PROTOTYPE
FACULTY OF ENGINEERING AND APPLIED SCIENCE
Journal of Undergraduate Engineering Research and Scholarship

PT-2013: Coastal and Ocean Engineering ENGI.8751 Undergraduate Student Forum
Faculty of Engineering and Applied Science, Memorial University, St. John's, NL, Canada March, 2013

Paper Code. (PT-2013 - Gibling)

Construction Process and Post-Construction Impacts of the Palm Jumeirah in Dubai, United Arab Emirates

Colin Gibling
Memorial University
St. John's, NL
c.gibling@mun.ca

ABSTRACT

The Palm Jumeirah is an artificial island located in Dubai, United Arab Emirates, created through the process of land reclamation. It was developed during an economic boom in Dubai, catering to the increased tourism and luxury living requirements of the city. Design of the Palm Jumeirah started in 2001 and construction has since been completed. Two other islands, the Palm Jebel Ali and the Palm Deira, are still under construction, and are on hold indefinitely following recent financial problems and slowing property markets in Dubai.

The Palm Jumeirah 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. Extensive dredging and land reclamation was required to build the two sections: the outer breakwater and the inner palm shape. Throughout the reclamation process, geographical surveys were completed to ensure that the island was being shaped correctly and built up to the designed elevation. After reclamation was complete, vibrocompaction was used to compact and strengthen the sand, making it a suitable base for construction.

With construction completed, the impacts of the Palm Jumeirah can be observed. Specific areas of interest are the impacts on the island itself, the surrounding geography and the ecosystem. Analysing these areas can give an indication of the success of the project, and be used to develop improved methods of design and construction for similar projects in the future.

The Palm Jumeirah is one of the largest artificial islands in the world, and is a significant coastal engineering feat. Such a large-scale project is accompanied with enormous challenges and requirements. This paper provides a background on the project, describes the challenges presented in construction, and analyses post-construction impacts and future considerations.

1 INTRODUCTION

1.1 Historical Overview of Dubai

Dubai is a city of approximately 2.1 million people located in the United Arab Emirates, a country in the Arabian Peninsula on the Persian Gulf. Traditionally a strategically located port and trading hub, Dubai experienced massive growth and change in the second half of the 20th century as a result of it's oil industry. The bustling economy and desire to grow led the city to become one of the world's top financial, real-estate and tourism centres, and has resulted in the some of the most ambitious development projects in the world, such as the world's tallest skyscraper, numerous shopping centres, amusement parks, hotels, and artificial islands. The first of these artificial islands, the Palm Jumeirah, began construction in 2001, and started seeing residents in 2006. The location of the Palm Jumeirah can be seen in Figure 1. Two other palm shaped islands, the Palm Jebel Ali and the Palm Deira, as well as the world map shaped World Islands, are still under construction and are indefinitely delayed following recent financial crises.

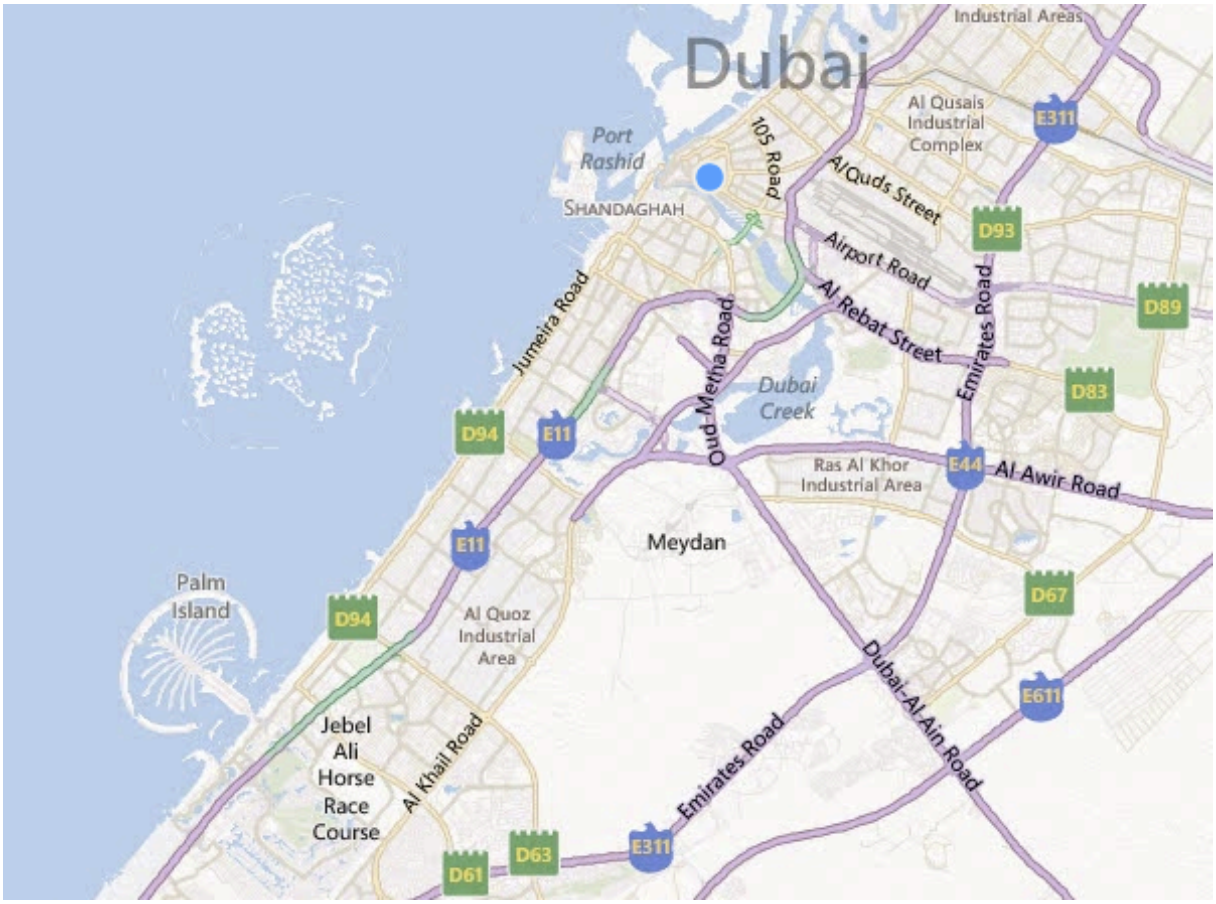

Figure 1: Map of Dubai showing the location of the Palm Jumeirah in the bottom left

1.2 Design Concept

The Palm Jumeirah was first envisioned in the 1990's as a luxury residential and commercial area, a tourist destination, and a means of providing Dubai with more development space. The unique palm shape is culturally relevant and symbolic to the region, and provides a significant amount of beachfront property by adding 78.6 km to the city's current 72 km. The island consists of two main regions: the breakwater and the palm (see Figure 2). The breakwater forms a circular arc that acts as a barrier to the sea, protecting the inner palm from potentially harmful wave action and water flow. The palm consists of a 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 [1].

Figure 2: Rendering of the Palm Jumeirah

2 CONSTRUCTION PROCESS AND CHALLENGES

The construction process for the Palm Jumeirah began in August 2001 with initial scientific studies and surveys. Dutch reclamation experts were hired to consult on the project as much of the land in the Netherlands has also been reclaimed from the sea. Construction started with the 11.5km long breakwater. The breakwater consists of three layers: an initial layer of sand built up 7.5m from the sea floor, a second layer of rock that reaches 3m above sea level, and a final layer of armour stone on top, with individual stones weighing up to 6 tons. Although the UAE has a vast supply of desert sand, it could not be used on the project as it is considered too fine and unsuitable for construction use. Sand was dredged from the sea floor 6 nautical miles out from shore and transported to the project location. Rock was blasted from local quarries, brought to site on barges, and put in place by heavy equipment.

With no visual means of determining where material should be placed, global positioning systems (GPS) were used to provide accurate deposit locations.

With the breakwater partially built and providing some protection, construction of the palm could begin and the two regions could be constructed simultaneously. The palm consists mainly of sand—the same as what was used in the breakwater. In order to deposit the sand above sea level, a process known as "rainbowing" was used. As seen in Figure 3, dredgers pumped the sand and sprayed it into the air in an arc shape, allowing the sand to reach areas where the ships could not physically manoeuvre. In total, 94 million cubic metres of sand and 5.5 million cubic metres of rock were used in the construction of the Palm Jumeirah [2]. With more and more land coming to the surface, it was necessary to monitor the shape of the island to ensure every section was the right shape and elevation. Workers would traverse the newly formed land with handheld GPS devices and take measurements, noting any discrepancies with the designed layout.

Figure 3: Rainbowing

As the land reclamation neared completion, an issue started to become apparent: the water within the breakwater was not circulating as expected, leaving areas in and around the fronds that were becoming stagnant. The breakwater had to be redesigned to have two openings to the sea, allowing the water to enter and circulate. This proved to be successful, and the improved circulation meant that water within the breakwater would be completely flushed out within fourteen days.

By October 2003, the land reclamation process had been completed, and the next phase of the project could begin: the construction of an entire city supported by a man-made island. Geophysical testing showed that the sand used could not yet support the massive amount of buildings and infrastructure that had been planned, and that the sand would need to be compacted in order to provide a stable base for construction. As an additional hazard, Dubai is located near an earthquake zone. If an earthquake were to occur, the sand could undergo a process known as liquefaction, where the sand

settles and fills in any available gaps. Water is pushed out and up, essentially sinking the island. To counter this, the sand underwent a process known as vibrocompaction, where vibrations from a probe cause the sand to rearrange into more dense configurations, reducing the possibility of future settlement. Over 200,000 locations were vibrocompacted, preparing the island for the numerous buidlings, roads, utilities and other infrastructure developments that were to come [3].

3 POST-CONSTRUCTION IMPACTS

3.1 Palm Jumeirah

A concern brought up early in the design of the Palm Jumeirah was the possibility of settlement, and the use of sand as a construction base. If not prepared properly, sand has the potential to settle several centimetres or more, which could lead to future issues with the infrastructure that was built on top of it. Despite the extensive vibrocompaction process completed prior to the construction of buildings and infrastructure on the island, it has been reported that the island is slowly sinking. These claims were issued as a result of a geological survey completed in 2009, which produced a settlement value of 5mm. The developer of the island, Nakheel, has since issued a statement advising that while the island has settled slightly, it is well within a reasonable limit, and that the island is going through a natural process. The island is expected to settle 25mm over the course of 100 years, and should not have any significant impact on the development [4]. When designing the island, the engineers also factored in a possible sea level rise of 50cm due to climate change, and adverse conditions such as storm surges and high winds.

Another issue comes from the fact that development of the Palm Jumeirah introduced new land to an area where there previously was none. The environment naturally wants to return to its previous state, and therefore, erosion of the new land can be expected to be greater than if the land had already been a naturally existing feature. Because of this, filters and particle nets have been installed in several areas on the island. In areas where this is not enough, the land must undergo periodic nourishment, where sediment is reintroduced to eroded areas. A significant cause of the erosion on the island is the flow of water and the wave action.. This has been proven to have a negative impact on more than just the Palm Jumeirah, and will be discussed in the next section.

3.2 Surrounding Geography

Prior to the construction of the Palm Jumeirah, coastal water flow and wave conditions followed its natural movement, 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. This change is beginning to show its impacts, and researchers are suggesting that erosion and shoreline patterns will be modified over the next several decades [5]. Figures 4.a) and 4.b) show an area of the shoreline just to the northeast of the location of the Palm Jumeirah. They are modelled after a period of 20 years, both with the Palm Jumeirah in place, and without. The presence of the island results in a noticeable alteration in the shape of the beach, with significant erosion in some areas and significant deposition in other areas.

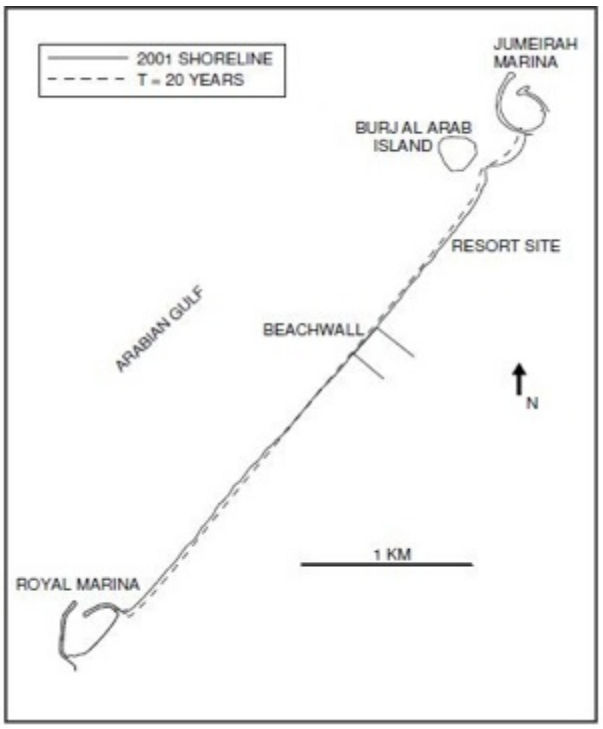

Figure 4.a)

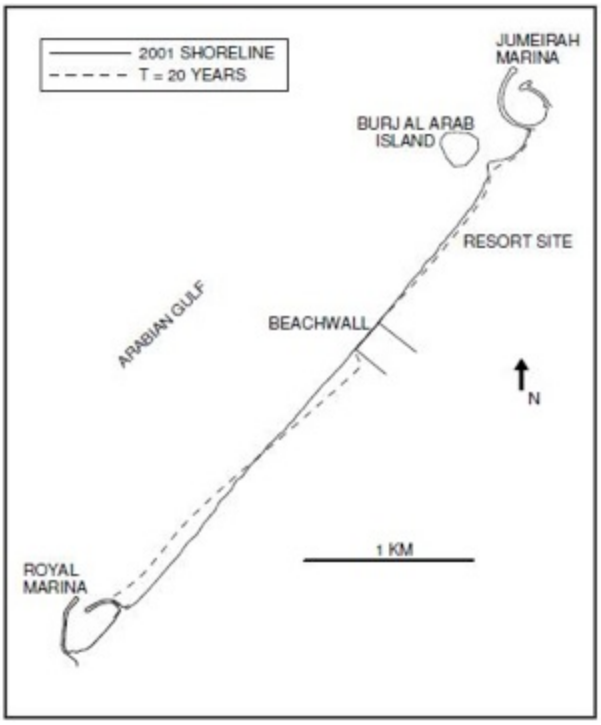

Figure 4.b)

Figure 4.a): Predicted shoreline evolution after 20 years without the Palm Jumeirah
Figure 4.b): Predicted shoreline evolution after 20 years with the Palm Jumeirah

Evidence of this type of change is already visible in some areas, and has been counteracted by resurfacing and nourishment of the beaches. It is currently unknown how this development may affect the shoreline further up the coast of the UAE, or in other countries within the gulf. It should be recognised that the Palm Jumeirah is relatively small compared to the other land reclamation projects being constructed. The environmental impacts of the collection of mega projects along the coast of Dubai will undoubtedly be greater than the Palm Jumeirah alone, and this is an area that extensive research should be committed to. The developers of the other projects should apply what they learn from the Palm Jumeirah and try to come up with building solutions that have less impact on the surrounding environment. If not, they will likely need to deal with erosion and shoreline changes in much the same way as the Palm Jumeirah, except at a much larger scale.

3.3 Ecosystem

Among the biggest concerns with the construction of the Palm Jumeirah is the impact on organic life in the area. The process of dredging and land reclamation has deposited and scattered silt into the normally crystal clear waters, burying coral reefs, oyster beds and sea grass in as much as two inches of sediment [6]. These organisms play an important role in the ecosystem, providing food and shelter to a wide range of marine species, protecting coastal regions from storms, and preventing coastal erosion. As well, they help support commercial fishing and recreation activities, such as scuba diving and sport fishing.

The developer, Nakheel, has responded to the reported damages to the ecosystem. They state that the channels between the fronds of the palm island appear to be an ideal habitat for sea grass, and the breakwater of the island is in itself, a rocky reef that is attracting a diverse number of marine species.

They are also creating artificial reefs by sinking objects onto the sea floor. The objects include, among other things, two F-86 jets, a passenger airplane and a London bus [7]. As seen in Figure 5, placing these objects on the sea floor creates habitats for coral and other marine life, while at the same time creating areas that will be popular for tourist and recreation activities.

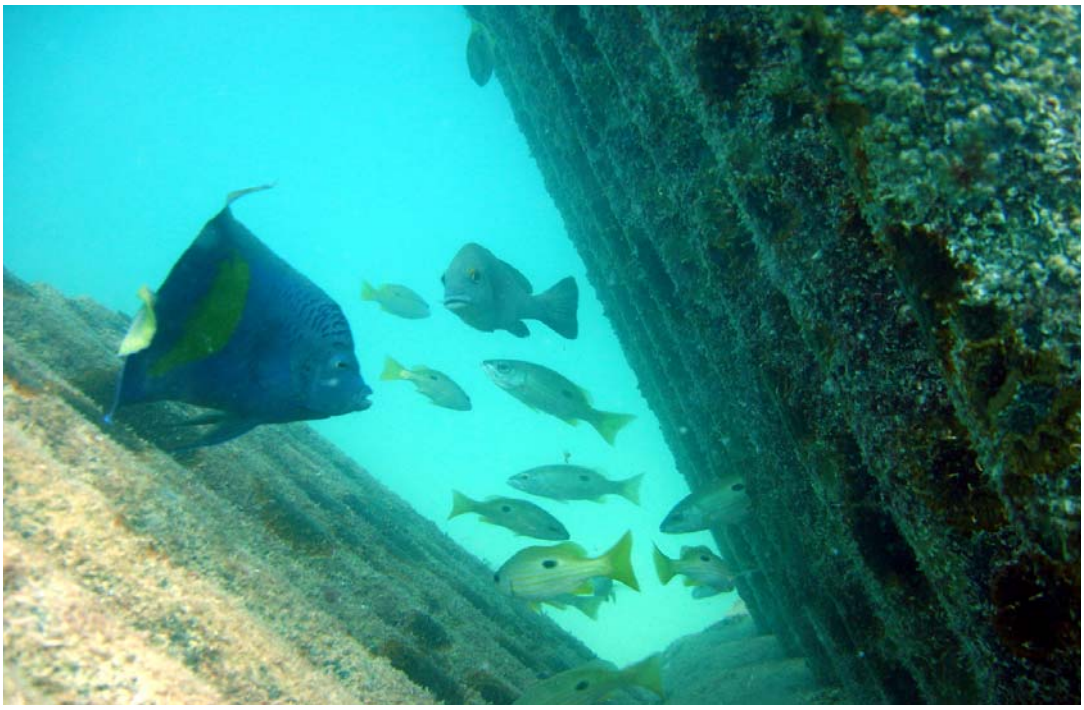

Figure 5: Marine life attracted to an artificial reef near the Palm Jumeirah

In addition, they have hired researchers and marine biologists to monitor and rehabilitate the existing damaged reefs. However, with the continued construction the Palm Jumeirah, the two other palm islands, and the World Islands, the problem of dispersed sediment in the marine habitat may not be resolved any time in the near future. It is hard to tell what kind of permanent impact this may have on the ecosystem, as well as the tourism, sport and recreation industry that uses it.

4 CONCLUSION

Building an artificial island in the Arabian Sea would seem like an overly ambitious dream to most, but for one of the wealthiest countries in the world, it was one of several ambitious projects that have come to make the country one of the top luxury and tourist destinations in the world. The construction of the Palm Jumeirah was a feat of engineering, but did not come without its challenges. An immense amount of sand and stone was used, and it all had to be placed in precisely the right location. The island was designed to withstand both the forces of nature and the forces of the city being built on top of it, all within a strict deadline.

With construction of the island complete, the post construction impacts can be observed. Of particular interest are the impacts on the island, the surrounding geography and the ecosystem. It has been speculated that the island is sinking—a claim debated by the developer and explained as being a

natural settling process that will not have any long term negative effects. The island is, however, being eroded, and is causing increased erosion of the surrounding geography. It has also disrupted or destroyed parts of a naturally occurring ecosystem, and will likely continue to do so until all of the land reclamation projects are complete. The developer is taking steps to remediate these issues, and in some cases, improve them to a level beyond what was seen before the island was built.

The Palm Jumeirah is an impressive project, and should now act as a tool for other similar projects in Dubai and the rest of the world. Knowing the challenges of building an artificial island can be helpful in figuring out more efficient and effective construction methods. Knowing the post-construction impacts will give rise to future designs and methods that help reduce these types of impacts. With these ideals in mind, ambitious projects like the Palm Jumeirah can continue to grow and evolve, producing even greater feats of engineering.

REFERENCES

[1] "The Palm Jumeirah", http://www.dubai-architecture.info/DUB-033.htm

[2] "The Palm, United Arab Emirates", http://www.designbuild-network.com/projects/palm-jumeirah

[3] Mega Structures, "Impossible Island: Dubai Palm Island", 2005

[4] B. Hope, "Palm is not sinking, says Nakheel", 2009, http://www.thenational.ae/business/property/palm-is-not-sinking-says-nakheel

[5] "The Impact of the Palm Islands, United Arab Emirates", https://sites.google.com/site/palmislandsimpact

[6] C. Hopkins, "Dubai Pilot Project: Test Report for 'Reef Systems' at the Palm Jumeirah", AquaMarine Advisors, Sweden, 2007

[7] B. Salahuddin, "The Marine Environmental Impacts of Artificial Island Construction", Duke University, 2006