

Numerical Investigation Of The Retrofitting Interventions Of The San Benedetto Church Complex In Ferrara (Italy) From A Seismic Vulnerability Perspective

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Abstract

The San Benedetto church complex is an iconic part belonging to the cultural and architectural heritage of Ferrara, an attractive small city in the north of Italy. This paper investigates two separate parts from the complex, which are respectively the church and the bell tower. The construction of the church dates back in the XV century, and many modifications to the original structure were carried through years. During the second world war the church was stricken and severely damaged, and then was fully restored to the original design. Reinforced concrete was used during the reconstruction works to conceive a better bond between the existing masonry structure and the new construction. The bell tower instead was not damaged during the second world war however it is a typical tower of northern Italy which due to the soft soil is notably inclined by 3° , which is the main cause of wall cracks. The last decade, severe earthquake sequences occurred in the nearby areas, and the occupancy of the structures was compromised. Several observed damages impelled upgrading measures, and consequently, many different retrofitting interventions are now executed. The vaults were reinforced by FRCM strips placed at the extrados, repointing technique or demolish and reconstruct ("scuci-cuci") was used for masonry walls on the visible cracks, the tower was confined with horizontal steel tie rods, and RC piles were used to reinforce the foundation for prohibiting the differential settlements. The interventions mentioned above are expected to change the dynamic behavior and the seismic load bearing capacity. Advanced numerical simulations are conducted in order to estimate the seismic vulnerability of each structure, by means of nonlinear static and dynamic analysis. A critical historical evolution of the structure is considered, and three models for each structure are conceived respectively. The church models consist of 1) a simple masonry material model; 2) the model with masonry and RC rods and 3) the recent retrofitted model. The bell towers models consist of 1) the non retrofitted inclined tower; 2) the model with retrofitting and 3) and the retrofitted tower with a soil subspace for modeling the soil-structure interaction. A comparative analysis is carried out based on the numerical results highlighting the pros and cons of each modeling technique and the efficiency of each intervention. Structural stiffening incorporated with a non-uniform distribution of the resisting capacities of the load bearing elements highlights the seismic vulnerabilities. The necessity for the advanced numerical simulation emerges by the evidenced vulnerabilities in the performed simulations concerning the overall safety. A concluding simplified seismic risk assessment affirms the efficiency of the interventions by the performance enhancement and provides some useful remarks for comparable cases subjected to elevated seismic hazards risks.