Futureproofing and safeguarding heritage structures through sensing

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The project

There are many historic buildings, monuments and structures in the UK that require measures to protect and conserve them. CSIC is working alongside industry to deliver sensing innovations to help asset owners better understand the behaviour of existing structures in order to safeguard them against new construction activity and to futureproof to enable continued use. This work includes monitoring the Victoria and Albert Museum (V&A) in London during deep basement excavations and monitoring masonry vaults at sites around the UK.

During deep basement excavation work at the V&A, the safety of the adjacent exhibits and building was paramount. CSIC, led by CSIC Research Associate Loizos Pelecanos, installed fibre optic (FO) cables to measure movement and temperature at critical locations in the building's foundations. Seven readings have been taken at significant points during the construction process, to assess basement heave, detect any changes to the foundation slabs, and to monitor the performance of the tension piles. This project marks the first time this type of monitoring has been possible.

Masonry vault structures form an important part of the UK's legacy infrastructure in tunnels and across the rail network. These structures are vulnerable to high service loads and ground settlements so understanding the behaviour of these assets will be key to securing their continued effective use. CSIC's masonry vault research, led by Co-Investigator Matthew DeJong with Research Asssociate Sinan Açıkgöz, aims to quantify the vulnerability of these structures and provide detailed and accurate data to better inform maintenance programmes and asset management. Conventional point sensors (e.g. strain and displacement gauges) only measure the behaviour of the material at the sensor location and do not provide sufficient information. CSIC has developed distributed sensing techniques using fibre optics, laser scanning and photogrammetry which sense continuous response along the structure, both under static and dynamic loads. These techniques enable sensitive detection of local damage, as well as a comprehensive description of global deformations.

The innovation

CSIC instrumented two piles and a part of the foundation slab at the V&A with two pairs of FO cables, one for measuring changes in strain and the other temperature. Any applied load or temperature causes changes in the frequency content of light propagated through an optical fibre. By measuring this frequency change, CSIC is able to back-calculate the induced load or temperature to deliver detailed information about the integrity of the underground structure and additional assets of the museum that no other sensor device can provide.
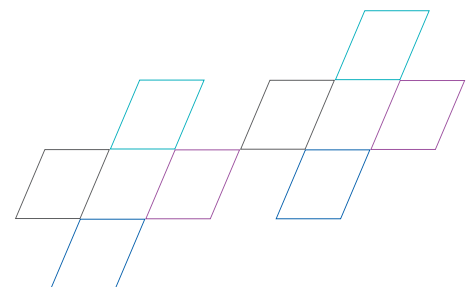
CSIC is using distributed sensing to deliver unprecedented detail concerning the response of masonry arches to short and long term effects. Various FO cables attached to the structure can measure the strain experienced along their length, providing detailed information on the dynamic behaviour, as well as long term static changes in the structure due to structural degradation and ground settlements. In particular, the novel use of Brillouin Optical Time Domain Reflectometry (BOTDR) for assessing the dynamic loads on the structure, represents a new technical advancement.

The non-contact laser scanning and photogrammetry sensing solutions provide further new insight on the response of masonry vaults. In particular, by investigating the precise 3D geometry quantified by laser scanners, it is possible to quantify the historic displacements experienced by the structure. New software has been developed for this purpose. Furthermore, CSIC utilises commercial photogrammetric tools, to detect the 3D movements of the masonry structures during dynamic loading. Overall, the sensing data from these new technologies complement one another and provide engineers with data to calibrate mechanical models of masonry to better understand the response of the critical masonry assets.

Impact and value

- the construction team at the V&A receives detailed information about the integrity of the underground structure which is of value to the contractor (safety), consultant (checks and improves design), and asset owner (ensures safety of heritage building)
- future use of this method could inform adjustment of design prior to construction, based on the actual performance of the tension piles, resulting in savings in material costs and greater confidence in design
- CSIC's ongoing research on new technologies of monitoring masonry arches improves the use of FO, laser scanning and photogrammetry techniques to offer effective and pervasive sensing that delivers a better understanding of assets and their state
- in general, new sensing techniques provide an unprecedented level of detail and a better appreciation of structural response to a range of factors. Asset owners can use this information to calculate risk and monitor complex engineering works carried out in the vicinity of historic structures
- smarter information confirms operations are safe for construction and better equips asset managers/owners to make decisions about the project.

Industry Partners

V&A   ARUP   Wates   NetworkRail   COSTAIN   TOPCON