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VENETIAN TASK

Moving a 22t drill rig for work in Venice's historic St Marks Square

The micro-driller is transported to St Mark's Square on a pontoon

VENETIAN VALUES

An intricate operation was needed to get a drill rig into position for work on the foundations of the bell tower in St Mark's Square, Venice. *EF* reports.

The Campanile di San Marco, Venice's 99m high bell tower, is affectionately known by Venetians as "el paron de casa" or "lord of the house". But for many years there has been concern that the lord is not as stable as he should be, and the structure has been subject to monitoring and evaluation, particularly its foundations.

The tower rises over St Mark's Square, and is one of the city's major tourist attractions. However, the structure visitors see today is not the 10th century original. Over 900 years the tower was expanded and remodelled, including significant reconstruction in the early 16th century after it was damaged by an earthquake.

In July 1902 the tower collapsed, and the structure in St Mark's today is an exact replica commissioned by the city's mayor afterwards, which was completed in 1912.

In the zeal of ordering the reconstruction process, mayor Filippo Grimiani (who immortalised the bell tower's rebuilding with the phrase "com'era, dov'era" or "as it was, where it was"), neglected to see that the foundation design would ensure the tower's long-term stability.

To avoid concentrating the loads on a relatively small surface, the new base structure involved strengthening the existing foundations by adding 3,000 larchwood piles, roughly 4m long, with large blocks of Istria stone and trachyte laid on top.

Although this was offered as the definitive solution, it was not to be, as insufficient cohesion between the existing foundations and the new containment system resulted in an uneven distribution of the loads, immediately producing new, albeit minor, damage to the structure.

> The bell tower today is slightly out of plumb, a defect that can be seen from certain angles even with the naked eye

Throughout the last century the bell tower underwent monitoring to ascertain its condition, specifically the extent to which cracks in the structure had advanced.

The combination of the natural corrosion of the poles from the brackish water and the micro-vibrations generated by the constant flow of tourists has aggravated the problem.

Although analysis shows that the cracks do not put the stability of the tower at risk, their existence calls for an appropriate intervention to solve the problem once and for all.

Moreover, the bell tower today is slightly out of plumb, a defect that can be seen from certain angles even with the naked eye – possibly further proof that the loads are not perfectly distributed at the base of the structure.

After a set of thorough analyses by the superintendent for architectural and landscape heritage of Venice, it was decided that the existing foundations should be consolidated by strapping a titanium "belt" around them.

The belt is, in fact, a double system of dynamometric chains, each composed of two titanium bars placed 200mm apart. Titanium was chosen for its resistance to salt-induced corrosion.

The 60mm bars are anchored to specially moulded blocks, which offset the foundation structures. The first "strap" will be constructed 400mm below the pavement, with the second about 2.5m below.

This solution best distributes the loads on the foundations without disrupting the original structure, and is similar to that successfully implemented for the façade of St Peter's Basilica in Rome.

It also has the advantage of allowing tourist access to the tower during the various stages of construction.

A special platform was used to distribute the nearly 22t of weight efficiently

The rig in position in the square

To allow the bars and offsetting blocks to be laid, and to enable future maintenance, the project involves constructing a series of small chambers at a depth of almost 4m beneath the pavement of St Mark's Square – one chamber for each corner of the bell tower and three intermediate chambers. These chambers have vertical walls but an irregular geometry.

Excavating these chambers safely under a 4m head of water, while avoiding slopes and drainage of groundwater, calls for the consolidation and waterproofing of the soil that makes up the walls and the bottom of the excavated area. This is being achieved by installing micro-piles through insitu wet soil mixing, reinforced with steel pipes.

Ground consolidation will be achieved with a mixing tool that breaks up and mechanically mixes the soil, at the same time adding a bond of water and cement.

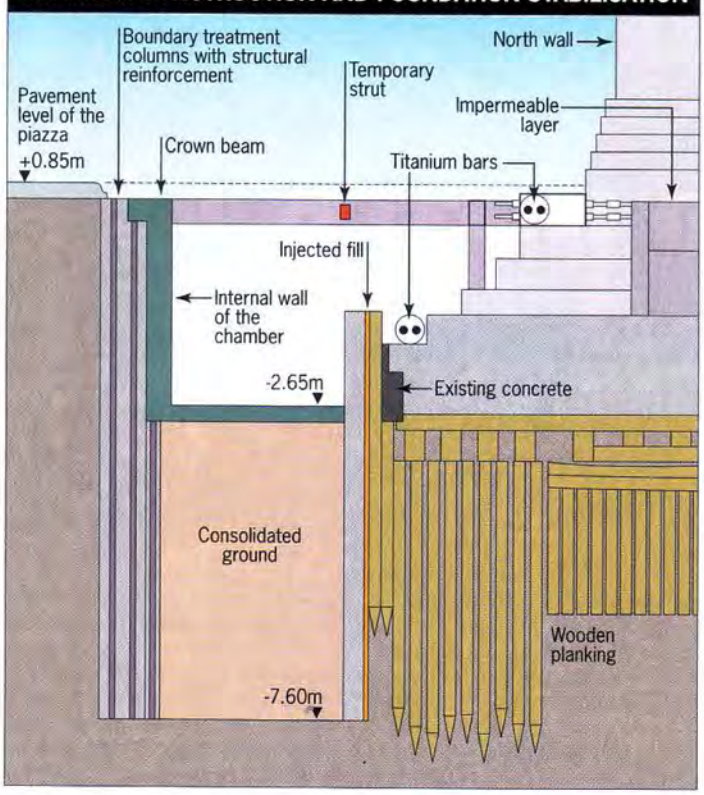
The choice of this technology stems from the need to minimise disturbance to the ground, and consequently to the bell tower's foundations, not to mention priceless works of art in its proximity.

The conservation group in charge of the restoration is Consortium Venezia Nuova (CVN), which has a concession with Venice's ministry of infrastructure and transport for works to conserve and protect the city and the lagoon.

The consortium is made up of large Italian construction firms, co-operatives and local contractors who have special logistical and operative capabilities.

CVN awarded the contract to consolidate the bell tower's foundations to consortium member Sacaim in 2008, and the contractor in turn sub-contracted the ground engineering works to Trevi Spa. The sub-contractor is using a Soilmec SM21 micro-drilling rig to install the piles.

CHAMBER CONSTRUCTION AND FOUNDATION STABILISATION



The machine was delivered to the site in early August 2009 after a major logistical exercise to work out how to get it into the centre of the historic square. It arrived at San Marco by water, having been loaded onto a pontoon at the pier at Cavallino Treporti, on the edge of the Venice lagoon.

Getting it from the water's edge to the work site surrounding the bell tower involved building a special platform that could efficiently distribute the nearly 22t of weight.

The platform was deemed necessary after evaluations confirmed that the masegni, or slab stones, in Euganea grey trachyte at the start of the route (the small square in front of the Biblioteca Marciana and St Mark's Square) could withstand a maximum load of only around 3kN/m2.

This meant that transporting the drilling machine would be a critical operation, exerting tangential stresses onto the pavement due to the changes in direction of the pathway, including an S-shaped curve between the landing point and the columns of St Mark and St Todaro, and another tight curve to enter the work site.

The technology being used will minimise disturbance to the ground and consequently to the bell tower's foundations

A platform capable of distributing the loads was built using 150mm of sand and a layer of neoprene, covered with wooden beams, over which were placed I-beams. To avoid their movement during the move, the I-beams were blocked laterally with retainers anchored to the wood beams.

The platform could not cover the entire 160m of the route, so the drilling machine was moved in four stages of 40m each, which also minimised inconvenience to tourists. After each stage the platform was disassembled, then reassembled in front of the machine, and in less than a week it arrived at its destination.

Construction started last year, and completion is scheduled for some time between late 2011 and early 2012. Much of the next two years will be spent installing the micro-piles and building the chambers.