Summary

Infilled Reinforced Concrete (RC) frame structures represent a large portion of the existing building heritage, worldwide. Although infills significantly influence the overall stiffness and strength, they have traditionally been considered as non-structural components and are often neglected in design procedures or modelled through simplified approaches. However, post-earthquake reconnaissance and various experimental and numerical studies have demonstrated their crucial influence on seismic performance, showing that their presence cannot be neglected in structural modelling, either at the design stage or during safety verification. By interacting with the surrounding RC frame, infills significantly alter both global and local structural behaviour. At the global level, irregular distributions in plan or elevation can generate torsional effects or soft-storey mechanisms. At the local level, instead, the stress transfer from the infill panel to adjacent members induces additional shear forces at column ends and beam-column joints, often responsible for brittle failures in non-ductile RC elements. Existing seismic codes recognise the structural relevance of infills but still rely on simplified modelling approaches, like the equivalent diagonal strut macro-models, that may not capture local interaction effects. Therefore, no validated and widely applicable approach is yet available to assess both global and local effects, leaving a gap between observed behaviour, refined numerical simulations, and practical tools for engineering practitioners.

To address this gap, this thesis develops a high-fidelity multiscale modelling framework for the seismic assessment of infilled RC frames. The main idea is to integrate advanced numerical simulations with simplified predictive tools, thus providing a consistent methodology capable of capturing both global and local effects. The research was framed into complementary studies, each addressing a specific objective:

i. validation of refined modelling strategies against global response and observed damage from experimental tests;
ii. investigation of local infill-frame interaction, extracting internal force distributions not accessible from experimental tests;
iii. development and improvement of simplified macro-modelling strategies able to reproduce both global and local responses, connecting refined simulation results and tools suitable for engineering practice.

To this end, existing modelling approaches for masonry-infilled RC frames under in-plane (IP) loading were first reviewed and discussed. Refined micro-modelling strategies were then implemented in the STKO/OpenSees environment. The first study involved the investigation of global and local effects on single-bay infilled RC frame structures. Calibrated micro-models were used to investigate the variation of global response and stress-transfer mechanisms between the infill and the surrounding frame under monotonic IP loading. By means of *section-cut* techniques, internal forces in RC frame members were analysed, providing insight into phenomena not directly measurable in experimental programmes. The results confirmed the amplification of shear demand induced by infill-frame interaction, which are consistent with post-earthquake reconnaissance and previous research, and established a solid reference for the development of simplified models.

Building on this foundation, the study proceeded to the validation of the micro-modelling strategy under cyclic IP-loading tests. The study involved the reproduction of full-scale single-bay specimens tested within the ERIES-ENFRAG project at the EUCENTRE laboratory. The experimental programme, which involved cyclic displacement-controlled IP loading at different drift and input energy levels, provided a robust benchmark for model validation. The calibrated numerical models accurately reproduced the global response and the evolution of damage, confirming the reliability of the adopted modelling approach.

The third phase of the research focused on connecting high fidelity modelling results with simplified macro-modelling, with particular emphasis on local effects. Two strategies were developed. The first consists of an analytical correction model for the single-strut macro-model, formulated to estimate the additional shear demand as a function of geometrical parameters and the axial force in the equivalent strut. The correction model was calibrated and validated against refined numerical replica of single-bay frames under monotonic IP simulations. This formulation preserves the simplicity and efficiency of conventional single-strut macro-model while improving its predictive accuracy for local interaction effects. The second introduces an equivalent three-strut macro-model, also calibrated and validated on micro-models' results. A genetic algorithm (GA) was employed to optimise the configuration, improving the balance between global and local response. These developments demonstrated that the proposed models can be conveniently applied in the seismic assessment of existing RC structures.

Finally, one of the two proposed strategies, namely the analytical correction model for single-struts, was validated under nonlinear dynamic conditions by numerically reproducing a shake-table test on a three-storey infilled RC building previously tested at the EUCENTRE laboratory within the ISAAC project. The refined model was rigorously calibrated through sensitivity analyses (SA) and GA-based optimisation of vibration frequencies in both elastic and non-linear phases. Once validated, this reference model served as a benchmark for testing the simplified solutions under dynamic excitation. Comparisons with refined simulations confirmed that the proposed model captured peak shear demands even under dynamic conditions, demonstrating their robustness and suitability for safety assessment as well as for large-scale or computationally demanding analyses, without neglecting infill-frame interaction effects.

Overall, the thesis offers a comprehensive framework for evaluating the seismic performance of infilled RC frames. The proposed methodology combines advanced numerical simulations, extensive experimental validation and simplified formulations to address both global and local effects. These outcomes bridge the gap between high-fidelity modelling, simplified modelling, and predictive tools, facilitating improved code provisions and enhancing the seismic safety of existing RC structures with masonry infills.