BREAKING RECORDS

Constructing a 6km breakwater with the deepest foundations in Europe is an engineering feat, not only because of the scale of the works, but also for the technical expertise and logistics required to execute its multiple phases. Sotiris Kanaris reports.

In February, the construction of the New Genoa Breakwater took another step forward with the installation of the 16th caisson on the seabed. A total of 100 cellular reinforced caissons – measuring up to 33.7m-high, 30m-wide and 66.8m-long – are to be laid at depths as low as 50m to form the breakwater.

Once complete, it will be the deepest offshore breakwater in Europe, approximately 10m deeper than the current titleholder in Algeciras, Spain. Stretching over 6km, it will be the continent's second largest in terms of length.

The sheer size of the caissons makes their fabrication challenging, requiring the development of a unique solution to realise the largest ones. At the same time, the team has to deliver an extensive sequence of offshore works, which precede the placement of the caissons in their final position, with a high-level of precision under tight deadlines.

BRIGHTER FUTURE

Genoa – the capital of northwest Italy's Liguria region – was founded as a trading settlement by the Romans in the 6th century BC, so the development of the city has always been inextricably linked to the development of the port.

The Port of Genoa extends 22km, with its western part hosting the container terminal which has its own breakwater dating from the early 1990s. The new breakwater will protect the oldest part of the port along the Sampierdarena channel, replacing the existing 5.2km-long breakwater built in the 1920s and located 200m from the port.

The existing breakwater is still structurally sound, but there is a need to replace it with one further offshore to allow the port to accommodate the ultra large vessels which have increased in size and number in recent decades.

Currently, if an ultra large container vessel docks along the quay line it leaves no room for other vessels to navigate and sail, which can be a safety issue.

The new breakwater is being built approximately 400m from the existing breakwater and will provide a new 310m wide entrance to the east, an 800m turning basin and a 400m-wide navigation channel. The left entrance will be used by container vessels, and the right entrance by cruise ships and vessels using the marina and dry docks.

Apart from allowing for the transit and manoeuvring of ultra large vessels, the new breakwater will enhance the port's climate resilience and enable the separation of vessels across dedicated lanes according to destination.

Western Ligurian Sea Port Authority is responsible for the governance and development of the Ports of Genoa, Pra', Savona and Vado. Its chief engineer and project manager of the Port of Genoa's new open-sea breakwater Marco Vaccari says: "Over the years we examined around 20 different layouts for the breakwater. The final decision on its construction was made in 2018 and we invested €6.5M (£5.7M) for the preliminary design of the breakwater," he says, adding that a special vessel had to be deployed for an important geotechnical survey.

Vaccari says this was the first time public consultation was undertaken for an Italian port project, highlighting the importance of the feedback given by those working for the coast guard and port in identifying the best layout.

The total project value is approximately £1.2bn. The project has been commissioned by the Western Ligurian Sea Port Authority and is funded by Italian central government, a European Investment Bank loan and the Port Authority.

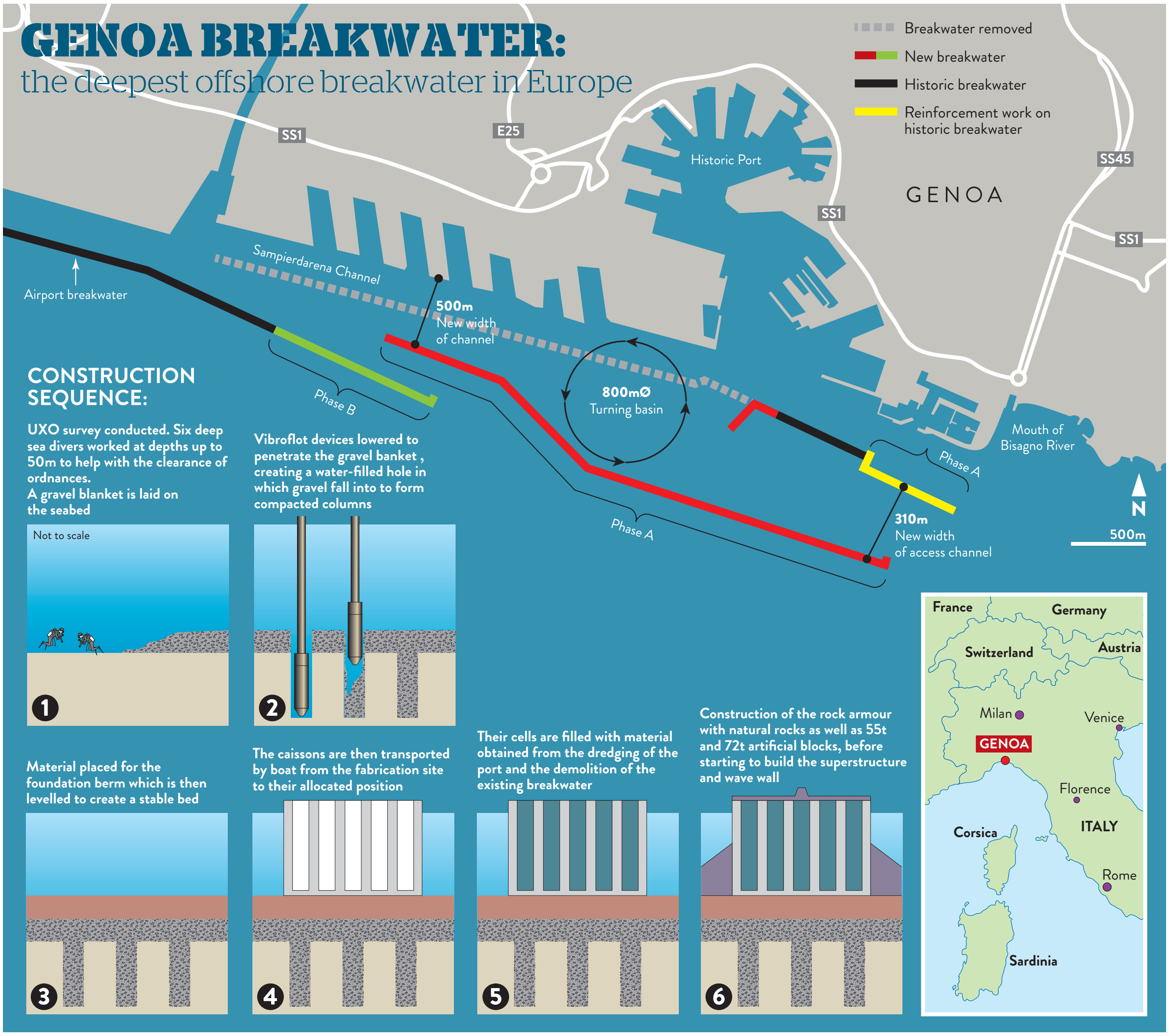
In October 2022, the Port Authority awarded the design and construction contract for Phase A to the PerGenova Breakwater consortium, led by Webuild, which works alongside Fincantieri, Fincosit and Sidra. The value of the contract is £756M.

The construction has been divided into two phases. Phase A involves the construction of 4.8km of breakwater as well as the reinforcement of the easternmost end of the 1.5km of existing breakwater that will not be demolished. 73 caissons will be installed during this phase.

Phase B will see the construction of 1.2km of breakwater west to the one constructed in the previous phase.

Webuild senior executive vice president of operations Nicola Meistro says the contractor drew from its experience in projects around the world for the design and construction of the breakwater.

"One example is the expansion of



the Panama Canal, the so-called Third Set of Locks. Webuild was part of the consortium that built it. We studied the concrete mixes for mass pours. It has helped us with finding the right mixture for the structures that make up the breakwater."

International expertise from outside the consortium also helped in the process. "Detailed 2D and 3D physical modelling was carried out at the HR Wallingford hydraulic laboratory in the United Kingdom to optimise the size of the caissons, superstructure, wave wall and armour layers," says Meistro.

"In the UK we also conducted real-time vessel navigation simulations to evaluate the optimal layout of the new breakwater, in terms of ship accessibility and navigation in the Sampierdarena basin on the part of the next generation ultra-large container ships, with a wide range of simulations performed in response to varying degrees of wind, waves and currents", adds Vaccari.

CAISSONS

Two types of caissons are being used for the construction of the breakwater. The largest ones measure 33.7m high, 30m wide and 66.8m long; while the smaller ones are 18.7-26.7m high, 25m wide and 40m long.

The caissons feature cells – empty cavities – that are filled with dredging or rock material when placed into position. Each of the biggest caissons has 74 cells, while the smaller caissons have 45 each.

All caissons are fabricated at sea – on a barge or floating dock – at the port of Vado Ligure, 20 nautical miles (37km) from Genoa.

The smaller ones are built on a floating drydock called Dario, with four overhead cranes and a tower crane carrying out the lifting activities.

Making the largest caissons requires specialised equipment; with a dedicated system designed and developed by WeBuild, Fincosit and Fagioli.

A Fagioli 1600 lifting system – comprising five cranes – has been erected on a quay, helping the 200 person-strong team erect the caissons on a floating platform.

Floating alongside it is the 110-m long and 45m-wide semi-submersible barge, called Tronds Barge 33. Its ability to submerge itself by up to 15m below the water's surface makes it easier to manage the placement of the caissons.

Credit: Webuild Image Library

All caissons are fabricated at sea – on a barge or floating dock – at the port of Vado Ligure, 37km from Genoa (top picture). Then they are transported by boat to their assigned position (Credit: Port of Genoa)

"The construction method is slipforming," says Meistro. It starts with the assembly of the steel formwork and a releasing agent applied to it. Concrete pouring follows to create the base slab. The next steps involve stripping the slab and lowering the slip formwork. After that, the team installs reinforcement bars and rebar hooks, and then the formwork is raised and concrete poured. The process is repeated until the desired height is reached.

Meistro says the caissons – as well as the superstructure and artificial blocks – are made with CEM III concrete which is popular for marine construction works. "It offers the resistance and durability required for a breakwater. The concrete mixes were designed to optimise casting times and reduce CO_{22} emissions, with the use of at least 5% of recycled material in the composition of most of the concrete mixes."

To date, a total of 20 caissons have been fabricated, three of which are of the largest type.

CONSTRUCTION SEQUENCE

The construction of the breakwater entails numerous phases. The process starts with the UXO (Unexploded Ordnance) survey and the clearance of ordnances along the site where the breakwater will stand.

A team of six deep sea divers from specialist Drafinsub worked at depths of up to 50m to help with the clearance of ordnances. The divers lived in a hyperbaric chamber built on a barge anchored offshore for 28 days. Inside the chamber they were surrounded by a gas mixture made up of 97% helium and 3% oxygen, the same pressure environment as on the seabed, allowing them to work without decompression issues.

Once that process was completed, a gravel blanket was laid on the seabed for the construction of 70,000 stone columns. Vaccari says gravel is transported to site by vessels from quarries in Italy, France and Spain. "It's a very complicated logistic activity, because we have to respect specific deadlines," he emphasises.

The 1100mm-diameter columns with a length up to 13.5m are being installed at depths ranging from 35m to 50m to improve the stability of the caissons and the settlement of the ground.

"They are constructed using vibroflots in a technique called vibroflotation," says Meistro. Vibroflot devices, needle-shaped instruments mounted on cranes, are lowered to penetrate the gravel banket using water and air jets. They create a water-filled hole into which gravel falls to form a compacted column.

Meistro says three floating platforms hosting a total of eight cranes equipped with vibroflots are being used for this operation, with more than 51,000 gravel columns already completed.

The consolidation of the seabed also involves the installation of 3,870 drains up to 22m deep.

Additionally, the project features a very important geotechnical monitoring system, Meistro says, which includes 10 sections with profilometers, extensometers, inclinometers and piezometers installed on the seabed. The system features wireless data transmission to eliminate the risk of cable damage during the work.

The geotechnical monitoring system

The new Genoa Breakwater will protect the oldest part of the port along the Sampierdarena channel. Credit: Webuild Image Library

is formed by a complex automatic system which is being implemented during the construction phases of the breakwater. The scope is to automatically monitor final settlements and excess hydrostatic pressure in the foundation soil over time.

After that the project team places material to form the foundation berm follows. Around 4.2M.t of material, including gravel and all-in aggregate, have already been laid with extreme precision to create a stable bed.

"Then you start levelling the gravel until you reach a horizontal layer because you have to place the caissons on top," says Vaccari. The caissons are then transported by boat from the fabrication site to their allocated position.

"Once they are placed on the rubble mound, their cells are filled with material obtained from the dredging of the port, and the demolition of the existing breakwater (crushed concrete). Material supplied by the Port Authority from other construction sites and dredging works is also used," Meistro adds.

Dredging is undertaken at the port to increase the depth to 18.5m to enable its use by the larger ships. Three vessels have removed nearly 110,000m^3 of sediment from the bottom of the access channels to the outer harbour, with another 700,000m^3 to be dredged during this year.

"Placing the dredging material inside the caissons' cells is a very difficult activity because it requires good weather condition and a good wave height," says Vaccari.

The next phase is the construction of the rock armour with natural rocks as well as 55t and 72t artificial blocks, before starting to build the superstructure and wave wall.

Physical models created at HR Wallingford showed that the seawall's best position is halfway of the caissons' width. This design's objective is to reduce pressure on the breakwater, limit the quantity of overflowing water, and increase the stability of the offshore asset.

The last phase involves the demolition of the former breakwater and the recycling of the material within the project. This was one of numerous actions the client has taken to make the breakwater's construction more sustainable, with another example being the transportation of material by sea rather than road. Apart from the environmental benefits, the client says the reuse of the material will cut costs that would have been derived from its disposal as waste and the purchase of new raw materials.

CHALLENGES

The contract deadline is the end of March 2028, with the team working hard to meet it while overcoming obstacles generated by external factors.

Vaccari says the project's offshore location makes it susceptible to weather conditions. He explains that the bad weather witnessed in Italy over the last few months negatively impacted the discharging of material for the foundation berm, the construction of stone columns and caissons. For the latter, work on the barge and floating dock has to stop when a certain wave height is reached, as it impacts stability of the fabrication area.

He indicates that the biggest challenge will be to ramp up production of the caissons to compensate for the time lost due to adverse weather. "Every week we produce a new time schedule. In terms of the bigger caissons, which will be placed at about 50m depth, we now have to realise a new caisson every 27 days, which is very challenging."

Apart from constructing the new asset, the team is also monitoring movements in the soil beneath the new caissons through a network of sensors. The monitoring system integrates readings across drones and satellite analysis to detect any movements of the individual caissons.

The network of sensors also monitors the level of acoustic and CO_{22} emissions, to ensure minimal impact on marine life while construction activities are taking place. The project team has also partnered with Genoa Aquarium to preserve the local ecosystem and safeguard protected species, including Gorgonian Corals. This partnership involves the temporary transfer to the aquarium and future relocation of marine organisms found on the seabed where the breakwater is being built.

Completion of the project will mark a new era for the Port, as the ability to accommodate bigger container vessels and cruise ships can considerably enhance its business. In addition, the Port Authority highlights that the local and national economy will also benefit as a result of the port's expanded capacity, as new jobs will be generated across the supply chain which will see the demand for their services rise.

Improving access to the port by sea is only one of many objectives of the Western Ligurian Sea Port Authority for the Port of Genoa. The port authority's £3.1bn capital investment plan – of which the breakwater forms part – includes a pipeline of infrastructure projects to improve its accessibility by rail and road. **N**