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Editorial

Advanced Methods for Structural Rehabilitation

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Structural rehabilitation has globally become an urgent need due to both widespread construction obsolescence and more demanding requirements from modern construction codes, especially in earthquake-prone areas, where upgrading the existing constructions has become a primary goal. Increasing economic resources are employed for this purpose, based on the simple finding that rehabilitation is more sustainable than demolition and reconstruction in terms of energy saving, carbon footprint, and resident relocation. Thus, researchers in this field are pushed towards the development and investigation of advanced retrofitting and strengthening techniques that are, at the same time, efficient and affordable.

This Special Issue collects selected innovative research studies on advanced methods for the structural rehabilitation of constructions. With this aim, 11 original articles are published, representing relevant contributions on innovative experimental, analytical, and numerical studies; novel strengthening techniques and design methods; and real case studies, including modern, historical, and archeological applications. The published papers are mainly focused on (i) the strengthening with FRP-based techniques of RC members; (ii) the strengthening with FRM, TRM and FRCM of masonry walls; (iii) new strengthening materials and techniques; (iv) seismic protection devices; (v) the protection of non-structural elements; (vi) cost–benefit analysis; (vii) conceptual design; and (viii) new developments in code making.

Grossi et al. [1] presented and discussed four different advanced design solutions for the structural rehabilitation of existing Pilotis RC buildings with a substantial lack of shear and ductility capacity at the first floor. The design solutions are described in detail and were applied to a real building designed only for gravity loads during the 1960s, despite being sited in a high-risk seismic Italian area. Design (1) is based on the strengthening of masonry infilled panels with the fiber reinforced cementitious matrix (FRCM) technique, while solution (2) is based on replacing infilled panels with non-interacting precast panels. Solution (3) implements friction dampers (FD) at every story to exploit energy dissipation, while solution (4) implements lead rubber bearings (LRB) at the building's basement to exploit both base isolation and energy dissipation. The performance offered by the proposed retrofit techniques was assessed by using nonlinear time history analysis, and the better solution in terms of the structural behavior, expected damage, and economic impact was identified for the case study.

Cantagallo et al. [2] proposed a multilevel procedure for the seismic safety assessment of historical constructions, based on three interrelated phases: building-knowledge acquisition, structural behavior analysis, and safety assessment. In particular, building-knowledge acquisition is crucial for a reliable safety evaluation and must be conducted according to a multidisciplinary approach articulated in five steps: (1) critical–historical analysis; (2) a photographic documentation and geometrical survey; (3) a structural identification and material survey; (4) a foundation and soil survey; and (5) cracking pattern and structural integrity analysis. The proposed methodology is described in detail and was applied to the case study of the Melfi Castle (Potenza, Italy), an example of the national cultural and architectural heritage. Comprehensive and multidisciplinary knowledge of

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this monument greatly facilitates an accurate seismic analysis, which was conducted at both local and global levels using a linear kinematic analysis and nonlinear static (pushover) analysis, respectively.

Gulinelli et al. [3] presented an experimental and numerical investigation of masonry walls strengthened with textile-reinforced mortar (TRM). This innovative reinforcing technique is based on high-strength fiber grids embedded into inorganic matrices, and it has recently been promoted for the seismic retrofitting of existing and historical masonry buildings. The experimental campaign considered two different commercial TRM systems applied to single-leaf clay masonry panels. The square-shaped specimens were subjected to diagonal compression tests to evaluate the effects of TRM on the structural performance. The proposed nonlinear FE model, based on the original multiscale approach, was developed to simulate the experimental tests. The numerical results show a very good agreement with the experimental data, including a proper capture of the failure modes. The proposed approach reproduces the macroscopic behavior of the masonry panels in terms of the force-displacement response, and it allows the simulation of bed joint sliding and TRM layer debonding.

Pavia et al. [4] proposed an original design approach for the seismic retrofit of historical masonry bell towers, based on the installation of an internal steel frame structure holding fluid viscous dampers as braces. Such an additional new structure allows meaningful energy dissipation during the earthquake, reducing the structural damage and preventing the historical manufact's loss. The proposed design approach is described in detail and was applied to the case study of the San Zenone Church bell tower in Fermo (AN, Italy), characterized by historical stratification dating back to the Roman age, including medieval transformations and reconstructions. A thorough description of the case study is provided, including historical analysis, a geometric and architectural survey, materials, construction techniques, and an existing-damage survey. Finally, the design approach effectiveness was assessed by means of FEM nonlinear dynamic analysis. The obtained results highlight the suitability of the proposed retrofit technique, which significantly improves the seismic response of the upgraded masonry bell tower under seismic actions.

Bianco et al. [5] developed a novel topology-changing multi-body mechanical model to simulate the double concave curved surface slider (DCCSS) dynamics under an earthquake, with the objective of contributing to the understanding and further improvement of this base isolation device. In fact, despite several experimental tests having being carried out worldwide, many aspects concerning DCCSS dynamic behavior still need to be clarified and some design details still require improvement and optimization. During an earthquake, the fulfillment of the geometrical compatibility between the device constitutive bodies gives rise to a very peculiar dynamic behavior, composed of the continuous alternation of sticking and slipping phases, yielding a temporary and cyclic change in topology. This study proposes a stick–slip model for the simulation of DCCSS behavior, focusing on geometrical compatibility and kinematics. The proposed approach is applied to two prototypes of DCCSS, and the obtained results are compared with the currently accepted compliant sliding approach, based on a friction pendulum-like behavior assumption. The main findings are presented and discussed.

Vona et al. [6] proposed a resilience-based methodology for the seismic retrofit design of existing strategic RC buildings, considered either individually or on a large territorial scale. The efficacy of some current retrofit techniques was evaluated, considering the overall reconstruction costs and post-earthquake recovery times in addition to the structural safety upgrade and damage reduction, by implementing a resilience index (RI) as a key element of the proposed methodology. The considered retrofit techniques were based on (1) the concrete jacketing (CJ) of existing RC elements, (2) new RC wall (RCW) implementation, (3) the new RC wall implementation and steel jacketing (RCW–SJ) of existing RC elements, and (4) seismic isolation system (SIS) implementation, using both elastomeric and sliding bearings. These retrofit techniques were applied to the case study of a strategic building sited in Senise (Potenza, Italy), hosting the management activities of the Senise Dam. For the case study's retrofit layouts, fragility curves and the RI were worked out, and the optimum design solution was identified, making use of the RI.

Vailati et al. [7] presented the design methodology applied for the seismic rehabilitation of a strategic building complex located in Florence (Italy), hosting the operational center of the main Italian highway network managing company. Three main RC buildings compose the complex, standing from a common basement, very peculiar from both architectural and structural points of view. The gaps between the buildings are too small to prevent pounding during an earthquake; in addition, they are crisscrossed by optical fibers and other technological facilities that must be kept in service for any expected earthquake intensity. Finally, upon the client's request, the building complex must be brought to the seismic safety level of a new building, following the Eurocode 8 standards. An original design strategy based on the employment of base isolation in a rather unusual configuration is presented in detail, fulfilling all the existing design constraints of this challenging case study. Some innovative aspects of the designed devices are highlighted, and a thorough discussion about the design and the realization phases is reported.

Calvanese et al. [8] presented and discussed the decision-making process involved in the design of preservation interventions for archaeological constructions. This process typically requires the cooperation of several professionals, with multidisciplinary expertise, and the responsible use of innovative techniques and materials to preserve archeological artifacts from natural and anthropic degradation. The proposed process allows for design optimization at an increasing knowledge level for the archeological constructions, flowing by steps: (1) historical data collection and a geometrical survey, (2) on-site material testing and structural monitoring, (3) damage assessment and risk analysis, (4) intervention-technique selection, design, and cost/benefit analysis. The case study of Championnet houses at the archaeological site of Pompeii (Napoli, Italy) is presented in detail, where innovative rehabilitation techniques were applied for ancient masonry wall preservation, such as grout injections, basalt fiber net and rope insertion, and the base isolation of roofing. Uncertainties related to ancient materials' performance, the existing level of damage, and the efficacy of rehabilitation works were soundly reduced thanks to the applied decision-making process.

Damiani et al. [9] proposed an original split wedge anchorage for fiber-reinforced polymer (FRP) cables to prestress existing RC members for structural rehabilitation purposes. A remarkable literature review of FRP cables is reported, including the short- and long-term effects of mechanical properties for aramid-, glass-, and carbon-fiber-based cables. A thorough review of existing anchorage systems is also reported, including bonded, clamping, spike, and split wedge typologies. Two different geometrical layouts of the proposed anchorage device were experimentally tested, proving they can limit both bond stress peaks and bond slippage, and enhance loading capacity, preventing the premature failure of the strengthening system. A finite element analysis based on digital image correlation (DIC) is presented to compare numerical and experimental stress–strain curves and enhance the comprehension of the failure mechanics. The obtained results highlight the fact that this new technology has great potential, even if further investigations are needed to check the variability of the results and eventually improve the system.

Khan et al. [10] presented a novel constitutive model for the masonry infill walls of existing RC frames, able to predict their failure mode as a function of some essential parameters, such as the coefficient of the friction between the mortar and brick surface and mortar strength, usually disregarded in current models. The proposed model was successfully validated by comparison with the experimental outcomes for a single-bay single-story infilled RC frame tested under vertical and cyclic horizontal loading, derived from the literature. Finally, a comprehensive case study of a three-story RC frame building located in Mirpur, Pakistan, hit by an earthquake of magnitude 5.9 in 2019, is presented. The numerical simulation of the case study, carried out by implementing the proposed infill model, highlights the improved structural strength and stiffness of the building, but also the reduced ductility, due to infills, and can adequately reproduce the real damage patterns. Therefore, it is essential that the effects of infill walls are carefully accounted for, both in designing new structures and in assessing existing structures.

Rahmat Rabi et al. [11] developed an original methodology to derive the mechanical fragility curves of RC frames with column-driven failures, based on a simplified analytical pushover implemented in a simple spreadsheet. Following the proposed methodology, the limit states at the structural level are derived from the attainment of the same limit states at the local level, in the columns' sections, avoiding additional criteria, such as interstory drift thresholds. New fragility curves were obtained for pre-code (pre-1990) and code-based (post-1990) RC frames with the number of stories ranging from 1 to 5, different numbers and lengths of bays, and varying element sizes, reinforcement ratios, and material properties. Additionally, the soil class' influence was easily accounted for in the analysis as an investigated parameter, showing an important influence on the obtained results. The obtained fragility curves were compared with some observational and analytical fragility curves available in the literature, showing acceptable agreement.

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