THE CRADLE OF PORT ENGINEERING IN VENTOTENE ISLAND

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The island of **Ventotene** (Pandaria, in Latin), located about 50 km from southern Lazio coasts (Fig.1), holds a special world record, highly esteemed by maritime engineers: it preserves almost intact and fully functional one of the oldest and most beautiful ports, the *Roman port*, built by emperor Augustus in 14 BC, over 2000 years ago, to accommodate ships up to 30 m in length. The port is still used today in its original form and is preferred over the adjacent modern port by the tourist and fishing fleet (Fig.2). As shown in Fig.3 the plan layout of the port is very modern (almost specular to that of new port of Gioia Tauro, though with much smaller size), ensuring calm conditions in all weather. The port layout has a narrow entrance open to the sea to the east (easily navigable and visible at night), followed by a cove with a gently sloping beach that absorbs the waves and allows the hauling of small boats. On the side, there is a well protected elongated rectangular mooring basin.

Figure 1 – Location map of Ventotene island

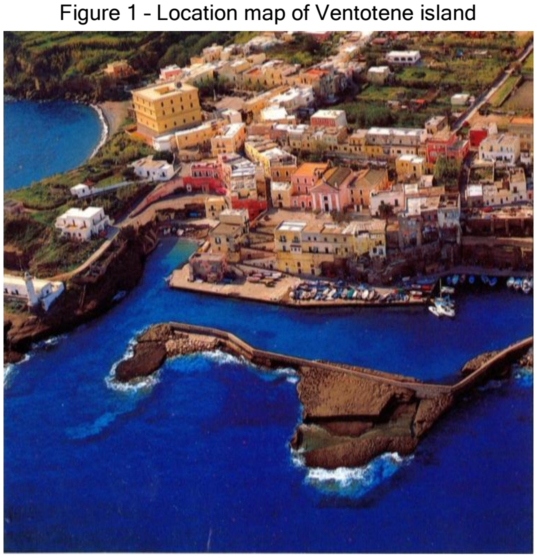

Figure 2 - Aerial view of the Roman port

Figure 3 – Comparison of layouts of Ventotene Roman port, 14 BC (above) and Gioia Tauro,1980 AD (below).Scale varies.

It is, in fact, an imposing sculpture, entirely carved by hand into the dark tufa rock (a volume of about 60,000 m^3 with excavations up to 9 m high), artificially creating a "natural" mooring basin of 7000 m^2 and 3 m deep. The breakwater, the mooring docks, and the escape of arches and caves-storage were also skillfully carved in tufa and have deteriorated to the point of resembling "petrified elephant trunks" (De Rossi, 1991) (Fig.4).

Figure 4 - Rock carved port storage caves

The excavation rocks were then reused as construction material. This original construction solution was also dictated by the particular island condition that made the transportation of equipment and construction materials more difficult and costly. In "sculpting" the coastal rocky bank, the Roman engineers shaped the natural ramp near the sea surface with a rough and gently sloping profile to attenuate the runup of breaking waves and collect the overflowing water volumes in a suitable drainage channel, borrowing ancient Phoenician inventions (Fig.5).

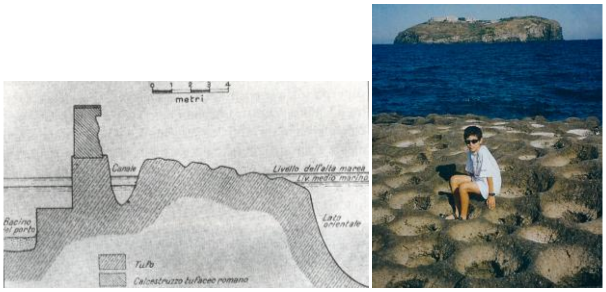

Figure 5 - Rock carved Roman breakwater (from Iacono 1938)

The external drainage channel is still clearly visible (Fig.6), while a small secondary opening on the opposite side to the main one, used for water exchange, is now blocked. These ingenious hydraulic systems are still used in modern projects, even to generate clean energy from waves (eg. OBREC pilot plant in Naples). In the Roman port we can observe other interesting old hydraulic and maritime devices, such as two aqueducts, two cisterns, and large bollards carved into the rock (Fig.6) to favour ship manoeuvers and moorings and even to close the entrance at night with a chain stored in the nearby visible small cave. The circular cavities visible on the rocky outcrops (fig.5) were instead used to collect marine salt after the water evaporated (today a desalination plant operates nearby...).

Figure 6 - Drainage channel and tufa bollards at entrance

It is presumed that the original vertical crown wall was shaped with a concave curved profile, as visible in a section of the inner side, to push the waves back to the sea. This wall crest geometry is still used today, even in the set-back parapet of the adjacent new port breakwater: built in the 1990s, it has a first section protected by concrete tetrapods and a second deeper section with large vertical caissons, perforated on the inner face to reduce residual agitation (Fig.7). The crown wall is set back from the edge of the outer caisson wall to reduce the total instantaneous wave forces exerted on the entire structure. These modern cellular caissons, also derived from a brilliant invention of the ancient Roman engineers, have the advantage, compared to traditional constructions and especially in the case of a small island, of being prefabricated remotely, towed in floatation and then sunk quickly in safe calm sea conditions. It is interesting to note that pozzolanic cement, still used in maritime works for its exceptional impermeability and durability, was invented by the Romans by adding to the lime the volcanic powder (pozzolana) from the near Vesuvian area. Both nearby ancient and modern coastal works are therefore an excellent compendium of port engineering for specialists!

Figure 7 - Curved set-back wall in old mosaic and in the modern caisson breakwater under construction (1992).

Finally, among the local hydraulic-maritime engineering works, the Roman fishpond (Fig.8) should also be considered: it was used for fish farming, also carved into the rock, just south of the port. The fishpond displays covered tanks (once decorated with colored plaster and stucco) and channels for water exchange, closable with perforated shutters to prevent fish escape, connected to freshwater conduits for proper mixing. The tanks were designed in relation to small tidal differentials and the dividing walls allowed the passage of the staff. The mean sea level 2000 years ago was about 1.2 m lower than today and these walls represent a useful benchmark for the analysis of longterm sea level rise..

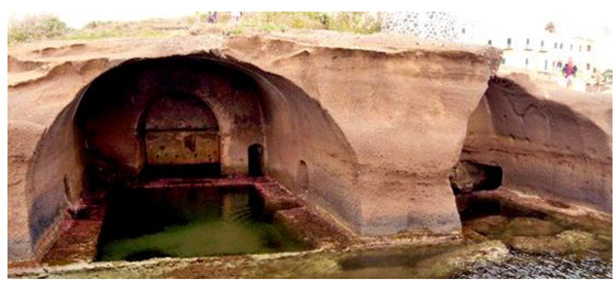

Figure 8 - Roman fishpond in Ventotene island

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