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Artificial Islands

Marcel J. F. Stive
Department of Hydraulic Engineering, Faculty Civil Engineering and Geosciences, Delft University of Technology, Delft, The Netherlands

Definition

Islands are defined as a relatively small land surface, surrounded by water. The largest island, Greenland, has a surface, which is still four times smaller than that of the smallest continent, Australia. The total surface of the earth's islands approximates 10 million km^2, which is comparable to Europe's total surface area.

It is common to distinguish between continental and oceanic islands. Continental islands are considered part of a continent when they are located on the associated continental shelf. Oceanic islands, in contrast, do not belong to a continental shelf. The majority of oceanic islands are of volcanic origin. Some oceanic islands (e.g., Madagascar, Greenland, Zealandia) could be considered as subcontinents, which have been separated from larger continents through tectonic processes.

All realizations of artificial or man-made islands as constructed so far are close to shores on relatively shallow water either in intertidal zones, in bays, on the shoreface, or on the nearby shallow continental shelf, and most are located in a sheltered environment. Based on the above definition, artificial islands belong to the class of continental islands. Because of their general close vicinity to the shore, artificial islands are very similar to land reclamations into the sea, certainly when such reclamation is separated from the existing land by a waterway or channel, which often has a water management purpose.

The history of island and land reclamation into the sea is some 2,000 years old, starting with dwelling mounds in flood-prone areas (cf. Kraus 1996; this reference provides historic context of works in Canada, Germany, Japan, the Netherlands, and Taiwan, described below). In the sixteenth and seventeenth centuries, land reclamations were becoming common practice in Western Europe. In the twentieth century, this practice has evolved worldwide. While this continues to be the case, the construction of islands or reclamations further offshore is only of recent times. Islands in support of a larger infrastructure or temporary islands for petroleum exploitation are of the last decades. Many feasibility studies on artificial islands with an intrinsic purpose (such as industry, urbanization, and airports) have been undertaken all over the world since the 1970s. However, it was not until 1994 that the first offshore-located island was completed for the realization of Kansai International Airport in the Bay of Kobe of Japan. Most recently, strategic tensions in the South China Sea also known as the East Sea has led to nourishments increasing the surface areas of very small islands that are not necessarily shoreface connected.

Concepts and Applications

Dwelling Mounds

Historically, artificial islands and reclamations go back a long way (cf. Van Veen 1962). The first known historic recordings of artificial islands are by the Romans. Plinius in 47 AD describes how the Friesians along the northern boundaries of the Roman Empire lived on artificial mounds (called "terpen" in Dutch) in order to keep "their heads above the water" during spring tides and storm surges. In all they built 1,260 of these mounds in the northeastern part of the Netherlands, which still exist today, although by now situated in reclaimed land. The areas of the mounds vary from 2 to 16 ha, and their surface level may reach as high as 10 m above mean

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sea level. The volume content of a single mound may be up to one million cubic meters (Mm^3).

Poldertype Reclamations

This period of family-based shelter against high waters reverted into a more collective form of shelter by seawalls and associated reclamations. The start of these constructions is expected to have been shortly after the declaration of the Lex Frisonian in 802. In the sixteenth and seventeenth centuries all over Western Europe, including Russia, polder-type reclamations have been realized both on seashores, estuaries and rivers, and lakes. A polder that is used to reclaim part of the sea bottom consists of an endiked continental shelf or intertidal basin area, with its surface, being the original sea bottom, below mean sea level which is maintained dry by the use of pumping stations (see entry on "► Polders").

One of the world's largest polder reclamations (Van de Ven 1993) concerns that of the Zuiderzee in the Netherlands, which started in 1918 (with the main damming realized in 1932 and the principle of constructing small polders first to learn by doing) and was finalized in the early 1970s when it was decided to not reclaim the last planned polder (Markermeer Polder). The closing off and the partial reclamation of the Zuiderzee have resulted in the gain of 166,000 ha of new land distributed over four polders. This new land is used for agriculture, urban development, recreation, and nature conservation.

Although the polders in the Bay of San Francisco are – intriguingly – called "islands," these are basically real polders with their ground elevation below mean sea level. These solutions are also introduced in Saemangeum, South Korea; in the Po Delta, Italy; and very recently in Jiangsu Province, China.

Petroleum Exploration and Exploitation Islands

In the petroleum exploration and exploitation industry, there exist several examples of island reclamations. One such example concerns Rincon Island off California (U.S. Army Corps of Engineers 1984). Another important example concerns a series of artificial exploration drilling rig islands of temporary nature in the Beaufort Sea – McKenzie Delta region, Canada. Through the construction of a number of such islands in the period 1973–1986, the presence of oil and gas reserves was confirmed, but exploitation in this remote, arctic environment was costly. The decline of the oil prices had hampered exploitation. The islands, with an expected lifetime of 3 years, were constructed in water depths varying between 3 and 21 m, just before the frost and ice formation would set in. A total of eight exploration islands of the sacrificial beach type and nine exploration islands of the sandbag-retained type were constructed. In both cases, a dense sediment core was placed, which provided the exploration space needed (surface areas of the order of 1 ha). The sacrificial beach type implied that the relatively steep slope of the core was protected with a gently sloping lower beach of less dense sediment, which would be able to withstand erosive forces by water (in summer) and by ice (in winter). The sandbag-retained type resolved the issue of required resistance by protecting the slopes of the core through geotextile sandbags (with volumes of 1.5–3 m^3). The issue of subsidence in this area is virtually absent because of the permafrost conditions.

Elevated Reclamations

The strong economic development of Asian countries over the last decades where the availability of land is scarce, for example, Japan, Singapore, Taiwan, and South Korea, has also resulted there in a series of reclamations. With the exception of South Korea, the acceptation of the polder-type reclamation in Asia has shown to be low. Although the execution method initially is similar, viz., endiking the area first and then drying by pumping, there appears to exist a preference in Asia for elevating the reclamation to above mean sea level (see entry on "► Reclamation").

Examples of this practice are the recent realizations (mid-1990s) of the industrial reclamation estates Chang Hua and Yun-Lin on the west coast of Taiwan, comprising 3,000 ha and 10,000 ha, respectively. The fill of these reclamations amounted to 800 mm^3 of sand, which was dredged by trailing suction hopper dredgers in the nearby offshore area. The reclamation locations were primarily on diluvial substrates formed by pre-Holocene ebb-tidal deltas, which implies that subsidence problems were virtually absent.

A recent (2017) mind changer in Singapore is the Pulau Tekong reclamation with 810 ha which is being executed as a polder, whereas all earlier reclamations were executed with the ground level above mean sea level. The main reason behind this is the difficulty to arrange access to sand resources of the neighboring countries.

Infrastructure Supporting Islands

Over the last decades, a number of islands have been reclaimed to support the construction of a larger infrastructure. An early example is the island Neeltje Jans in the mouth of the Eastern Scheldt estuary. This was created on a subtidal flat, separating the main estuarine channels, with a twofold purpose. The island served both as a working area for construction of the elements that were to form the Eastern Scheldt Storm Surge Barrier (completed in 1988) and to form part of the barrier itself.

Other examples concern the construction of islands in cases where the two banks of a waterway are connected by a combined bridge-tunnel connection. At the transition of the bridge to tunnel and vice versa, the island serves as the connection area. One North-American example is the Chesapeake Bay bridge-tunnel connection; a European example is

the Øresund bridge-tunnel connection between Denmark and Sweden.

Airport Islands

It might be stated that the introduction of offshore artificial islands in larger depths with a ground level above mean sea level was benchmarked by the construction of Kansai International Airport, Japan (1994). Chek Lap Kok International Airport, Hong Kong (1998), and Inchon International Airport, South Korea (2001), followed up soon. A common problem to these three airport islands is formed by the foundation. Being international airports demands that important loading forces (400 metric tons for future intercontinental aircraft) need to be sustained. Since all of these islands are constructed in relatively sheltered areas, the local sea bottom commonly consists of alluvial clay, which calls for special measures.

Kansai International Airport, *Japan*: The main concern in creating the artificial island has been the foundation of the island. Not only was the local water depth some 18 m but also an alluvial clay layer of more than 20 m covered the geotechnically stable diluvial (Pleistocene) clay substrate. The alluvial clay layer was artificially compacted by about one million piles that were driven into the layer to drain the water out. Subsequently, a sea defense was constructed of some 11 km circumference, within which 178 mm^3 of material was dumped. Because of the scarce availability of suitable sand dredge material, the majority of the fill was taken from quarries near Osaka. Thus, an island was created which has an elevation of 33 m above the sea bottom. Since the construction, the subsidence has continued and is expected to continue another 30–50 years. In the next phase, the surface area of the island will be extended.

Chek Lap Kok International Airport, *Hong Kong*: A quarter of the artificial island consists of the island of Chek Lap Kok (350 ha); three quarters consist of sea reclamation. The average local depth was some 6 m. In contrast with the solutions for Kansai and Inchon, the alluvial clay layer of 10–15 m was removed. The reclamation consisted of a lower layer of rubble mound material quarried from Chek Lap Kok and supplemented with sand dredged in the nearby area. To avoid expensive layer gradation, transitions between the rubble mound material and the sand geotextiles were applied. The fill quantities amounted to 350 Mm^3, of which two-third was dredged sand.

Inchon International Airport, *South Korea*: This airport site covers 5,600 ha in total, of which 4,700 ha consists of reclaimed land between the islands of Yeongjong and Yongyu along with 900 ha of existing land. To endike the area between the islands, three dams of a total length of 17 km were constructed, varying in crest height between 7.5 and 9.4 m. Their widths at their foundations are 90–120 m and 20 m at the crest. The reclamation of the 4,700 ha required approximately 180 Mm^3 of fill. Around 80% of the fill was dredged from the sea, and the remaining 20% was quarried from mountains and hills in the area. The top layer of the reclamation site, which is largely an intertidal area, is composed of a soft alluvial layer of 5 m average thickness. A sand drain technique was applied to achieve higher soil-carrying capacity. Vertical sand pipes of 400 mm diameter were driven into the soft soil every 2.8–3.8 m to drain pore water. The expected additional settlement is less than 0.5 m.

Conclusions

Although the history of artificial islands or island reclamations is long, it may be expected that the increasing pressure of urbanization, industry, and tourism in the densely populated coastal regions is yet to result in a further boom of construction of islands and island reclamations, even though the constructed Palm Islands (Dubai) and the World Islands (Dubai) are still struggling to turn into a success. The three main technical problems that one will generally face in the design and execution are those of geotechnical foundation, of connection to the mainland, and of availability of fill material. Besides this, one faces the important issue of environmental impact, where the aspects of impact minimization, nature substitution, and working in harmony with natural system forces are the keywords.

Cross-References

- ▶ Dredging of Coastal Environments
- ▶ Geotextile Applications
- ▶ Polders
- ▶ Reclamation
- ▶ Small Islands
- ▶ Storm Surge

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