with the construction being complete. Areas of particular interest are how the island itself will be affected along with the surrounding geography and the ecosystem. Carrying out an assessment and analysis of the project at the end can help improve processes and methodologies and lead to a better work in future similar projects. The island has settled very slightly, but continues to be within the scope of the reasonable limit, and it is a normal process. The island is expected to settle by about 25mm over the next 100 years, and will not have much impact on development. The construction of Palm Jumeirah has brought land to the areas where there previously was none, increasing the rate of erosion. Water flow and wave action are significant causes of the erosion process. As a result of this, filters and particle nets have been installed in various number of areas on the island. This alone won't be sufficient and the land must be periodically nourished, which means adding sediment back to eroded areas. Before the Palm Jumeirah was built, water flowed along the original coastline along Dubai. Since construction of the island, water flow properties have changed, and the water is required to travel from the shoreline, around the outside of the island, and back to the shoreline. These changes are just beginning to be seen, and researchers have suggested that shorelines will continue changing for the next several years. The island has caused the beach to change shape, with erosion occurring in some areas and deposition occurring in others. Some areas have already begun to show the effect of this change but countermeasures are being taken to replenish the beaches. Compared to the other land reclamation projects being constructed in Dubai, Palm Jumeirah is small. Construction continues on two other islands, Palm Jebel Ali and Palm Deira, they have not yet been completed. So, the future consequences of these of these projects are yet to be known. Though similar to Palm Jumeirah, The effects will be undoubtedly on a much larger scale. It's important that the people who run the other projects learn from the Palm Jumeirah and try to come up with new ideas and innovations that ideally will have fewer impacts on the environment and ecosystem.

6. Conclusion

The Palm Jumeirah was one of several projects in Dubai that were planned to enhance its image as a tourist destination. The Palm Jumeirah also solved

Dubai's problem of being short of beachfront and has added 78.6 kilometers to the existing coastline. The essence of the project is its design – its palm shape, which dictated every step of its development. The palm represents Dubai's heritage as palm trees are locally known as the 'bride of the orchard'.

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