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Editorial

Seismic Assessment and Retrofitting of Reinforced Concrete Structures

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1. Introduction

Many constructions are globally built with reinforced or prestressed concrete and a large part of them are designed or expected to resist earthquake actions in addition to gravity loads. In many cases, these actions also work together with other more specific actions, e.g., road or railway traffic loads in bridges or hydraulic actions in dams, and require a more complicated seismic analysis, design and assessment of such structures. In any case, climatic actions cause the corrosion of reinforcements and undermine the initial seismic performance of such structures, exposing them to a greater damage under earthquake actions. Often, regardless of the detrimental actions of aging of materials, the increase in the evaluated seismic hazard requires interventions of seismic retrofit.

In the attempt to limit the effects of seismic events on reinforced or prestressed concrete structures, many attempts have been made by researchers in order to (i) improve the knowledge of the response of materials (steel bars and concrete) and members to persistent and transient loading conditions by means of laboratory tests, (ii) improve the numerical models for such structures, (iii) improve the capacity models, (iv) improve the procedures for the dynamic analysis, (v) improve the procedures for the correct assessment of the seismic performance, and (vi) suggest innovative interventions for the seismic retrofit of old and damaged reinforced or prestressed concrete structures.

In the last decades, researchers have provided valuable contributions to all the above issues and seismic codes have evolved due to the findings and proposals of the scientific research. The large number of reinforced or prestressed concrete structures and the continuous efforts made by researchers for the comprehension of the seismic behavior of such structures have been among the main reasons of the present Special Issue titled "Seismic assessment and retrofit of Reinforced Concrete Structures".

2. Contributions

Many researchers have contributed to this Special Issue. As a result, this thematic issue is composed by eleven contributions covering important topics for Seismic Assessment and Retrofit of Reinforced Concrete Structures.

One paper [1] is devoted to the evaluation of the nonlinear seismic response of irregular r.c. buildings retrofitted by base-isolation. The effectiveness of advanced nonlinear static methods of analysis in predicting the torsional response due to plan irregularities has been widely studied for non-isolated structures, whereas the response of base-isolated irregular structures has been generally determined by nonlinear time-history analyses. The paper under examination [1] points out that the mode-adaptive bidirectional pushover analysis (MABPA) predicts the peak responses of irregular base-isolated buildings with accuracy even if its application is limited to buildings that can be classified as torsionally stiff.

One study [2] intended to propose a structural solution for buildings with curtailed shear walls. To reduce the drifts of the upper part of the frame under earthquakes, buckling-restrained braces (BRBs) are added. The genetic algorithm is applied to determine the optimum locations of BRBs by considering three main parameters in the fitness function: the interstory drifts, the damage index of the beams and the total number of BRBs. Numerical analyses, calibrated against the results of experimental tests, prove the effectiveness of the proposal.

Three studies [3–5] are focused on the retrofitting of existing r.c. buildings. The retrofitting technology proposed in [3] consists of a RC frame rigidly connected to the external façade of the existing building by means of anchor rods placed at every floor level. The anchor rods are designed based on capacity design principles. The RC-framed skin is casted on site by using prefabricated expanded polystyrene modules as formwork, which also ensures the thermal enhancement of the building. Pushover analyses show that the proposed retrofitting technology provides the existing structure with significant increases in stiffness, strength and often is accompanied a more ductile failure model. In another paper [4], a steel exoskeleton is, instead, used to perform the combined seismic–energy retrofit of a former reinforced concrete industrial building. Most of the existing retrofitting techniques requires time to be realized. In the case of buildings damaged during mainshock events, quick and effective strengthening interventions are important to reduce further damage during aftershocks. To investigate this issue, in [5], a three-story RC frame building is first subjected to a mainshock excitation. Then, the damaged structure is retrofitted by three retrofitting schemes with combined strip-shaped shear-and-flexural steel dampers installed between chevron braces and upper beams. The response of the three considered retrofitting schemes under aftershocks is finally compared.

An accurate evaluation of the seismic response of existing buildings requires a proper simulation of the degradation of materials. One of the major degradation causes of RC structures consists in the corrosion of steel reinforcements. To evaluate the influence of localized corrosion on the cyclic behavior and failure modes of RC columns, one paper of this Special Issue [6] considers different modelling strategies (based on the reduction in constitutive law by uniform or pitting corrosion; bar discretization and section reduction and bar discretization and morphology-based constitutive law reduction). The accuracy of the modelling strategies is validated against results of experimental tests.

Three papers are devoted to the analysis of structural members [7–9]. Two of these studies are related to retrofitting techniques for beams [7] or columns [8], whereas the third study proposes a bolt-connected precast reinforced concrete deep beam as a lateral resisting component to be used in framed structures to resist seismic loads [9]. Specifically, in [7], the structural capacity of reinforced concrete beams is improved by the use of modularized steel plates. This technique leads to rapid and economical construction and, as proved by experimental tests, to an increase in the ductility capacity of the reinforced concrete beams, which is about 2.5 times that of the non-retrofitted beams. A strengthening method based on fastening steel jackets is introduced for columns in [8]. The steel plate thickness, fastener number and connection spacing are designed to prevent brittle shear failure, ensure a lateral load capacity larger than the lateral load demand, limit the axial load ratio and provide adequate flexural stiffness. In regard to bolt-connected precast reinforced-concrete deep beams [9], the seismic performance of two scaled specimens is determined under cyclic loads by experimental tests. A parametric analysis, carried out on the numerical model calibrated against the results of the experimental tests, shows that shear resistance, elastic lateral stiffness and displacement-based ductility are significantly dependent on the height-to-length ratio of the deep beam.

In one paper [10], recently tested real-scale RC-framed-wall infilled structures with innovative seismic protection through polyurethane joints (PUFJ) or polyurethane impregnated fiber grids (FRPU) are investigated. The frames reveal a highly ductile response while preventing infill collapse. Suitable FE models are developed in order to reproduce the experimental results.

Finally, one paper of the Special Issue is devoted to Progressive Collapse [11]. Three different column removal scenarios are considered with reference to a case study that is upgraded by different retrofitting strategies, e.g., X-braces, diagonal braces, inverted

V-braces, viscous dampers and carbon-fiber-reinforced polymer. The damage levels of members under the above-mentioned scenarios are compared.

3. Conclusions

We were very pleased to guest edit this Special Issue and we thank all the authors of the above papers for their contributions to the advancement of the research in the field of the seismic assessment and retrofit of reinforced concrete structures. We hope this Special Issue can reach the widest audience in the scientific community and contribute to boosting further scientific and technological advances into the attractive world of reinforced concrete structures.

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References

1. Fujii, K.; Masuda, T. Application of Mode-Adaptive Bidirectional Pushover Analysis to an Irregular Reinforced Concrete Building Retrofitted via Base Isolation. *Appl. Sci.* **2021**, *11*, 9829. [CrossRef]
2. Maulana, T.I.; Fonseca, P.A.d.F.; Saito, T. Application of Genetic Algorithm to Optimize Location of BRB for Reinforced Concrete Frame with Curtailed Shear Wall. *Appl. Sci.* **2022**, *12*, 2423. [CrossRef]
3. Talledo, D.A.; Rocca, I.; Pozza, L.; Savoia, M.; Saetta, A. Numerical Assessment of an Innovative RC-Framed Skin for Seismic Retrofit Intervention on Existing Buildings. *Appl. Sci.* **2021**, *11*, 9835. [CrossRef]
4. Formisano, A.; Messineo, Y. Seismic Rehabilitation of Abandoned RC Industrial Buildings: The Case Study of a Former Tobacco Factory in the District of Avellino (Italy). *Appl. Sci.* **2022**, *12*, 5705. [CrossRef]
5. Yang, F.; Wang, G.; Li, M. Evaluation of the Seismic Retrofitting of Mainshock-Damaged Reinforced Concrete Frame Structure Using Steel Braces with Soft Steel Dampers. *Appl. Sci.* **2021**, *11*, 841. [CrossRef]
6. Molaioni, F.; Di Carlo, F.; Rinaldi, Z. Modelling Strategies for the Numerical Simulation of the Behaviour of Corroded RC Columns under Cyclic Loads. *Appl. Sci.* **2021**, *11*, 9761. [CrossRef]
7. Kim, M.S.; Lee, Y.H. Flexural Behavior of Reinforced Concrete Beams Retrofitted with Modularized Steel Plates. *Appl. Sci.* **2021**, *11*, 2348. [CrossRef]
8. Shan, Z.; Chen, L.; Liang, K.; Su, R.K.L.; Xu, Z. Strengthening Design of RC Columns with Direct Fastening Steel Jackets. *Appl. Sci.* **2021**, *11*, 3649. [CrossRef]
9. Li, J.; Jiang, L.; Zheng, H.; Jiang, L.; Zhou, L. Cyclic Tests and Numerical Analyses on Bolt-Connected Precast Reinforced Concrete Deep Beams. *Appl. Sci.* **2021**, *11*, 5356. [CrossRef]
10. Rousakis, T.; Vanian, V.; Fanaradelli, T.; Anagnostou, E. 3D FEA of Infilled RC Framed Structures Protected by Seismic Joints and FRP Jackets. *Appl. Sci.* **2021**, *11*, 640. [CrossRef]
11. Ali, B.H.; Mete Güneyisi, E.; Bigonah, M. Assessment of Different Retrofitting Methods on Structural Performance of RC Buildings against Progressive Collapse. *Appl. Sci.* **2022**, *12*, 1045. [CrossRef]