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Roman ports: significance of their role, their structure and construction

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Abstract

This article presents Roman innovation in port construction. It begins with a brief presentation of the history of Roman ports, in order to explain their economic and social significance and the factors that led to their development. The main material for port construction, the famous and revolutionary opus caementicium, will be thoroughly discussed. A description of basic port structures, meaning the breakwaters, the jetties and the quays, will follow. The lighthouses and the port canals will also be presented as secondary port structures.

Keywords: Roman ports, opus caementicium, construction, structure.

Introduction

The primary reason for building ports was to support the human need and desire for communication and the movement of people, ideas, and products by sea. The Mediterranean area, a crossroads of three continents and a cradle of important cultures has been an important trade and travel passage since the beginning of navigation.

The Roman Empire dominated the Mediterranean Sea from the end of the Punic Wars (264–146 BC) until the beginning of late antiquity (late 3rd century AD). During this period, Roman ships travelled the semi-closed Mediterranean Sea, carrying and spreading merchant products, transporting people and ideas and introducing an early form of globalization. Roman ports were the cornerstone of this navigation. Throughout this era, ports overwhelmed the Mediterranean region, forming a sea -network that covered an area of 2,500,000 km². The infrastructure of the Roman merchant ports was the result of a technological and constructive evolution that began in the Mediterranean in the Bronze Age. It is worth noting that the remains of Roman ports indicate that the development of port construction was very limited until the eighteenth century when ports (due to the First Industrial Revolution) began to increase in size (De Graauw, 2019: 1).

Constructing a Roman port

The book De architectura (ca. 25 BC), Vitruvius' magnus opus, is the most important literary source on the construction and structure of Roman ports. Vitruvius believed that port locations with a natural curve towards the interior of the location should be preferred (Vitruvius, De architectura, liber V, chapter XII, 1). In cases where the geomorphology was disadvantageous for a potential port, he suggested the creation of walls and embankments to ensure the protection of the port from natural phenomena (Vitruvius, De architectura, liber V, chapter XII, 2).

Opus caementicium

The major Roman contribution to port construction was the invention of an advanced type of mortar. Since the seventh and the sixth millennium BC, standardized mortars and plasters, consisting of hydrated lime, beach sand and water were used in the Mediterranean area. However, Roman hydraulic mortar differed from previous mortars by replacing or supplementing the silica sand with volcanic ash from the site of Puteoli (Becerra-Duitama et al., 2022: 496). Vitruvius recommended a mixture of two parts volcanic ash to one part of lime to produce a hydraulic mortar "that hardens as well underwater as in ordinary buildings" (Hobbs and Siddall, 2011: 51). Residual analyses of Roman cement from port sites across the Mediterranean indicate that the proportion of ingredients varied. Pozzolanic ash consists of aluminosilicates which, when mixed with lime and water, produce calcium hydroxide. Although the chemical mechanisms that determine these processes are not yet fully understood (Becerra-Duitama et al., 2022: 496), when calcium hydroxide is mixed with water, the mortar becomes extremely hard, much more resistant to compression and it coagulates faster. A secondary benefit of using Roman concrete is the use of significantly less mortar mass in the construction of a project than it would require for a similar construction with conventional mortar.

Between 2002 and 2009, ROMACONS, a research team from MIT, extracted and studied concrete cores from 11 Roman Mediterranean ports. The research results indicated that opus caementicium, Roman hydraulic cement, could "self-repair" in cases of cracking. When its ingredients were mixed at high temperatures, nuclei of a solidified mixture of calcium, silicon and chloroaluminum formed a crystalline structure in the body of the concrete. Over time, these nuclei crumbled and when there was a crack, they slipped, in the form of powder, into the void and recrystallized, filling it anew (Jackson et al., 2012: 57–70).

Vitruvius' hydraulic cement construction techniques

Vitruvius described three methods of underwater building using Roman concrete. The first method regarded building an underwater caisson, a wooden casing consisting of oak stakes, connected together with transverse planks. After the caisson construction followed ground levelling and the unloading of hydraulic concrete mixed with crushed stones (rubble) in the timber formwork (Vitruvius, De architectura V, XII, 3).

The second method concerned cases where it was not possible to use pozzolanic concrete and required concrete mortar casted in a dry environment. A caisson was constructed with double walls, each of which consisted of charred piles fastened together with inset boards and uprights between the walls. Clay was pressed between the double walls. After the clay dried, water pumps were used to dry the space inside the caisson. After this procedure, the bottom was cleaned and excavated until it was solid. Then cement, consisting of rubble, lime and sand, was discharged into the mould (Vitruvius, De architectura V, XII, 5).

The third method was applied in cases where the position did not allow the construction of a caisson. A platform was created on the water's edge and developed in an offshore direction. Its width would be equal to half its length and it would be inclined towards the sea (Vitruvius, De architectura V, XII, 3). Then, on the sides of the platform, wooden walls were built up to the level of the platform. The space between the sea bottom, the platform and the walls was filled with sand. A concrete block was cast on the surface of the platform, and when it solidified, the walls were removed and the sand, which was held by the walls, was swept away by the sea. The result was that the concrete block slid into the water and filled the gap left by the sand (Vitruvius, De architectura V, XII, 4).

Port structures

Concerning commercial port structures, we will differentiate them as main and secondary structures. The breakwaters, the jetties and the quays will be characterised as main structures, for the reason that they ensured that ships could approach and moor at the port safely and contributed to merchant activity. Lighthouses and port canals will be defined as secondary structures, since their existence was not obligatory for the function of the port, but served collateral purposes.

The breakwaters

Breakwaters are the artificial elongated structures that enclose a harbour. Their purpose is to protect it from strong and dangerous waves. During the Roman period, the two main breakwater construction techniques were the rock pile method (an embankment of rubble, a riprap[1]) and the casting or placing of rectangular parallelepiped hydraulic concrete blocks on a locally sourced stone (e.g., use of kurkar rock – aeolian quartz limestone from the coast of Anatolia in Caesarea Maritima; Bergin, 2018: 378) pile foundation (De Graauw, 2022: 1). Typical surviving Roman breakwaters constructed according to the pile method are those of Portus (Fiumicino, Italy, over 3000 m in length) and Leptis Minor (Lamta, Tunisia, about 560 m in length, submerged in shallow water). A typical example of breakwater construction using the second technique comes from Caesaria Maritima (Israel). Between the years 21 and 9 BC, two large breakwaters were built in the open sea (the first breakwater extended 600 m to the southwest and the second one prolonged 300 m to the north), which formed an almost enclosed port basin of 200,000 square meters. Concrete blocks were built based on the third method of building described by Vitruvius, with hydraulic concrete. The gaps between the concrete blocks were filled with

[1] Riprap: “A a foundation or sustaining wall of stones or chunks of concrete thrown together without order.” “Riprap.” Merriam-Webster Dictionary.

riprap (Oleson, 2007: 152). The 30 m gap between the two breakwaters formed the harbour entrance (Hohlfelder, 1984: 134). Underwater investigations showed that part of the northern breakwater, located at the entrance of the port, was constructed with concrete blocks approximately 15 m long, 12 m wide and 2 m thick, which were placed directly on the sandy bottom (Oleson, 2007: 153).

A breakwater type that made its first appearance during the Roman era is the arched breakwater. The arches of this breakwater resemble the famous aqueducts of the period. Its gates had a smaller width, limiting water circulation and the entry of waves into the harbour. The construction material of the underwater part of the pillars was Roman hydraulic concrete. The only surviving arched breakwater is located at Civitavecchia in Italy (De Graauw, 2019: 10).

The jetties

A jetty is an artificial protrusion on the side of a port, being perpendicular to the shoreline and extending into the water. Its external side was usually covered by a platform, in order to stop the force of the waves. The internal side provided infrastructure suitable for the mooring of ships. The jetties were built using hydraulic concrete and local stone. The typical mooring types are the stern-to and bow-to for reasons of space economy (the well-known “Mediterranean mooring” or “Med mooring”; Wilson, 2013: 38). In some ports the positions of each ship were distinguished by numbered columns, while the amount of space allocated to each vessel varied from port to port (e.g., 3 m wide in Leptis Magna, while in Terracina even over 17 m). The tying of the ship (“cable tying”) was done on mooring stones (De Graauw, 2022: 226).

The quays

The quay had the form of a platform, which had land on one side and provided berthing on the other. The quay was the part of the port which facilitated landing and boarding passengers and constituted the point where loads were carried out. The quays’ construction could be made using Roman concrete, or wood or could be a stabilized raft or a robust wooden surface fastened to wooden poles (Nakas, 2020: 5; De Graauw, 2022). The quay height was equal to the usual height of a ship handrail, around 1 m above the water level of the ships (the Torlonia relief provides us with a characteristic depiction of the typical Roman quay height). Ships’ mooring was also done with the stern-to and bow-to type. In the Roman port of San Cataldo (Lecce, Italy), holes were detected on the surface of the quays. Firstly, they were identified as supporting holes for stone mooring pillars. But the fact that the holes were below the level of the platform and close to the sea level led to the second and more plausible explanation of being supporting holes for wooden piles, which were associated with the presence of machines for loading and unloading merchant products (Ferrari and Quarta, 2019:8).

The lighthouses

Lighthouses were tower-like structures of great height, at the top of which there was a source of light that emitted a luminous signal during the night or when the visibility was limited, to guide ships. The Hellenistic lighthouse of Alexandria is considered to be the first lighthouse in history (Wilson, 2011: 46) and its template was adopted by the Romans. It was distinguished on three levels. The first level was used as the lighthouse crew’s accommodation. The second level was elevated and had a staircase, which led to the third level. There, a fire brazier, with metal curved reflectors around it, was placed to spread the light further (Trethewey, 2018: 1–3; Trethewey, 2019: 1).

Port canals

By the term "port canal", researchers mean a man-made structure that acts as a water transport conduit, either diverting part of the water of the harbour basin to the sea or directing the water through the land and out of the harbour to an inland or coastal destination (see Portus). The canals met a variety of needs within the framework of the Roman ports. They functioned as channels of communication between the sea and port basins (e.g., the port type of Kothon; Carayon, 2005: 2-15; Blackmann, 1982: 93-94), as navigable man-made beds, through which the ports were connected to land positions and as a means of removing silt and transport materials from the port basin (flushing channels) (Salomon et al., 2014: 6). Depending on their use, each channel was constructed in a different way. The connecting channels of the harbour basins were made of strong masonry, while the cleaning channels were large conduits carved out of the outcrops to the desired depth. The land interconnecting canals were artificial watercourses, products of excavation.

Summary

The Romans, having the clarity to understand the value of Mediterranean port construction and the foresight to develop it, flourished, creating a maritime empire, whose foundation was its ports. The discovery of opus caementicium, along with other innovations, made it possible to build ports wherever economic, political or military reasons dictated it, regardless of the terrestrial or underwater geomorphology (Olesson et al., 2014: 199-200). This new technological development contributed to the intensification of economic activity in the Mediterranean world and strengthened Roman dominance (Keay, 2020: 1).

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