

The Extension of Port Hercule in Monaco

Port Hercule in the Principality of Monaco has been extended, in 2002, with a floating breakwater and a counter-jetty which have considerably augmented the reception capabilities of it. The vocation of the Principality to give berth to cruise liners ships and big yachts can be satisfied now in a very effective way. The construction of the new section of the Port Hercule was conceived in the early 90s and implementation required adequate studies of coastal topography, sea bottom morphology and meteorology. This paper gives a brief history of the harbour and a summary of the hydrographic surveys carried as a support to the engineering works and in preparation of the new edition of the nautical chart of the harbour.

Herculis Monocei Portus (Latin expression which mean: port of the unique God Hercules) was known, since the times of the Phoenician, Greek and Roman mariners, as a good harbour of the north-west Mediterranean for commercial and military purposes. However the port was subject to the swell originated by easterly winds thus reducing its sheltering capabilities.

When the Grimaldi initiated their dynasty as Princes of Monaco in 1297 the use of port was increased and the Monaco's powerful navy was very helpful in protecting the sea trades in the region. However the protection of the interior part of the harbour was not ameliorated until the reign of Prince Albert the 1st who conceived in 1900 the Monaco's harbour first significant improvement. The solution adopted and realised in the years 1902-1914, was to build two 170m breakwaters on either side of the shore with a 100m channel in between them. This was the only possible way to construct a shelter in the deep of the waters (between 20 and 50 m) at the entrance of the harbour. In the sixties of XX century, further studies were ordered by the Government of the Principality in order to improve the protection of the port and finally in the nineties the "fixed seawall" concept was adopted. The main part of the project (putting in place the counter jetty and the floating breakwater) was completed in September 2002. The first liner to call on the new port was the "Seven Seas Voyager" in April 2003 (Figure 1).

The Realisation of the Extension of "Port Hercule"
The project consists of:

- The "Platform Area". This is constituted by one hectare of building land just below "Fort Antoine" at the southern extremity of the harbour's entrance. The realisation of this area was obtained by the following operations:
 1. a preliminary dredging carried out by the specialised ship River Nile.
 2. the construction of underwater foundations made of riprap consolidated by vibro-sinking and grouting.
 3. On top of the foundations four concrete caissons were superimposed. The caissons were made in La Ciotat and Marseilles (France) by a consortium of enterprises, they were towed to Monaco in 2001 and eventually sunk on top of the foundations (Figure 2)
- The Counter Jetty. This is made of concrete; length 145m, width 30m, draught 9m. It was built in La Ciotat (France) by the same consortium which built the Platform Area and it was towed to Monaco where it arrived on 7 July 2002. The counter jetty is connected to a shore abutment and its seaward extremity is now superimposed to a caisson sunk on a riprap foundation. The abutment and the caisson were also made in La Ciotat and towed to Monaco. The counter jetty admirably complements the sheltering effect provided by the floating breakwater (Figure 3)
- The Floating Breakwater. It is also made of concrete and built in Algeiras (Spain) by the Spanish enterprise "Dragados". Its dimensions are impressive: 160,000 tons displacement, length 352.5 m, width 28 m on surface and 44 m at the bottom (which is provided with two 8m stabilising wings), 16 m draught; The breakwater was towed from Algeiras to Monaco where it arrived on 26 August 2002 after 12 days of navigation. It was connected to the abutment caisson of the platform area with an original steel made articulation system called in French "la rotule" which gives it the possibility to move around the junction point (1). The floating breakwater anchoring system is constituted by: eight mooring heavy chains connected at the harbour entrance extremity five of which (those towards the open sea) are 500 m long and the other three 100 m long, plus two supplementary anchoring chains the length of which is 200 m towards the open sea and 150 m land side securing the land extremity of the breakwater; these latter two chains may be used to move away the breakwater from the platform area in case the articulation system gets broken. The anchors which the chains are connected to are constituted by steel piles the diameter of which is 72", 60" and 42" buried 29m and 20m into the sea bed; the water depths of the 5 piles towards the large are between 72 and 75 m. For putting in place the piles it was necessary to carry out a coring campaign aimed at determining the sea bottom constituents carried out by a specialised Russian ship in preparation of the work for putting in place the piles.
This latter was executed by the Russian ship Stanislav Yudin equipped with a crane of 2,500 tons (Figure 4).
The positioning of the piles was done with the aid of DGPS and the extremities of the chains which had to be lifted on board of the breakwater and connected to the stabilising wings, were marked by couples of buoys submerged at 20 m depth (Figures 5 and 6)

The Hydrographic Surveys

Bathymetry was one of the points of the contract's specifications for the construction of the port. Soundings had to be referenced to

the Monaco's General reference Level (NGM) which has a difference from the present French General reference Level (NGF) of 66 mm (being the Monaco's level lower than the French level); the contract was also indicating that the chart datum for the Mediterranean was the Lowest Astronomical Tide which is 399 mm below the NGF. The hydrographic surveys had to permit the identification of dumping areas, obstacles and obstructions in the area affected by the construction particularly in the areas of the foundations. Hydrographic profiles had to be conducted with an accuracy consistent with 1:100 scale representation (which means that a sounding's horizontal accuracy of 0.1m had to be achieved). The hydrographic survey operations were sub-contracted to the French company GEOID. A complete hydrographic survey was conducted in 1999 before the works started over the entire area. This campaign was done using: a multi-beam equipment "GEOSWATH" produced by "GEO ACUSTIC", a side scan sonar for obstacles detection (a small and already known wreck was detected) and a boomer (for measuring the sea bed sediments' thickness). Kinematics positioning was done with the use of the equipment Trimble MS 750 (DGPS RTK). For more refined sounding measurements a, portable echo sounder ODOM Hydrotrack single beam 200 KHz was used, All the survey equipment were mounted on board of a fibre-glass hull launch named TamourÃ© provided by the Monaco's enterprise EMRR. The software Hypack (Coastal Oceanographic) for survey guide and for sounding data analysis and elaboration was used. Particularly accurate surveys were conducted over the terraces on which the abutments and the caissons had to be sunk. Over these small areas the line spacing was 1m and the sounding accuracy reached was 5cm. The soundings were reiterated after every riprap compacting operation. Eventually a final "survey as built" was carried out on completion of the works in March 2003 and a compilation plotting sheet at the scale of 1:1,000 together with the digital data was provided to Monaco Government. In summary the result of the surveys was excellent and caissons and abutments were all put in place with the requested accuracy. It should be noted that the accuracy achieved corresponds to that prescribed for the "special order" in Table 1 of the IHO publication S-44 (Accuracy Standards for Hydrographic Surveys). However the horizontal accuracy needed and achieved for this type of survey 0.1 m, is well beyond that of S-44 (2 m) (Figure 7).

Charting the Ports of Monaco

As known the French Hydrographic and Oceanographic Service (SHOM) has always produced by tradition the nautical documentation of Monaco's waters. At present there is the intention to formalise, at governments' level, this co-operation and to adjust the INT charting scheme of the area in order to satisfy the requirement of Monaco. A new chart of the ports of Monaco (Port Hercule and Fontvieille) has been projected and, as requested by the Monaco's Directorate of Maritime Affairs, a preliminary geodetic determination (static mode) of 21 characteristic points in the two ports was carried out by a SHOM team in January 2003. It is expected to produce a new International chart in paper (A0 format) and electronic (ENC) versions.

Conclusion

Grace to the accurate project, the constant dedication of the Government of Monaco and the expertise of the enterprises, the extension of the Port Hercule has been executed with excellent results and now the port is getting ready to host in a much better way than in the past a variety of ships.