Geophysical Research Abstracts
Vol. 20, EGU2018-17127, 2018
EGU General Assembly 2018

A multidisciplinary integrated approach for assessing structural damage and material degradation of heritage buildings: application to Palazzo dei Consoli in Gubbio

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Resilience of heritage buildings against natural hazards is a key research topic to define proper maintenance strategies in view of their conservation over time. This work is focused on the assessment of the combined effects of environmental actions, especially related to local climate change, and natural events, such as earthquakes or heat waves, on an iconic Italian monumental buildings such as Palazzo dei Consoli in Gubbio. Palazzo dei Consoli, a medieval palace built between 1332 and 1349, has a regular rectangular shape in plan (about 20x40m), but different levels of foundation, which confer to the structure a total height of about 60m. It is mainly constituted by limestone, with the exception of some internal walls and vaults on the top part of the building that were constructed with brickwork masonry during the XVIII century. The survey operations, of both material and structural degradation, have allowed to understand the current building state, to classify the pathologies and, in general, to make hypotheses about their causes. This analysis has been also based on the results of an integrated numerical simulation, considering both structural and thermo dynamical aspects, in order to perform consistent interpretations of the observed damage state and highlight the most critical regions where climate-induced degradation and structural damage may negatively interact in the future.

Regarding the structural aspects, a finite element model has been elaborated and calibrated on the dynamic properties of the structure, such as natural frequencies and mode shapes. A preliminary ambient vibration test has been carried out to identify the first five modes of the building, by using nine piezoelectric high sensitivity uni-axial accelerometers deployed in three levels of the palace. The calibrated model has then been used to perform nonlinear static analyses, which highlighted that the damage scenario observed on the structure can be related to both dead loads and lateral inertial loads, probably related to past seismic actions. As far as it concerns the evaluation of the impact of expected climate change on materials' state of conservation, an experimental continuous monitoring of the main indoor and outdoor environmental parameters hes been carried out to calibrate a building model used to perform dynamic simulations in future climatic conditions. The simulations have been carried out to predict the thermal-energy performance of the building, both in current and future climate conditions, and the temperature evolution of the external surface walls, which is closely related to material degradation. The results allowed to obtain a map of material degradations risk over the main façades of the Palace, highlighting that certain regions and specific types of stone degradation are highly critical in relation to climate change, and that the speed of degradation could locally increase where structural cracks may develop as a consequence of future earthquakes.

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 700395.