ISSN XXXX XXXX © 2019 IJESC

Research Article Volume 9 Issue No.3

Artificial Islands

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Abstract:
An **artificial island** is an island that has been man-made rather than formed by natural means. They are created by expanding existing islets, construction on existing reefs, or amalgamating several natural islets into a bigger island. Early artificial islands can be floating structures in still waters, or wooden or megalithic structures erected in shallow waters. In modern times artificial islands are usually formed by land reclamation, but some are formed by the incidental isolation of an existing piece of land during canal construction, or flooding of valleys resulting in the tops of former knolls getting isolated by water.

Key words: Artificial Island, construction methods.

1. INTRODUCTION

An **artificial island** is an island that has been man-made rather than formed by natural means. They are created by expanding existing islets, construction on existing reefs, or amalgamating several natural islets into a bigger island. Early artificial islands can be floating structures in still waters, or wooden or megalithic structures erected in shallow waters. In modern times artificial islands are usually formed by land reclamation, but some are formed by the incidental isolation of an existing piece of land during canal construction, or flooding of valleys resulting in the tops of former knolls getting isolated by water. Some contemporary projects are much more ambitious. Kansai International Airport is the first airport to be built completely on an artificial island in 1994. Dubai is home to some of the largest artificial island complexes in the world, including the three Palm Islands projects, The World and the Dubai Waterfront, the last of which will be the largest in scale. The Israeli government is now planning for 4 artificial islands, of the coasts of Tel Aviv, Herzliya, Netanya and Haifa. Each island will house some 20,000 people and bring in 10,000 jobs.

Figure.1.1. Kansai International Airport

Figure.1.2. the World (Dubai)

Figure.1.3. Khazar islands

Figure.1.4. Kawasaki island

Figure.1.5. Hong Kong international Airport

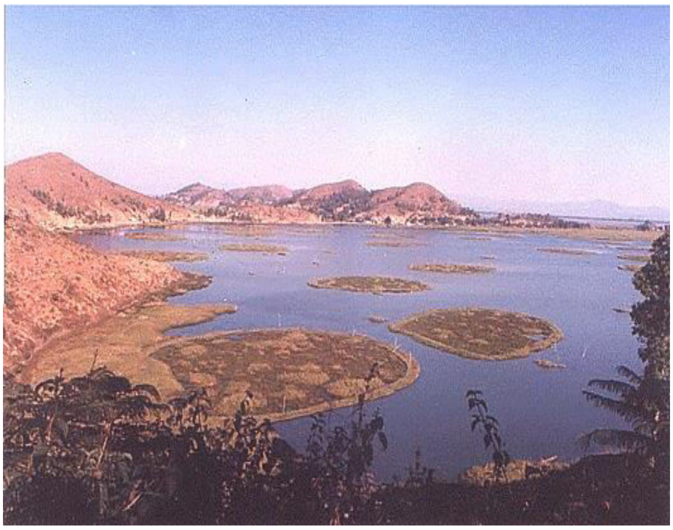


Figure.1.6. Loktak Lake

2. METHODS AND MATERIALS TO CONSTRUCT AN ARTIFICIAL ISLAND

2.1Dumping Method:

The easiest (and simplest) method is to import large quantities of rocks and soil into a shallow pool of water until the hill it forms breaks the surface. This method gives a solid foundation but this is expensive and cannot be moved.

2.2 General Floating Island:

Floating islands are generally made of bundled reeds, and the best known examples are those of the Uros people of Lake Titicaca, Peru, who build their villages upon what are in effect huge rafts of bundled totora reeds.

Figure.2.1. Lake Titicaca, Uros

2.3 Seacrete Method:

Utilizing electricity to cause minerals to be deposited onto a mesh of conductive wire. Over time it will form a substance similar in strength to concrete. By using a low current and a metal mesh you can cause minerals to be deposited on the mesh. Rate of deposition is limited by current used, flow rate of water and many other variables. This is a fairly green technique as the only resources it requires that is not easy to provide from a renewable source is the mesh. Although, perhaps it is feasible to recycle scrap metal. Of course, the energy to produce the electricity must also be considered and this will require resources.

2.4 Pikecrete/Pykrete Method:

Pikecrete is a compound invented by a British scientist named Geoffrey Pyke working under Lord Mountbatten during the Second World War. It consists of ice with 14% sawdust or wood pulp and 86% water mixed into slurry and frozen. Serve as an extremely strong island material, it has the same strength as concrete but it floats. It can be used to hold a foundation until a permanent location is found. Alternately, if you would like to roam, just make a mold of a vessel and then pour it onto the mold with a flat top as a foundation. It could also potentially serve as a boxing fence to pour in dirt or sand to form an island. At present pikecrete/pykerete is not considered relevant by most scientists. Pykrete is generally only used for glacial reconstruction.

2.5 Volcano Method:

Many islands have been formed as the result of undersea volcanic activity-the Hawaiian Islands are an example. A volcano is simply a point where the molten rock has squeezed through a fissure leading to the surface of the earth. If an appropriate point can be found where a volcano can be stimulated by drilling or placement of explosive on the ocean floor, a subsequent eruption may form a cone of lava that reaches above the surface of the water.

2.6 Concrete:

Concrete is not a particularly green material. Every ton of concrete releases two tons of carbon dioxide during production and curing. However it is fairly cheap to construct using concrete and the techniques are well known.

2.7 Steel and other metals:
Steel hulls have some great benefits. It's readily available all over the globe, it's not prone to marine borers, it is quite cheap once you come up to a certain scale (some where around 7 meters in diameter for a circular island). But it certainly has some backsides as well. Since sea water is inherently eroding on almost all metals, the steel has to be protected in some way. The obvious solution to the layman is of course different kinds of paints and varnishes. As one intuitivly understands, this not an ecological way, and since it usually demands some re-applying every now and then you might have to see to that your island is capable of being dry docked. Another alternative of conservation, or more correct, for delaying the erosion, is using anodes. The two methods can be combined.

2.8 Plastics and ceramics:
The word **ceramic** is derived from the Greek word (*keramos*). The term covers inorganic non metallic materials which are formed by the action of heat. Up until the 1950s or so, the most important of these were the traditional clays, made into pottery, bricks, tiles and the like, along with cements and glass. Clay-based ceramics are described in the article on pottery. A composite material of ceramic and metal is known as cermets. The word *ceramic* can be an adjective, and can also be used as a noun to refer to a ceramic material, or a product of ceramic manufacture. *Ceramics* may also be used as a singular noun referring to the art of making things out of ceramic materials. The technology of manufacturing and usage of ceramic materials is part of the field of ceramic engineering. Many ceramic materials are hard, porous, and brittle. The study and development of ceramics includes methods to mitigate problems associated with these characteristics, and to accentuate the strengths of the materials as well as to investigate novel applications.

3. ARTIFICIAL ISLAND FACILITIES

Artificial Island consists of the following facilities:

- Water
- Food
- Power
- Communication

3.1 Water:
Purification of Sea Water:
Sea water can be processed to remove any dissolved salts to provide almost pure water. The simplest technique for doing this is simply to heat the water until it evaporates and then recon dense the water into a fresh water tank. As a by-product of this you will have a large quantity of salt.

3.2 Food:
If you do not live on the island permanently and have a main base on another land, it would be more practical to send routine supplies to the island rather than attempt any of the following.
Food Producing Plants
Freshwater Plants:
Plants are kept away from the saltwater when the island is of floating type. One solution is to plant these above the grounds. If the island has no native soil then it will be required to either import it or generate it from raw materials.
Saltwater Plants:
Edible marine plants include the seaweed kelp and the red alga carrageen an.
Fishing
Fish are the most available source of meat for an island. Although means of cooking them would be less readily acquired. Sushi is an alternative, combining farmed seawedd and raw fish. Shellfish can be gathered in large amounts by use of cages and traps.

3.3 Power:
OTEC Generators
OTEC is an acronym standing for Ocean Thermal Energy Conversion. It uses the difference in temperature between the cold water at depth and the much warmer water at the surface.
Wind Power
Off-shore the wind has few obstacles that cause turbulence; because of this the wind tends to blow slightly stronger. (Mention anchoring to seabed or floating platforms (and anchor problems) and economies of scale)
Advantage: 24 hours, except when no wind
Wave Power Generators
These types of generators that harness the energy created by sea-waves is, so far, too expensive and impractical for the average island-maker. Many of the various designs for the generator are still frustrated by the practical challenges of the sea, chiefly storm damage and saltwater corrosion. The salter's duck is one example of a wave based generation system.
Current turbines
There are many currents in the sea, the most obvious one to most people is the gulf stream. This flows year round at around 4 knots. A single turbine placed in this stream could produce significant amounts of power. It is unknown how much power we could remove from a current such as this before it may have an appreciable effect on the world. (Mention Betz theorem as related to wind and adjust to water as just another fluid dynamics problem).

3.4 Communication:
Communications can be split into two general areas, data and voice.
External Communications
Tying into the worldwide telephone network is not difficult even if out at sea. There are a number of satellite networks designed for just this purpose.
Internal communications
There are many options for this, the cheapest solution would be to leverage standard commercial hardware for the purpose. This boils down to 3 media types and a handful of standards. The media types are radio, fibre and cable. Each of these has advantages and disadvantages. Radio is very cheap to install but has problems with interference, range and lack of bandwidth. Cable, meaning Gigabit Ethernet in this case also has a range problem unless routers are used but has quite a lot of bandwidth and more can be added by just running an extra cable. Fibre is the most expensive to install but has fewer limits of range (few km for multi mode fibre and around 80km for single mode fibre) and has a lot of scope for upgrading bandwidth (WDM can be used to send multiple signals down a single pair).

4. A CASE STUDY: THE PALM ISLANDS IN DUBAI

The **Palm Islands** in Dubai are the three largest artificial islands in the world. They are being constructed by Nakheel Properties, a property developer in the United Arab Emirates, who hired the Dutch dredging and marine contractor Van Oord, one of the world's specialists in land reclamation. The islands are **The Palm Jumeirah**, **The Palm Jebel Ali** and **the Palm Deira.** The islands were commissioned by Sheikh Mohammed bin Rashid Al Maktoum in order to increase Dubai's tourism. Each settlement will be in the shape of a palm tree, topped with a crescent, and will have a large number of residential, leisure and entertainment centers. The Palm Islands are located off the coast of The United Arab Emirates in the Persian Gulf and will add 520 km of beaches to the city of Dubai. The creation of The Palm Jumeirah began in June 2001. Shortly after, The Palm Jebel Ali was announced and reclamation work began. In 2004, The Palm Deira, which will be almost as large in size as Paris, was announced. Palm Jumeirah is currently open for development. Construction will be completed over the next 5-10 years.

Figure.4.1. Map of Dubai showing the location of the Palm Jumeirah in the bottom left

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 island consists of two main regions: the breakwater and the palm (see Fig 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.

Figure. 4.2: Rendering of the Palm Jumeirah

5. 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. 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.

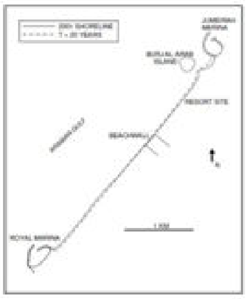
Figure.5.1. Rainbowing

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 vibro-compaction, 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 vibro-compacted, preparing the island for the numerous buidlings, roads, utilities and other infrastructure developments that were to come.

POST-CONSTRUCTION IMPACTS:

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 centimeters or more, which could lead to future issues with the infrastructure that was built on top of it. Despite the extensive vibro-compaction 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. 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.

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. 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.



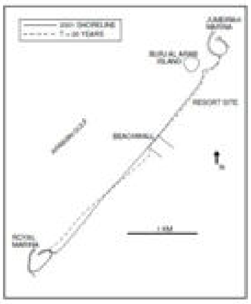


Figure 5.2 **Figure5.3**

Figure.5.2. Predicted shoreline evolution after 20 years without the Palm Jumeirah

Figure. 5.3. 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 recognized 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.

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. 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. As seen in Figure 5.4, 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.

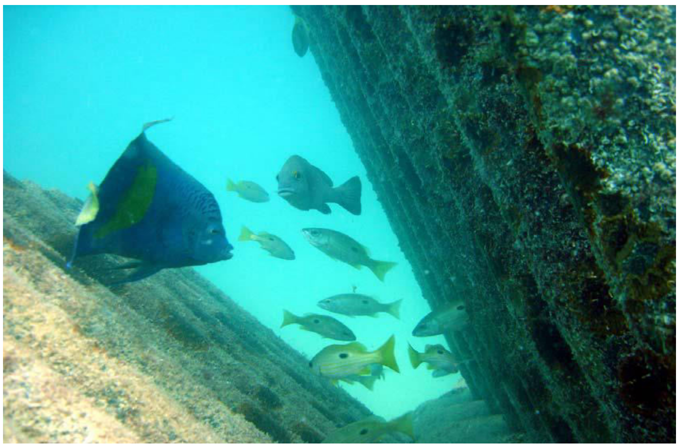


Figure. 5.4. Marine life attracted to an artificial reef near the Palm Jumeirah

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.

6. CONCLUSION:

Building an artificial island 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 an artificial island was a feat of engineering, but did not come without its challenges. With construction of the island complete, the post construction impacts can be observed. The island is, however, being eroded, and is causing increased erosion of the surrounding geography. It has also 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.

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