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Assessment of structural behaviour and seismic retrofitting for an Italian monumental masonry building

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Abstract: This paper deals with assessment of structural behaviour and seismic retrofitting of Rocca Strozzi, a monumental masonry building located in the Municipality of Campi Bisenzio, near Florence, in Italy. The paper consists of three parts. The first part is dedicated to description of the geometry and state of conservation of the building. The second part presents results of a multi-level approach prescribed by the Italian Code, including finite element analysis, which allowed for the static and seismic capacity of the building to be assessed. The third and last part of the paper illustrates a strengthening design approach aimed at increasing both the load-bearing capacity of some portions and the global seismic capacity of the building. Innovative solutions are proposed to strengthen the chemin de ronde and roof of the main building. The case study highlights that in many cases the strengthening design of an existing monumental masonry building may be successfully developed even if the knowledge of geometry, constructive details and material properties is limited.

Keywords: monumental masonry building, knowledge level, double-leaf masonry, mechanism analysis, finite element analysis, strengthening design

1. Introduction

The structural analysis of historical and monumental masonry buildings requires care and caution, as it is not an easy task neither to recognize the actual static scheme, which in many cases could have been modified over time, nor to identify structural details and mechanical properties of the masonry. In many cases, additional uncertainties come from the lack of an exhaustive experimental campaign to characterize mechanical properties of structural materials, especially when the building is under monumental protection. Therefore, researchers are required not only to analyse the historical constructive evolution of the building [1] but also to verify geometry and investigate constructive details and mechanical properties of materials to such an extent that a target knowledge level can be reached [2, 3]. Preliminary analyses could be useful to design the in-situ investigation and choose the most appropriate knowledge level [4]. Moreover, non-destructive techniques, combined with numerical modelling, may be used to detect the damage state of the existing construction [5, 6, 7, 8].

Monumental masonry buildings were often built taken into consideration only static loads, while no attention was paid to seismic loads, even if they were built in regions of moderate or high seismicity. This is the reason why the main cause of damage and losses to cultural heritage is represented by earthquakes. Only in those regions where earthquakes occurred with a high frequency, builders adopted suitable constructive details to strengthen the building against seismic loads. Seismic horizontal loads can significantly change stress patterns in masonry walls, produce cracks and activate local failures or, in the worst case, the global failure of the building. The seismic vulnerability of monumental buildings is often due to the presence of large rooms covered by thin masonry vaults or very deformable wooden floors without a satisfactory connection to supporting walls, slender walls, arches [7, 9], projecting parts like walkways lying on corbels, large openings, multi-leaf walls with an inner core of bad quality, and so on. Therefore, even if the masonry is of good quality, the seismic capacity of a monumental building could be very low. Due to a large number of historical and monumental buildings located in seismic regions, their vulnerability analysis should be performed first at territorial scale using simplified methods and utilizing a few geometrical and mechanical parameters, eventually taken from literature. Then successive evaluation levels are required to design local retrofitting or global retrofitting of the building. This multi-level approach is adopted by the Italian Guidelines for assessment and mitigation of seismic risk of Cultural Heritage (IGCH) [10]. To reduce and limit strengthening works, giving higher priority to conservation issues and monitoring, IGCH consider three evaluation levels: LV1, LV2, and LV3. The first level (LV1) uses simplified analysis methods and qualitative data to allow for the evaluation of the seismic vulnerability on many buildings at urban scale. The second level (LV2) uses local models for independent portions of the building and may be applied to design strengthening works of single portions of the building. The third level (LV3) concerns the whole building and requires a global model or, alternatively, the