The Study on Construction of Artificial Island Using Land Reclamation Techniques

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Abstract: The advancement and development in construction field has changed the scenario of world today and an artificial island has been perfect example to represent infrastructural development at present time. An artificial island is landmark surrounded all sides by water which is constructed artificially by means of human manpower with uses of advance technologies and machineries. An artificial island is an application of various engineering concepts that has brought a drastic change on construction technology. This report incorporates the details about the construction process involved in artificial island like land reclamation, dredging, soil-bed preparation, underwater concreting with various challenges and advantages. Land Reclamation technique is the most crucial process used for construction of artificial island which means preparation of new land from oceans, river beds or lake beds. This report is all about procedures and impact analysis of land reclamation process on artificial island construction. This concept has been mostly used on developed countries like Qatar, Japan, etc and my main motive of studying about it is to grab depth knowledge about its construction technologies and requirement so that we can use it on India and many other countries to promote tourism industry as well as for geotechnical exploration.

Key Words: artificial island, land reclamation, underwater concreting, impact analysis

1. Introduction

An artificial island is man-made island constructed over sea, ocean or river beds. The construction of artificial island is done by land reclamation, expansion of existing islets, combining small group of islets and filling different materials over sea or an ocean bed. In ancient periods they were constructed over lakes by driving piles into lake beds but at present artificial islands are constructed using new technologies and land reclamation process is one of common technique. Till present dates, some of the artificial islands that exist are Kansai Airport (4km × 2.5 km) located in Osaka Bay, Japan and The Palms (50 km\textsuperscript{2}) located in Dubai.

The construction methodologies for artificial island using land reclamation techniques commonly involve three major procedures and with site conditions and requirements there may be some changes. These major three stages of artificial island construction are:

- Remediation of seabed
- Construction of sea defences (sea wall)
- Fill

Remediation of seabed consists of reforming the seabed in case of settlement problem. Remediation process varies from island to island due to different soil characteristics and geological features. For example different type of remediation process was used to stop settlement on artificial island construction of the Kansai International Airport located in Japan. Due to presence of Holocene clay layer in seabed, there was occurring differential settlement problem and it was reduced by help of sand drain method which artificially speed up the remediation process. The sand drain process helped to minimize settlement problem within one year else it would have taken a longer period (more than a decade).
As in figure above, the mean sea level is maintained lower than the reclaimed ground level during construction of artificial island by land reclamation techniques. The sea defences are the structures constructed in between reclaimed land and sea water. Sea defences are constructed in different forms using cassions, rubber mould and concrete armour elements. The process of construction of sea defence is done to provide protection to the reclaimed land. Sea defences used for artificial island construction are soft defence system, hard defence system and combined defence system. The main purpose for use of sea defences is to prevent different energy waves from entering into reclaimed area so that erosion related problems on island can be minimized. Filling is the main process of land reclamation for artificial islands. Fill includes all those materials like sand, soil, gravel and rocks that are used to construct the land over the sea bed.

2. Design considerations for artificial island construction

Before designing and commencement of artificial island construction on any site of sea beds or river beds we should collect various data and information. Some of major information we have to collect for design of artificial islands is listed below:

- Water depth
- Wave height ranges
- Ice conditions
- Tidal range
- Currents
- Foundation conditions
- Earthquake risk
- Source of materials
- Shipping lanes
- Existing pipelines and cables

So these are important information we should have knowledge of before designing any artificial island and on basis of these data our construction works are carried out. The construction of any structures in an island is a serious challenge due to presence of water currents, different tidal ranges, climatic variation sand earthquake; so before construction of island there should be maximum effort from every part to minimize effects of earthquake, wave currents, etc. e.g. Preparation of site by remediation of sea bed is essential to reduce the effects of earthquake on the island.

3. Land reclamation process and its advantages on artificial island construction

Land reclamation is the technique by which new land is formed or gained from sea beds or wetlands. The land reclamation process for artificial island construction is common method and is more preferable over breakwater construction and vibro-compaction methods. The land reclamation method involves many steps and basic knowledge of these steps is also included on this report.

3.1. Soil bed preparation: The preparation of soil bed on depth of ocean or sea for remediation of soil bed so that uniform settlement of soil bed will occur under different loading conditions is initial step for land reclamation. The preparation of soil bed requires a number of steps which includes formation of isolation layer, provision of ballast (small rock pieces), surcharge for preloading, drainage system construction and reducing soil voids.

3.2. Sand Placement: The sand is major construction material required for land reclamation. Coarse grained sands of good engineering qualities such as crushing strength, impact value, etc must be located near to the site of island construction. The dumping of sand in site is done by using trailers. The dumping procedure varies with the water depth of the sea bed. Rain bowing process is the common and fast method for placement of sand during land reclamation process. After the placement of sand, a bitumen emulsion and sand is sprayed over it. Finally plantation of grass is done to reduce erosion on the reclaimed land.

3.3. Dredging: The process of excavating soil from marine sites like seas, ocean bottom or coastal areas is called dredging. The dredging process is operated with help of various dredges and trailers such as trailing section hopper dredgers. These dredgers work on repeating process of dredging, loading transport to dumping site and dumping of load. The selection of dredges depends on type of soil, depth of excavation, operation area and various machineries qualities like cutter type, type and stroke of spud carriage. So, Dredging can be termed as the maritime transportation of the natural minerals from water environment to any other dumping areas.

There are numerous advantages of using land reclamation process for island construction. By land reclamation techniques, an artificial island can be constructed of any shape, any size & anywhere. Land reclamation will definitely increase land area for a certain country. Mining of natural resources
such as oil and gas can be done with artificial island construction. The generation of tidal and wind energy can be possible on artificial island zones. Reclamation of a lot of lands from flooding will also be possible using this technique. Development of mass tourism has been possible by construction of artificial island such as Palm Island located in Dubai has collected a large amount of revenue from tourism sector.

3. Different types of loadings on artificial islands

The design and construction of any types of structures require the different types of loading acting on structure, their magnitude and direction. The artificial islands are subjected to three major types of loads: permanent loads, variable loads and natural or environmental loads.

3.1. Permanent loads:
- Dead loads like weight of all types of structures calculated using nominal values,
- Permanently installed machineries and equipments,
- Forces due to hydrostatic pressure during calm sea conditions calculated from sea level,
- Loads due to ballasts used during filling process,
- Permanent earth pressure

3.2. Variable Loads:
- Different types of temporarily installed machineries and equipments such as dredgers, trailers, etc.
- Differences in internal and external pressures of natural resources like water, oil, etc caused by normal operating of structures
- Loads acting on island due to movement of vessels, landing of air vehicles, use of cranes and drilling operations

3.3. Environmental Loads:
- Wind loads and other loads caused by climatic variations on surroundings
- Loads due to wind, climatic variations of surrounding, tidal loads and currents
- Seismic loads due to earthquake and loads due to tsunamis

4. Construction and design problems of an artificial island

There are always numerous challenges in every construction works. With various case studies on different islands construction, some construction and design problems of an artificial island are earthquake, morphological impacts, high costs and uneven settlements. The earthquake can impact on sea defences and may cause liquefaction problems on soil. Morphological impacts include erosion and accretion of soil on coastal lines and soil removal at borrow sites. The cost of equipments during construction like dredgers, trailers and cost of fill materials and sea defence is high which need more investments. Similarly undesirable settlements of sea beds may also cause serious problem both during pre-construction and post-construction. From economical point of view the construction artificial island is restricted to water depth of 30m. So construction at depth more than the limit may cause economical problems to investors.

5. Limitations of land reclamation techniques for artificial island construction

There are various factors that may cause problems to use of land reclamation techniques for artificial island construction. Some are listed below:
- As the process is very costly this can lead to financial crisis.
- Lack of machineries like trailers and dredgers may slow down the construction procedure of island.
- Land reclamation process is a time consuming process of an island construction.
- Faulty construction process can cause settlement of the island in deep waters, as in the case of Kansai Airport, Japan.
- Land reclamation can be damaging to corals and marine life.
- High probability of occurrence of natural calamities such as tidal forces, earthquake and tsunami loads and due to these forces special provisions should be adopted during design of an artificial island.

6. Conclusions

- The establishment of industrial estates near to residential areas, working offices and business zones have caused a lot of problems to human life due to air, land and noise pollution. So, Construction of artificial island plays crucial role on preventing these environmental problems by providing areas for establishment of industrial estates. So, my report can be a platform of knowledge for many people and respective industrial organization about minimizing environmental problems that has been causing serious problems these days.
- The advancement in technologies in every field is very common these days. So artificial island can also help in construction of extended runways, infrastructures like ports...
and airports, etc which can bring a lot of luxury to a lot of people.

- We are using our natural resources as source of energy from a very past which have now resulted a vulnerable stage to a lot of non renewable natural resources. Artificial island can bring a lot of help on mining of natural resource mostly non renewable resources that can help in our environment conservation.

- People are fond of recreational activities these days and construction of artificial island can be a lot of beneficial for mass tourism activity. E.g. Palm Island.

So As a student of civil engineering it has been immense pleasure for me to study about artificial island construction and I got idea that it can bring great revolution on civil engineering technologies. Only a few countries have constructed artificial island and they have been highly beneficial from environmental, economic and social point of view. Developed countries like Qatar, China, Japan, etc are able to construct artificial islands and observing its increasing benefits every country should consider the use of this technique in civil engineering technology.

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