Artificial Island Based Port Expansion: A Review On Environmental Impacts

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Abstract: All ports need to be ready to handle more cargoes from mega ships that arise with deeper draft. The nature of port expansion and development requires enormous amount of land area as well as waterfront. Lack of suitable land area adjacent to the waterfront makes it difficult for the expansion of the existing port. One of the recommended solutions to this problem is the construction of an artificial island in the sea nearby. In this paper, we review the impacts of construction of artificial island to the coastal zone and examine the consequences of changing the shoreline. Furthermore, we will investigate the possible layout plans such as T-shaped artificial island for the construction of future port/wharf development and maritime related industries. The paper will include the impact of land-based pollution to the coastal environment as a result of allocating the industries on the artificial island.

Index Terms: T-shaped wharf, artificial island, land reclamation, port expansion, environmental impact, sea pollution.

1. INTRODUCTION

All ports need either technically or strategically to be ready to receive mega ships that come with deeper draughts and an increased volume of cargoes [1][2][3]. The port development and expansion definitely requires enormous amount of land area as well as waterfront [4][5]. Lack of suitable land area adjacent to the waterfront to be utilized for wharf purposes makes it even more difficult for the expansion of the existing port [4][6]. Wharves of a port require a number of technical requirements to suit with the ship specifications such as the ship's draft, length, and under keel clearance [6][7][8]. As the ship drafts and length become bigger and longer, ports need to expand to have a deeper water depth and longer berth structure for their wharves [2][6][9]. One of the solutions to this issue is the creation of the so-called artificial islands for wharf system at the sea nearby which will conceivably possess many problems during its pre-, during, and post-construction [10][11]. The construction of an artificial island (T-shape wharf is a well-known shape for this issue) is a non-naturally man-made form of structure adjacent to the coastal line towards the sea. The reason to build this artificial island or T-shape wharf is to reach deep water area which is essential for large transshipment port to adjust or to accommodate the giant ship drafts [2][9]. There are numerous artificial island notions have been used for port/wharf expansion such as in Port of Singapore (Pasir Panjang and Tuas, Singapore), Port of Tanjung Perak (Surabaya, Indonesia), and Khalifa Port (Abu Dhabi, United Arab Emirate). In old times, people make simple jetties to reach the deep water, but these jetties either semi or permanent construction does not accommodate the required land area for future port expansions [4]. To obtain the large amount of land area, the reclamation is necessary [11][12]. To fulfill the need of area on the other hand followed by major impact on the soil i.e. coastal zone area and activities. The environmental issue also takes place due to the pollution especially during the construction [10][11]. Although the construction of artificial islands for the expansion of ports is justified in international law, it has a long history in the human relations to the environment. It is undeniable that coastal states have the rights to construct whatever infrastructure they deem essential for their economic development in their territorial sea (12 nautical miles from the coastline) or in the contiguous zone (12 nautical miles from the territorial sea) or in their exclusive economic zone (200 nautical miles from the coastline), or in their continental shelf as these rights are granted in the UNCLOS (United Nations Convention on law of the Sea) [13][14]. Besides, the coastal state also can exercise their right to allow other states to build artificial islands in the said zones. Other important note is about the right to develop the high sea which is something unforbidden and granted to all states [13]. Even though states have the freedom to construct artificial islands or build installations and other structures in the high sea, but, the artificial islands and others constructed in the high sea that may cause problems to the shipping lanes of international navigation should be avoided [13][14][15]. Besides, coastal states and users of the artificial islands are obliged to ensure the safety of marine navigation and give notice of construction to appropriate authorities, remove all abandoned structures or not in use, and establish appropriate safety zones around the artificial islands [13][15]. The environmental impact caused by the construction of the artificial islands must also be taken into account.

1.1 SHORELINE IMPACTS

Large scale constructions such as port expansion near coastal sea space definitely designate the interaction between infrastructure projects at sea and the coastline and their negative impacts should be managed for at least of ten years. A careful planning and execution of infrastructure projects in the near coastal sea space with a coastline protection may be beneficial for the future of coastal defenses [15]. The construction of groynes on the shore on either side of the island would also reduce the volume of sand trapped in the sheltered zone between island and shore [16]. The potential environmental impacts of artificial islands development are related to the construction activities that involve mainly the dredging and dumping of large amounts of soil material (e.g. sand, stone, and dirt) from the existing location in addition to the structure installment activities [10][11][17]. The literature has shown a number of impacts of dredging activities and the deposition of dredge spoils on local communities and their

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environment. These impacts include water quality degradation, water clarity problems, erosion, stirring up long-buried contaminants and pollution, which can kill off seagrass and coral populations [10][11]. Although the artificial islands have been a vital option for stimulating economy and business activities, they come at a high environmental cost. The new islands creation changes the characteristics of sea waves and sediment deposition patterns on coastlines that at the end can lead to coastal degradations [10][11]. Furthermore, they may also destroy coral reefs and threaten the existence of many marine species. Of course, the degree of impacts of an artificial island is not the same from one to another. It depends on its size, location, and purpose. In contrast, in some cases, artificial islands might offer numerous advantages to the environment, such as the island structure can fascinate positive marine life.

2 ARTIFICIAL ISLAND DESIGN AND CONSTRUCTION METHODS

Land reclamation becomes a common choice of T-shape wharves. However, recent development shows that floating platforms using concrete, steel or stone reduce the choice for land reclamation [18]. Planning and designing an artificial island will depend largely on specific operations intended to be applied on that island. Comprehensive investigations should be done on site selection for artificial island with special attention made to surrounding environment such as; sea, land and air. The following aspects of artificial island's design should be strictly adhered to: Tidal range where the island is intended to be constructed that might induce an effect in submerging the installation in case of heavy storms [19]. Current energy, types, and wave breakers to minimize the energy carried by sea currents which can cause island's shore erosion [20][21]. Wave height models must be done prior to construction to understand wave patterns in the selected site [22]. Water depth should be estimated in case of any changes in sea floor topography [23][24]. Strength of island's foundation conditions such as concrete and steel tensile strength and durability should be carefully calculated [25]. In case of natural disasters like earthquake, floods, storms, risks should be estimated [25]. Existing pipelines and cables networks must be examined when constructing the island to minimize the risk of damage to the network [26]. Shipping lanes in the vicinity of the site selected should be considered in order to prevent chances of ship collisions with the installations [14]. Marine laws must be consulted with a law firm to comprehend legal aspects associated [27]. Specific attention should be made to native natural resources such as fisheries and fish stocks [28]. Based on the literature, the construction of an artificial island as the foundation for a port/ wharf expansion consists of the three processes:

2.1 DREDGING

Dredging is an unavoidable option for a port that faces depth problems. Dredging is the activities of removing top layer to some extend of the water bed to create deeper channels or waterways, turning basin and wharf area. Various types of dredging equipment might be used for deepening activities but it depends upon the following consideration [29][30]:

Deepness or volume of dredging
Seabed layer material characteristics
Operational area characteristics such as water depth, sea wave, and so forth
Degree of dredger automation used, etc.

2.2 BED PREPARATION FOR WHARF [30][31]

The core process of an artificial island is the bed preparation where the bed should be of a strong and solid. After the dredging process is completed and hard and solid strata is found, then the next process will be dumping the good quality coarse grain sand (reclamation materials) into dredge construction site. The reclamation materials are transported and dumped to the location with the help of specific equipment such as piping system or barge transportation. The reclamation materials (such as sands) need to be secured from seawater waves by concrete or rock or stone revetments or other retaining wall protection system. Bitumen emulsion is sprayed followed by layer soil on the top surface. To minimize the erosion of the soil, the surface needs to be treated such as putting concrete slab or grass or alike is planted on the embankments.

2.3 CONCRETE WORKS [30]

Concrete construction is needed for the wharf infrastructure on the artificial island. The piling works such as tube pile, sheet piles and tie rods are necessary to support and improve the strength of the sea bed. Rock bundles need to be filled hydraulically to remove sea water and form an island. Concrete protective units (such as armor) need to be placed permanently all around the island to protect it from scouring of sea waves. The next process is to install the piles at the sea bed to make sure the stability of the structure. After evacuating some soil materials out of the artificial island, the cofferdam structure is installed. Wide and thick concrete slab are laid down at the base and reinforced concrete retaining wall is built around the island.

3 INDUSTRIAL ASPECTS

Environmental, technical and structural design of artificial islands should adhere to certain industrial aspects and standard that will ensure maximum performance and execution of intended operation objectives. Industrial aspects pertaining to artificial islands are the following [13][30][32]:

- Safety procedures.
- Geological conditions.
- Variable costal circumstances.
- General environmental and natural conditions.
- Controlled maintenance cost.
- Minimize working time.
- Variety of structures associated with port operation
- Maintain construction quality.
- Prevention of pollution incidents in adjacent marine area

4 ADVANTAGES AND DISADVANTAGES

Construction of artificial island in shallow or deep marine water is considered as a reasonable method to the port and industrial area. Artificial islands are also approved means of oil and gas development in shallow and offshore marine areas [33]. Over the years, advances in industrial technology and installation techniques of have proven to be both economically and technologically feasible for end users. Table 1 shows some advantages and disadvantages of choosing artificial islands for port expansion.

Table 1 *Advantages and disadvantages of artificial islands as a mean of port expansion*

Advantages	Disadvantages
The construction of wharf/artificial island can be of any shaped, size and location	The reclamation project is very costly and time-consuming
Port will have additional land space for its activities from a land reclamation	The project requires specific equipment, good weather, and high engineering know-how and skills.
More new land means more spaces for buildings and other infrastructure as well as the operations.	During the construction process, it can cause settlement in deep waters
More lands can be meant more productivity for the port	The reclamation contributes to the degradation of corals and marine life
	The island is exposed directly to tidal forces, sea storm and tsunami.

4.1 T-SHAPE ARTIFICIAL ISLAND AND FUTURE EXPANSION

T-shape artificial island is constructed towards the deeper sea water to allow the bigger ship berthed [6]. The selected area adjacent to the existing port enable for future expansion [30]. The deck on pile T-Type wharf construction is an efficient wharf construction because it could accommodate vessels at both sides of the wharf [30](figure 1). However, there should be sufficient water depth in the wharf relatively close to shoreline to anticipate the vessels are required to berth at shallower water. In order to avoid cross current to the berth the brake water and sufficient area for ship maneuvering or turning basin can be built to accommodate larger ships

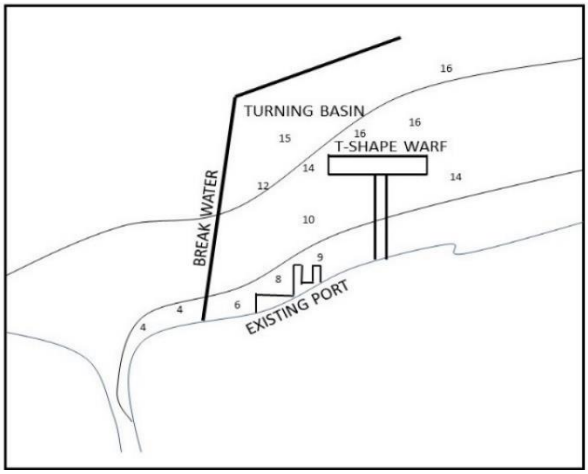

Figure 1 *T-Shape artificial island*

The future expansion of the T-shape artificial island is by reclamation the area towards the land and can be constructed in several stages or phases [10][30]. The newly built additional area is the answer to increasing demand of space for maritime related industries such as ship yard, car manufacture, logistics distribution center etc.,

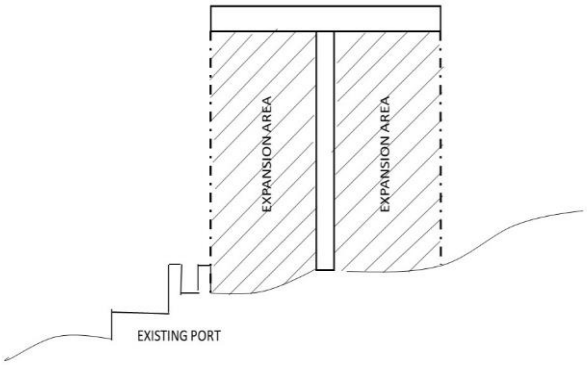

Figure 2*. Future expansion of T-shape artificial island*

4 CONCLUSIONS

In its various forms, artificial island is a common concept of port/wharf expansion to reach deeper water in order to catch bigger vessels [2][6]. Even though the concept has its long history in port development, but any execution of port expansion based on artificial islands has to consider its impacts to the environment. For this reason, it would be wise to begin any port expansion by carefully learning and studying how these island structures might generate negative impacts so that a well-informed decision can be made [4][5]. As port expansion affects sea and land territories at the same time and it covers a wider area of impacts, all the stakeholder i.e., the port operators, funding agencies, shipping agencies, the scientists, and most importantly, government agencies need proper planning for new artificial island projects, and to conduct extensive pre-construction studies on water quality and ecology parameters e.g. contaminant levels, water clarity, nutrient levels, and surveys of animal life e.g. species, cycle of life, and characters of feeding and migration, to reduce the level of and even prevent them from the impacts [4][10]. The studies on the impacts of port expansion based on the artificial islands need to be carried out in multistage: prior to construction, during construction, and post construction as their scale of impacts is significant, long-lasting, and change the environment. The construction of artificial island-based wharf will fundamentally change sea currents around the islands, which led to significant coastal erosion. The construction artificial islands also may affect the integrity of surrounding natural islands.

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