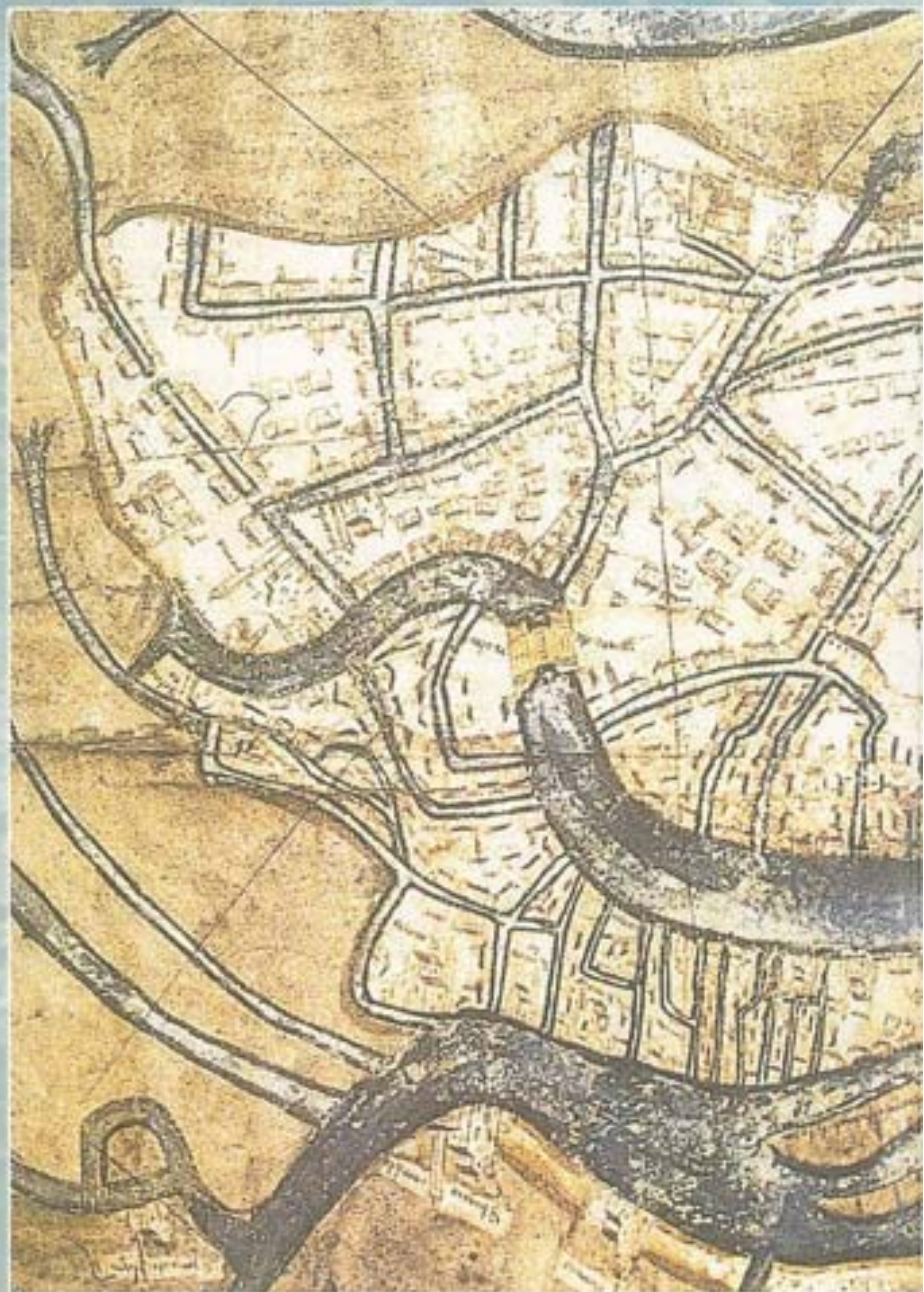
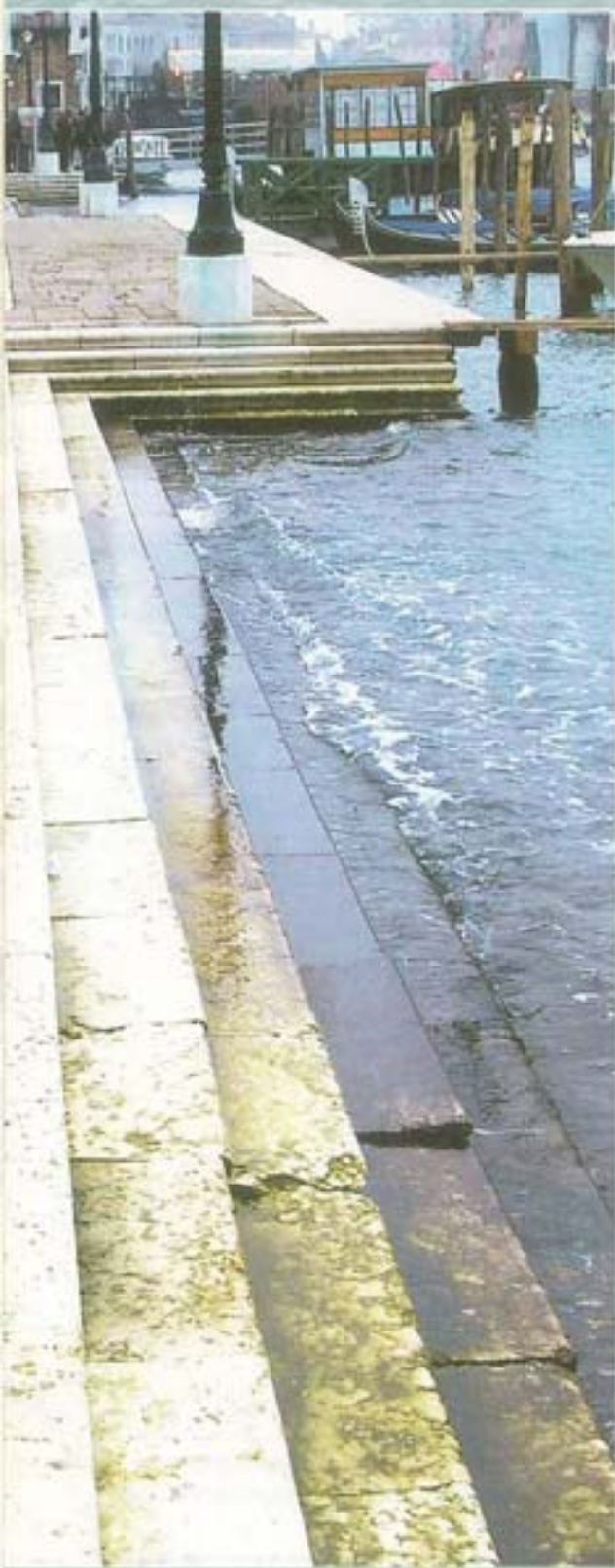


Maintaining the



Redeveloping the canals and banks of a stunningly beautiful city like Venice is no easy matter.

Venice is not just a very special city because of its unique artistic beauty and heritage, but also because of the peculiar structural engineering problems involved in architectural renovation and maintenance operations. The tricky undertaking of maintaining the canals was already an issue back in the days of the Venice Republic, when work had already begun on salvaging the canals despite all the tidal action. Over recent years there has been growing pressure to work on the walls along the banks, which has not just meant repairing the most obvious cases of damage and instability, but also providing suitable means of prevention, monitoring of random factors, and containing the damage they cause. These problems have required

Canals of Venice



Photo 1.
Picture of a canal during maintenance work. Note the injection pipe stems already set in place.

Photo 2.
The bank walls in Venice are made from various building materials: the photo shows the example of a brick wall.

careful planning of operations serving reinforcement, maintenance and protection purposes. Down the years intensive special maintenance work has been carried out on the banks of the Venetian canals as part of what is known as the "Integrated Canals Project" financed through special law no.139 of 1992. Excavating the canals and repairing their banks together form the main and most urgent part of an extensive special maintenance, hygiene-improvement and building programme for the city of Venice, which also involves maintenance of the bridges, rationalising sub-services and repairing the sewers. The urgency of the

programme mainly derives from the actual level of the canals, which, ever since the 1980s, has even been creating internal navigation and safety problems. Drying out the canals, required for getting rid of all of the mud, made it possible to uncover the banks and carry out systematic cleaning and maintenance operations on them. Canals actually inside the city of Venice extend over a distance of 45 kilometres and, if we add those in Murano and Burano, the figure increases to about 49, 42 of which in need of dry excavation.

Damage to the Banks

The last time proper dry maintenance

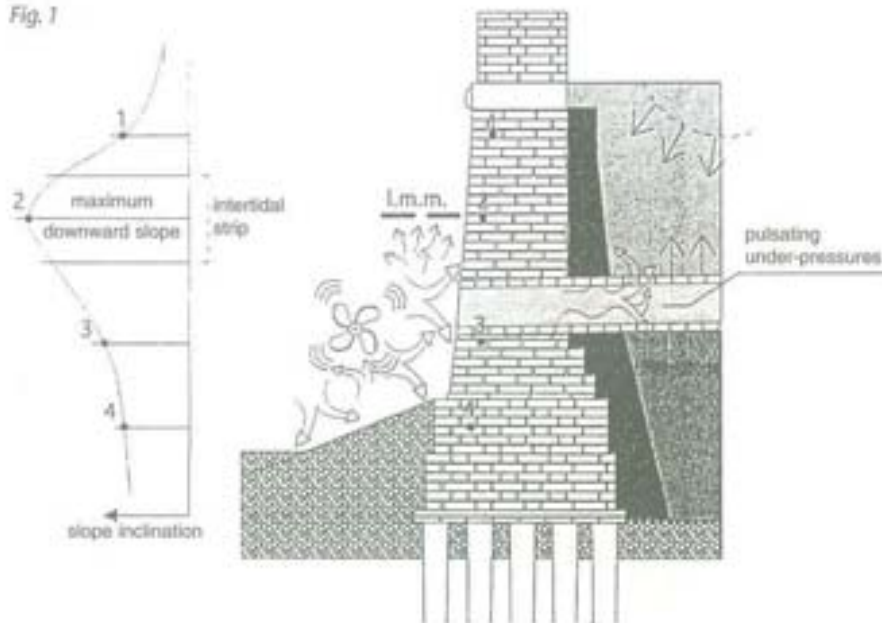
operations were carried out on the canals was in the mid-1960s, and the precarious state of the banks has clearly emerged whenever there are low tides. But only in the most serious and urgent cases have any operations been carried out to remove the mud from water in the central sections of the canals. The amount of sediment that has built up along the banks has concealed the true state of the foundations, which only becomes apparent when the canals are dry and the mud can be removed. Indeed, even though field surveys can be carried out during the planning-design phase, there are inevitably plenty of surprises in store when the foundations are uncovered, often calling for alterations to the original projects to cope with the unexpected. Damage to the banks may vary in extent, ranging from just a loss of impermeability due to grouting being washed away around cracks or cracks in the facing, a loss of constituent elements or even holes inside the structure causing parts of the walls to actually cave in. All the damage and disrepair is also due to heavy motorised nautical traffic, the ebb and flow of high and low tides, blocked drains and sewers, rising damp causing the crystallisation of salts, the quality and age of materials, and the frequency of maintenance operations.

As has already been mentioned, not all the banks show the same extent of disrepair, so the amount of repair work required also varies in relation to the actual state of the banks at the time when it is carried out. Based on the state of repair assessed after removing sediment, different salvage operations need to be carried out: from simple re-waterproofing work to the reconstruction of missing parts of the wall facing.

Mapei Operations

The delicate issue of the maintenance of banks and canals, and the kind of damage and disrepair they suffer due to the gradual wearing away of bank walls, has called for careful scheduling of operations, both when first being carried out and then later during maintenance and protection work. Unless the constant washing effect of the water, that is

Fig. 1



seeping more and more easily into the underwater walling, is effectively combated, then the banks are gradually weakened and the bearing structure suffers increasingly serious damage. Unless quick and effective action is taken, the worsening state of general



Photo 3. A dry canal. *Stabilcem*, a superfluid expanding cement binder used for filling cracks and cavities and porous gaps in rock and concrete, is injected into the canal bank. The product has here been used in the HV (high viscosity) version, specially developed for this building work.

decay will in future force the city council and private bodies to carry out more elaborate and tricky repair work. In actual fact, taking prompt action to repair the damage and decay means less invasive and intrusive work is required, calling at most for only partial demolition and reconstruction of the bank structures. Constant monitoring of the state of decay and careful attention to damage suffered by the constructions, followed by prompt remedial action prevent the damage from spreading, so that extensive tricky repair work, that might jeopardise the basic structures and be extremely costly, can be avoided. The repair work is carefully designed to ensure the walls serve their purpose, only carrying out indispensable operations and avoiding anything superfluous. However obvious it



Figure 1.
How cavities form on
the wall faces.

Figure 2.
Excavations in the
presence of water for
maintenance and
hygiene purposes.

The two figures are
taken from: I. Turlo, *Foundations and canal
beds in "Le fondazioni
degli edifici a Venezia",
Minutes from the
Conference of Venetian
Architects, Ateneo
Veneto, December
1994.*

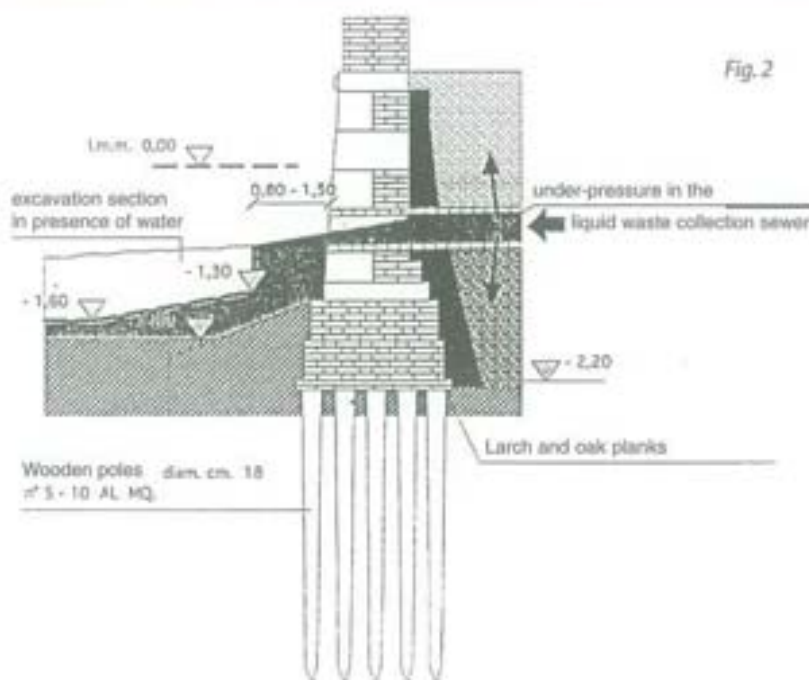


Photo 4.
The HV version of
Stabilcem is made by
incorporating additives
with microsilica-based
components improving
the properties of the
cement system and
making the paste more
cohesive, mechanically
resistant and
impermeable, as well
as making it easier to
pump the concrete.

Photo 5.
Stabilcem is injected
after sealing the grouts
on the wooden coating
with Mapegrout T60S,
a mortar resistant to
chlorides and
sulphates.

Photo 6.
A protective layer of
plaster was applied at
the foot of the
foundations using
Mapegrout T60S as a
mortar and an
electrically welded
stainless steel mesh.
The mesh was "guided"
into position to
withstand the ebb and
flow of the tides and
constant aggressive
action of the water,
and to act as plaster-
carrier reinforcement
to make it more
resistant to accidental
bumps and bangs.

might seem, this calls for special efforts by technicians, based on plenty of well-documented information about the extent of damage, missing parts and structural anomalies incurring. This data is then cross-checked and compared with in-depth knowledge about the physical nature of the construction, properties and characteristics of the materials used to make it, construction techniques, static data, structural engineering information, and how they all vary over time. Bearing these factors in hand, Mapei, which has already worked very successfully on bridges in Venice like the one over Rio Marin, suggested solutions which, when put to the test, managed to combine technological and architectural factors, using injection mortars with average resistances even in the walls along the canal banks of between 18-28 N/mm². In a setting like this, using injections to strengthen walls turned out to be easily the most effective technique, thanks also to research work carried out in Mapei laboratories allowing products to be formulated with compounds containing microsilicas, whose granules are ten times smaller than cement's. The formation of a large number of small crystals increases the properties of the paste's microstructure reducing its porosity in favour of resistance and hence durability through time, despite the action of sea water. The work was carried out using STABILCEM®, a superfluid expanding cement binder injected into holes and cavities and filling porosity in concrete and rock. The product soon proved its versatility when used on cavities in wall faces forming due to the cavity-forming effect of salt water. A HV (high viscosity) version of STABILCEM® was prepared for this application by incorporating additives with micro-silica based components, which improve the cement system's properties, make

the paste more cohesive, and give it greater mechanical resistance and impermeability, as well as making it easier to pump the concrete. All this can be done by saturating the empty spaces without having to struggle to place it in the canals or neighbouring areas. To prevent such difficulties, STABILCEM®'s original formula has been altered to slow down the system's rheological properties, so that the viscosity can vary when pressure on the mass drops, thereby keeping the sodium and chloride's chemical resistance stable. This ensures the gaps in the



7

walls are filled while guaranteeing the injected product does not decay over time, even if subject to both mechanical and chemical stress. The product's properties produce a smooth-flowing and cohesive paste, keeping its fluid-expansive characteristics unaltered without bleeding or segregation risks. This means the muddy residue in the wall structure is useful again, due to both their beneficial retaining/interstitial-saturation action and to positive alterations to mechanical resistance and elastic modulus. After sealing the grouts in the wooden coating using MAPEGROUT T60S*,

a sulphate-resistant fibre-reinforced controlled-shrinkage mortar resistant to chlorides and sulphates, the injection holds even, as in this case, in the presence of wet environments or where water is likely to seep in.

At the foot of the foundations, from less than 70 centimetres from the average sea level to the bottom of the canal, an approximately 6 cm protective layer of MAPEGROUT T60S* was applied using stainless steel mesh (measuring 10x10 calibre 5).

The mesh had to be "guided" into position to prevent expansion as the product was setting

Photo 7.
The foundations of Arzere after renovation work carried out by injecting HV Stabilcem in the bank walls and facing the main block using Mapegrout T60S.

(chosen to withstand tidal action and the aggressive effects of water) and also to act as a grout-carrier support helping to prevent damage due to bumps and bangs.

The sheer scope of the operations involved meant it took months to complete and called for serious team work involving Mapei in the front line with its own technicians, but also Insula Spa, notably the engineer, Mr. Ivano Turlon, and the surveyor, Mr. Giuliano Molon – respectively the technical manager and project manager – for the various technical solutions required; there were also important working partnerships with various design firms represented by the engineers Luigi and Stefano Muffato, Giovanni Cocco and Daniele Rinaldo. The building firms involved in the project carried out preparatory work for making the injections and getting the concrete and cement ready for the banks, so that salvage work could be carried out on the canals at S. Stefano, S. Trovaso and Fondamenta dell'Arzere.

These important operations on Venetian canals are part of a more extensive programme of maintenance and conservation work for the whole of the city of Venice, also now involving bridge renovation and redevelopment work. For all these operations, which are already under way, Insula once again opted to work with Mapei, which developed some new systems, such as carbon fibres used for salvaging the bridges.

Generally speaking, a major project has been set in motion, which will take a long but definite time to complete and will certainly have an impact on city life.

"The products referred to in this article belong to the "Building Speciality Line". The technical charts are available from the "Mapei Global Infonet" CD and Internet site: www.mapei.com.

Mapegrout T60S: a sulphate-resistant fibre-reinforced thixotropic mortar for repairing concrete.

Stabilcem: a superfluid expanding cement binder for injection slurries, mortars and concretes. Here used in the specially developed HV (high viscosity) version.



TECHNICAL DATA

Venice canals, Italy

Work: repair and maintenance of canals and banks in the Venetian districts of S. Stefano, S. Trovaso and Fondamenta dell'Arzere.

Contractor: Insula Spa, Venice
Project and Works Management: Luigi Muffato, Sinergo Engineering from Martellago (Venice)

Building Firms: Rossi Costruzioni from Marcon (Venice), Edilcostruzioni from Camponogara (Venice) for CO.DEMAR, from Valli did Chioggia (Venice), Tiozzo Costruzioni from Mestre (Venice)

Year: 2000-2001

Mapei Products: MAPEGROUT T60S, STABILCEM

Mapei Co-ordinator: Paolo Alberti, Mauro Orlando and Pasquale Zaffaroni.

