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Towards an effective fusion of satellite InSAR and in-situ data for structural assessment and monitoring of heritage buildings: first experiences in Gubbio and Heraklion

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The preventive conservation of historical constructions and heritage sites against natural hazards, such as extreme climate events, floodings and earthquakes, is a major societal and scientific challenge of European countries that is highly stimulating intersectorial and multidisciplinary research efforts. This work is aimed at presenting some results of ongoing research activities concerning the fusion of deformation measurements from satellite synthetic aperture radar (SAR) interferometry (InSAR) data and in situ monitoring technologies, for structural assessment of monumental buildings.

Activities presented in the work have been carried out within HERACLES European research project that has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 700395. The project covers three test beds affected by various forms of material and structural degradation, mostly caused by climate-change related hazards. These are: the city of Gubbio in Italy (in particular the ancient city walls and the Palazzo dei Consoli), the Knossos Palace and the Venetian Fortress of Heraklion in Crete.

The sites of Gubbio and Crete have been monitored since 2011 with series of COSMO-SkyMed high resolution and very high resolution SAR acquisitions processed by persistent scatterer pair (PSP) InSAR technology. The satellite technology makes possible to obtain dense (tens of thousand per sqkm) and precise (millimetric) deformation measurements over very large areas at relatively low cost. For these characteristics, this technology can be a powerful tool, complementary to in-situ measurements and structural analysis technologies, for monitoring of historical sites, often large and/or sparse in the territory.

A specific attention has been therefore devoted (considering in particular the Palazzo dei Consoli in Gubbio test site) to the interpretation of millimetric deformation measurements obtained from PSP InSAR technology through a cross-correlation against data provided by an in-situ structural health monitoring system and through engineering interpretation based on damage survey and structural analysis via Finite Element simulation. A first analysis has been carried out in order to identify anomalies that can possibly indicate the activation of local failure mechanisms consisting of overturning of lateral façades.

Results of such a preliminary analysis have been analyzed in light of the outcomes of a detailed architectural and damage survey, as well as in light of damage scenarios predicted by finite element simulations. This analysis, complemented by visual inspections, has guided the definition and installation of a mixed static-dynamic continuous structural health monitoring (SHM) system deployed over the building, that has been in continuous operation since July 2017.

The availability of some months of continuous monitoring data has represented a notable opportunity to cross-compare remote sensing with terrestrial monitoring data, thus contributing to understanding the potential of InSAR technology to enable large-scale remote structural monitoring of monumental buildings.

The obtained results are very promising, and can be applicable to the structural assessment and monitoring of buildings and infrastructure in general, even though the study has focused in particular on historical sites.