MOSE A BARRIER FOR VENICE

The floodgates of the Mose system positioned at the northern entrance to the Venice lagoon.

The Mose floodgates were raised this year on 3rd October. By 10:15 am, all the gates were in position and expectations were high as the system began its first real test under critical conditions. The 78 floodgates were raised and the difference in level between the sea and the lagoon rose to 40 cm. The level of the lagoon did not rise any further and Venice was not flooded.
That was the first official test for a structure that had taken almost two decades to build, and which was designed to protect Venice from high tides, events which have become all too common.

A long-waited project

MOSE (an acronym for MOdulo Sperimentale Elettromeccanico, or Experimental Electromechanical Module) is a hydraulic structure designed to hold back water if it rises above a certain level. The structure is like an automated dam with 20 m-wide barriers in various thicknesses that use their own weight and the force of gravity to help them operate. The idea of this kind of system was first suggested 40 years ago. Following numerous delays and public enquiries, construction work commenced 20 years ago and is scheduled to be completed by the end of 2021. The system consists of 78 mobile steel floodgates measuring up to 29 m in height, with each one operating independently. The system is

ON 3RD OCTOBER, 17 YEARS AFTER WORK STARTED, THE SYSTEM OF DAMS DESIGNED TO STOP HIGH TIDES MADE ITS DEBUT. SEVERAL MAPEI PRODUCTS WERE ESPECIALLY DESIGNED TO BUILD THE SYSTEM

Mose is a system of mobile dams that come into service to isolate the lagoon from the open sea during high tides and protect Venice from the risk of flooding

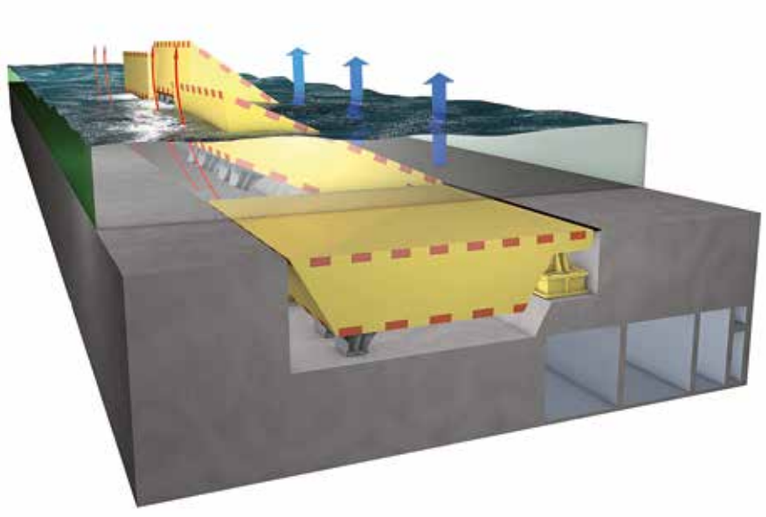
able to isolate the lagoon from the sea during high tides. Other works have also been carried out in the area, such as reinforcing stretches of coastline outside the entrances to the port to alleviate the effect of normal tides and raising quaysides and paving in the lowest areas of the inhabited areas around the lagoon.
The floodgates are housed in concrete caissons positioned on the seabed at the entrances to the three ports on the lagoon - Lido, Malamocco and Chioggia – and are designed to be raised when the tide exceeds a level of 110 cm.
The Mose system is designed to protect Venice and the lagoon from high tides of up to 3 m and from a 60 cm rise in sea-levels over the next 100 years.

Outlets to the open sea

The Mose system is made up of four barriers positioned at the three outlets to the open sea. The widest outlet – which is the one closest to Venice – is positiat Lido and is made up of two channels, each with a different depth. There are two barriers to protect this outlet: the north barrier, which is made up of 21 floodgate modules, and the south barrier with 20 modules. The two barriers are connected by an artificial island where the equipment used to operate and manoeuvre the system is located.
The entrance to the port of Malamocco is the deepest in the lagoon. This is the one used by ships heading to the industrial and commercial port, which is why a navigable basin has been constructed for the ships. The barrier at this entrance is made up of 19 floodgates.
The entrance to the port of Chioggia is used mainly by fishing boats and pleasure craft and a sheltered port with a double navigable basin has been constructed so that boats can enter and exit the port, even when the barrier is closed. This opening is protected by 18 floodgates.

How the Mose system works

When the floodgates are in stand-by mode they are completely invisible, full of water and sitting in caissons on the seabed.
When there is a high tide that could potentially flood the surrounding area, compressed air is pumped into the gates to displace the water. As the water is expelled from the floodgates, they swivel on their hinges, rise up out of the caissons and block the entrances to the lagoon. On average, the time required for the floodgates to seal off the port entrances – including the time required to manoeuvre the floodgates into position – is 4 to 5 hours.
The gates only remain in this position during high tide. When the tide ebbs and the lagoon and the sea reach the same level, the floodgates fill with water and then retract into their housing.
Each floodgate is made up of a hollow metal structure which is attached to the caisson housing with two hinges.
Each floodgate is 20 m wide, while their height depends on the depth of the port entrance channel where they are positioned and their thickness also varies.
The caissons housing the floodgates and the mechanisms used to manoeuvre them form the base of the barrier and are connected to each other by an inspection tunnel.
The structure that connects the barriers to dry land is made up of large support housings which contain all the equipment and plants required to make the gates operate correctly.



TOP. The floodgates being manoeuvred into position at the entrance to the port of Chioggia:
LEFT. The floodgates are housed in caissons sitting on the seabed. When there is a high tide, they rise up and block the sea at the entrance to the lagoon.

BACKGROUND AND FIGURES

1984
A team of experts is commissioned to carry out a feasibility study for a system to protect Venice from high tides.

1992
The Mose project is presented. The objective is to build it in three years. Construction of the mobile dams only gets underway in 2003 with a target completion date of 2016.

2013
The first gate is raised in October 2013, but enquiries and court cases lead to a block being put on all the open sites until work finally recommences in 2018.

2020
On 3rd October, all 78 gates are raised for the first time and stop the level of the tide in the lagoon at 70 cm. Venice is not flooded. Completion of the Mose project is scheduled for the end of 2021.

Costs of the project

5.5 billion Euros
to construct Mose

700 million Euros
cost of repairs to structures damaged and deteriorated over the years

100 million Euros/year
cost of routine maintenance

Source of information in the article: Italian Ministry of Infrastructures and Transport - Interregional Department of Public Works for Veneto - Trentino Alto Adige - Friuli Venezia Giulia, former Magistracy for the Waters of the Province of Venice.

MAPEI SOLUTIONS FOR THE MOSE PROJECT

Mapei took part in the Mose project as a technical partner and had a dedicated team that regularly interfaced with design engineers, works directors and contractors. The company's Technical Services, working in tandem with the Research & Development laboratories, proposed several special, innovative, high-performance products.

Grouting the joints

MAPEFILL MF 610 was specifically developed for this project and used for grouting the joints and creating the watertight seal required in order to connect them with their matching fittings on the caissons housing the floodgates.

The caisson housings were positioned in sequence in a trench and were connected together with a special jointing system made up of two separate elements to form a watertight seal. The first element of the system is the so-called "Gina ring-joint" that keeps the external part watertight and forms a temporary watertight seal between one caisson and the next one while they are being installed. The second element is the "Omega seal" which is installed inside the Gina joint during construction of the caissons and guarantees that the entire caisson remains watertight.

Reo-plastic concrete was required for this job to ensure it would maintain a high level of workability at high temperatures (around 3 hours at +35 °C). The Gina collar used to house the joint was made from super-duplex stainless steel, an extremely expensive material that left no margin for error during installation.

1. Reinforced concrete caissons used in the Mose project during their manufacture. The joint housings for the caissons were connected together with a jointing system made up with MAPEFILL MF 610.
2. Preparing and positioning formwork on the caissons before pumping MAPEFILL MF 610.

HOW WE SOLVED THE PROBLEM OF THE HINGES

WE SPOKE WITH ENRICO PELLEGRINI, FORMER SITE MANAGER FOR GRANDI LAVORI FINCOSIT S.P.A.

Mr. Pellegrini, what role did you have in the Mose project?

From 2005 to 2015 I was the manager of the site where the precast concrete caissons were manufactured for the inlets to the ports of Lido San Nicolò and Malamocco. The site was located on a 13-hectare artificial embankment created specifically for the project on the island of Pellestrina.

Which part of the work on the Mose project proved to be the most challenging with regards to its design and the materials to be applied?

The structure of the Mose barriers is made up of two main elements: the reinforced concrete caissons, which anchor the barrier to the seabed, and the metal floodgates, which are those big, yellow boxes which we can see rising up out of the sea to stop high tides.

The two elements are joined together by a highly sophisticated device: the hinge.

The caissons are fixed permanently to the seabed, whereas the metal floodgates can be removed periodically to carry out scheduled maintenance work.

This means that the hinge element must allow the floodgates to be disconnected from the caissons, which is why it is made out of two parts: the female part, which is fastened permanently to the caisson, and the male part, which is an integral part of the floodgate.

To anchor the steel female part to such an enormous reinforced concrete structure (the largest caissons are as big as a three-story apartment block) with pinpoint precision was a really challenging design and construction matter, which we managed to overcome by applying materials of the very highest quality and by planning the application procedures down to the minutest details.

What problems did you have to overcome to anchor the hinges in place?

It was extremely important that the female hinges integrated with the foundation structure to perfection.

The difference of the two materials (reinforced concrete and steel), in terms of thermal and elastic behaviour, the difference in the design codes and construction methods applied, as well as the need to create a seal that would remain perfectly watertight at a great depth, required a very careful, in-depth study of the behaviour of the two elements when joined in one single element.

Which is why MAPEFILL MF was chosen; a product that would be able to guarantee the maximum level of adhesion between the two elements, with high mechanical properties, while maintaining sufficient elasticity and the ability to be distributed into any tiny gaps in the spaces left to connect the two elements together.

The hinges for the barriers are the technological heart of the mobile barriers

Any structure immersed in water must be fully waterproof. What were the most significant characteristics of this part of the work?

As I mentioned previously, while the floodgates will have to be extracted so their protective waterproofing system can be replaced and maintained at regular intervals, this won't be possible for the concrete caissons.

This made it extremely important to design one or several systems that would completely waterproof the structure. This is why, for the construction joints, three waterstop systems were provided, with the external one coated with a cementitious waterproofing membrane. In spite of all these precautions, after carrying out a thorough analysis of the costs and benefits, the contractor decided on site to integrate these safety systems even further by treating the entire surface of the caissons, from top to bottom, with a specially designed formula of MAPELASTIC FOUNDATION mortar, which was further integrated by applying a coat of a primer specifically designed by the Mapei R&D laboratories.

Because of the new materials and technologies adopted, do you think the Mose site can be considered a pilot project for other sites of this type?

Obviously I can only speak for the work carried out on the site I was involved with, but I would say that, more

3. The precast concrete caissons being manufactured in the Malamocco site.

than anything else, it was the way the project was managed from a technical point of view that could be used as an example of how to set up a major works site. One such example is the care taken in choosing the right materials, which was dictated not only by the principles of affordability, but also by means of a long series of tests and cost/benefit evaluations.

You worked very closely with Mapei Technical Services and the company's R&D laboratories in Milan.
How did this team-approach work exactly?
I was in no doubt about MAPELASTIC's waterproofing capacity and elasticity, but I was still concerned about two factors: how strongly it would bond to the substrate and its durability.
That's why I personally wrote out a procedure which included an extensive range of tests to be performed on-site to demonstrate which would be the best technology to prepare the base, but also which was the best primer to apply in order to guarantee the highest level of adhesion for the membrane.
The Mapei product performed better than those of the competitors, thanks also to the direct and prompt interest shown by the company's R&D lab, which made some slight modifications which greatly improved its final performance properties.
Besides, it was really comforting to be able to rely on an experiment carried out by the laboratory at the Polytechnic of Milan, which demonstrated that MAPELASTIC maintains its performance properties, even after a series of extended immersion cycles in seawater.
Also worth highlighting is how the Mapei lab followed our progress throughout the entire construction, which lasted around one year, by coming to monitor and test the application of the product on a regular basis.
We found this to be very reassuring and it provided us with a further guarantee of the final quality of the work we carried out on site.

It was extremely important to design one or several systems that would completely waterproof the caissons

The Gina joint was connected to the concrete caisson by pumping MAPEFILL MF 610 into formwork.
This is a fibre-reinforced powdered grout made from high strength cement, selected aggregates, special admixtures and polyacrylonitrile synthetic fibres. When mixed with water, it forms a fluid grout which does not segregate and is able to-flow even into spaces with a complicated shape.
The product has low capillary absorption (complying with EN 13057), is highly impermeable to water, adheres very strongly to iron and concrete and is highly resistant to mechanical stress, including dynamic stress.
Thanks to its performance characteristics, MAPEFILL MF 610 fulfilled all the client's requirements during both the application phase and the qualification tests.

4 and 5. The metal floodgates are anchored to the reinforced concrete caissons with a hinge mechanism which allows them to be raised and lowered. The hinges were anchored using MAPEFILL MF, an expansive, fluid mortar especially designed for this site.

Anchoring the hinges and waterproofing the caissons
The metal floodgates, which are raised when required to block high tides, are anchored to the reinforced concrete caissons with a hinge mechanism which allows them to be raised and lowered. As Enrico Pellegrini, former Site Manager for Grandi Lavori Fincosit SpA, explained in the interview on the previous pages, to anchor the hinges to the caissons, a great deal of design work and testing was conducted to identify the most appropriate products and technology to fasten a metal component, in this case the hinge, to concrete.
Mapei specifically developed MAPEFILL MF for this application, an expansive, fluid mortar for anchoring elements in position with great precision. The mortar was applied by injecting it into one side of the hinge and then it flowed to perfectly saturate all the gaps and free spaces to form a single, solid body with the caisson it was anchored to.
The waterproofing system for the caissons, which are then placed on the seabed, also had to be carefully designed and thoroughly tested in order to identify products that would guarantee excellent, long-lasting results. After performing tests on site and in the lab, the external surface of the caissons was treated with MAPELASTIC FOUNDATION, a two-component, flexible cementitious mortar for waterproofing concrete surfaces subjected to both negative and positive hydraulic pressure.
The product chosen for the inside of the caissons, on the other hand, was MAPELASTIC two-component, flexible cementitious mortar. It was applied after treating the substrates with a specially designed version of PRIMER 3296.
This part of the work, as with the challenge of anchoring the hinges, was closely followed by the Mapei Research & Development Laboratory in Milan, which carried out testing on the application of the products for the entire duration of the site.

TECHNICAL DATA
MO.S.E. (Experimental Electromechanical Module), Venice (Italy)
Period of construction: 2003-ongoing
Period of the Mapei intervention: 2007-2015
Intervention by Mapei: supplying products for grouting the Gina joints, anchoring the hinges, waterproofing the caissons
Design: Italian Ministry of Public Works, Technital
Owner: Italian Ministry of Infrastructures and Transport - Interregional Department of Public Works for Veneto - Trentino Alto Adige - Friuli Venezia Giulia, former Magistracy for the Waters of the Province of Venice
Malamocco site director: Enrico Pellegrini
Malamocco site main contractor: Grandi Lavori Fincosit SpA
Mapei coordinators: Claudio Azzena, Pasquale Zaffaroni, Renato Pasqualato, Mauro Orlando (Mapei SpA), Orlando Sas

MAPEI PRODUCTS
Sealing Gina joints:
Mapefill MF 610
Anchoring the hinges:
Mapefill MF
Waterproofing caissons:
Primer 3296, Mapelastic, Mapelastic Foundation

For further information on products see mapei.com