Fragility assessment for as-built and retrofitted building typologies via STICK model

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Task 4.3 Vulnerability of Residential Buildings: Fragility Curves for Reinforced and Aggregate Buildings
Task 2.3.3 Vulnerability of Reinforced Concrete Typologies
Task 2.3.6 Computational Mechanics and Dynamics Applied to Regional Vulnerability Analysis

INTRODUCTION

"Modern probabilistic risk assessments often require numerous nonlinear dynamic analyses to account for aleatory uncertainties in hazards and epistemic uncertainties in exposure and models. Reduced-order models (ROMs) help derive fragility curves by simplifying the original model, improving computational efficiency. However, ROMs can introduce biases that reduce accuracy. Therefore, clear mechanical interpretation and accurate simulation are key to balancing accuracy and efficiency when assessing a building performance under specific hazards.
For this reason, the STICK model [1] was firstly proposed within the ReLUIS 2019-2021 project to assess the structural performance of buildings subjected to seismic hazard in a simple but rather consistent approach suitable for fragility and risk assessment both at the building scale [2] and at the large scale [3].

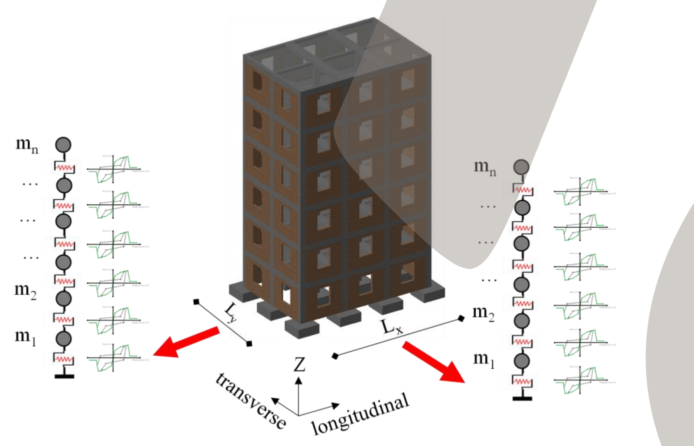

Figure 1. Sketch of the structure transformed in STICK models for each main direction

STICK model for as-built and retrofitted buildings (Task 2.3.3-2.3.6)

The STICK model is an MDOF system with lumped masses connected by nonlinear interstorey shear springs, calibrated to reflect inelastic storey-level behavior assuming a shear-type response (Fig. 1). Multi-linear interstorey displacement-shear relationships are derived by summing contributions from structural and non-structural elements acting in parallel.

The model generation has been improved [4], allowing interstorey curves to be created through a simple mechanics-based procedure using data such as:

- Number of storeys
- Age of construction
- Design level.
- In-plan dimensions
- Infill typology and opening percentage.

The STICK model is developed based on simulated designs following code compliance and professional practice, incorporating the mechanical behavior of both structural (columns, beams, joints) and non-structural (infills) elements. It accounts for brittle failure mechanisms at both member (buckling, bar-slip, shear) and sub-assembly (beam-column joints) levels. It allows to account for the possible implementation of retrofit strategies both at the local level (FRP wrapping) and the global level (RC jacketing, Fig.3).

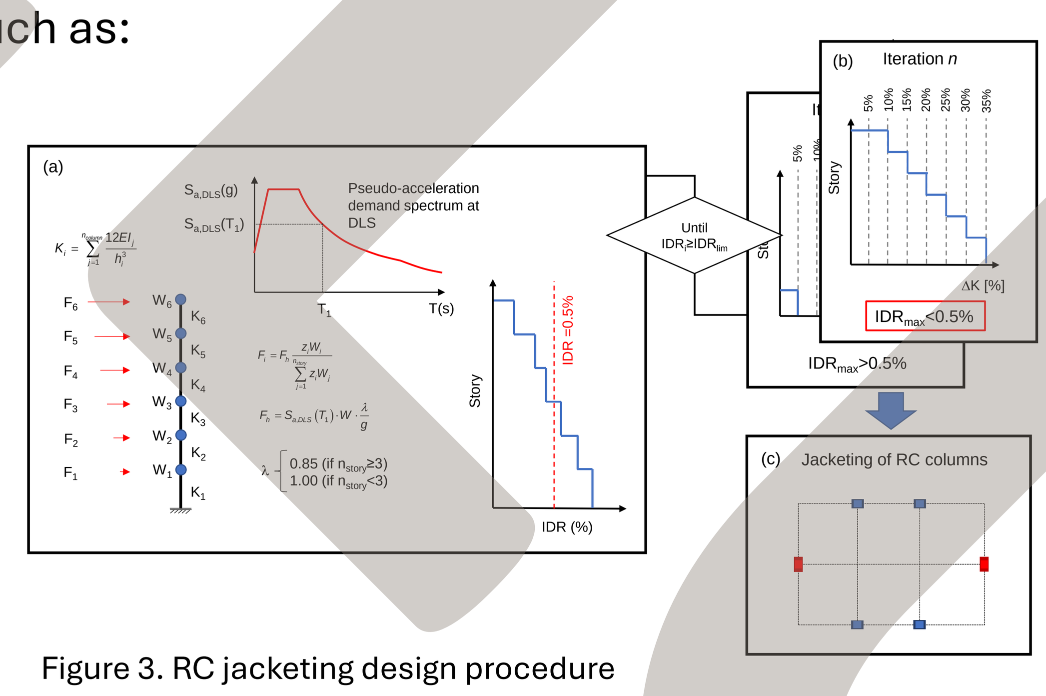

Figure 3. RC jacketing design procedure

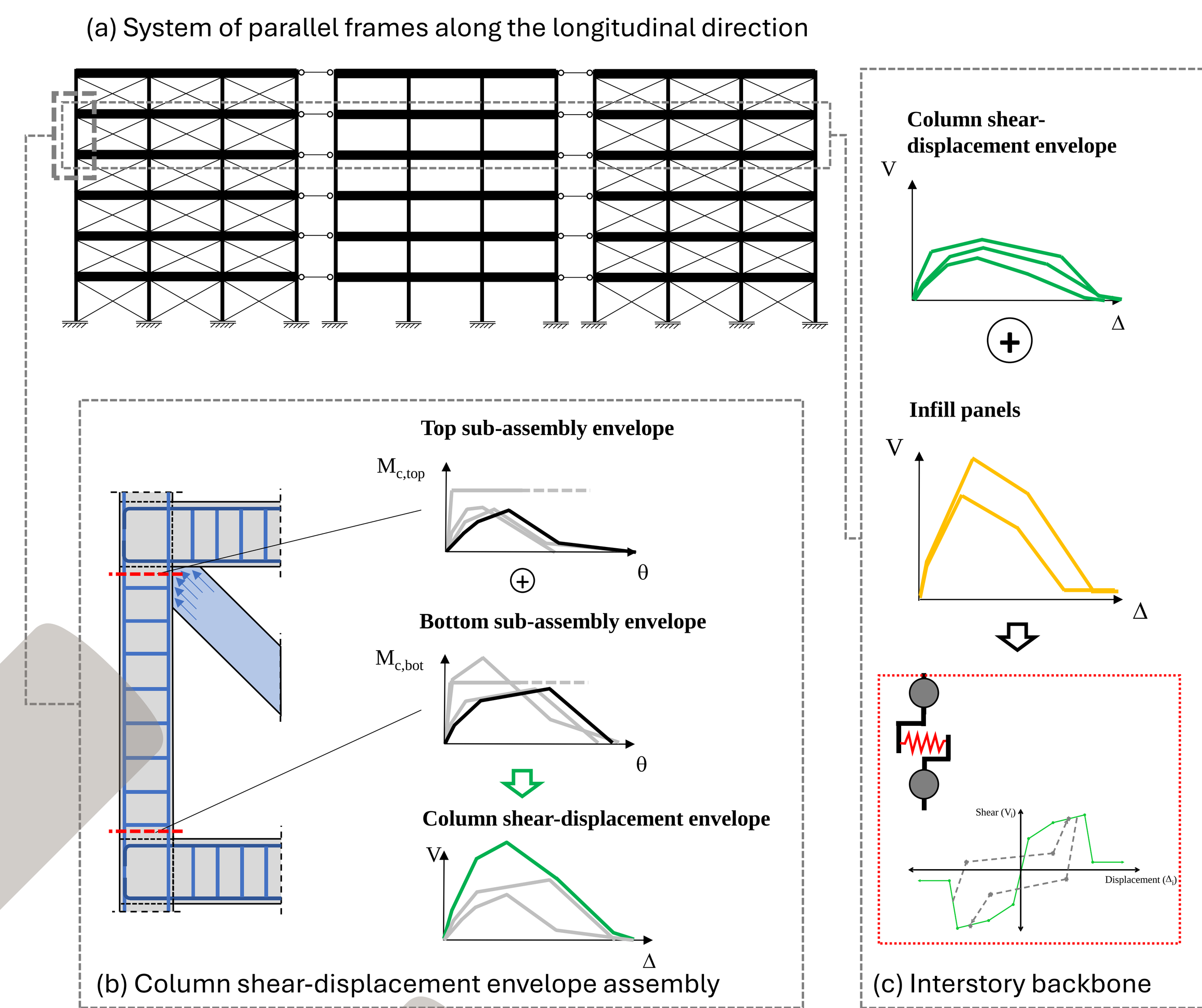

Figure 2. Procedural framework for the generation of interstorey backbones: (a) system of parallel frames, (b) composition at the sub-assembly level (in series), and (c) generation of the interstorey curve considering columns and infill elements (in parallel).

Fragility curves for as-built and retrofitted buildings (Task 4.3)

Damage fragility curves derived through an analytical approach for reinforced concrete building classes representative of the existing Italian building stock. Fragility curves are generated by adopting a fully probabilistic framework that relies on a cloud-based approach including the effect of the main uncertainties that are the inter-building, intra-building, and record-to-record variabilities, as well as variability related to the definition of the building damage level are explicitly considered. Fragility curves are developed for Damage States compatible with the EMS98 scale as a function of the peak ground acceleration for building classes defined adopting as main attributes the number of storeys (2 to 8), the age of construction (1950s, 1970s, 1980s), the design level (gravity load and seismic load designed), the typology of infill panels (Weak, Medium, and Strong), and considering the effect of local and global retrofit strategies (Fig. 4, [5]).

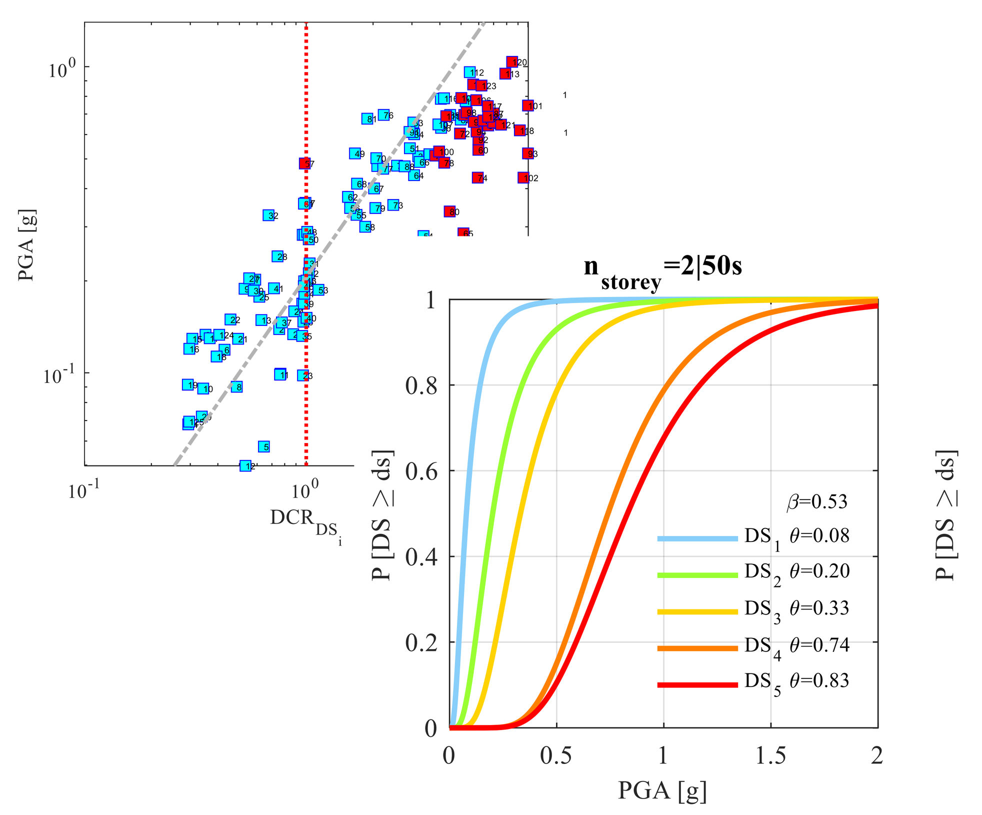

Figure 4. Generation of damage state fragility curves adopting a cloud-based approach

Large scale application (Task 4.3)

Stick-IT model was adopted within a probabilistic framework to predict and compare with actual data, the damage and expected losses for a set of 120 residential buildings located in L'Aquila town that were damaged during the 2009 earthquake [3].

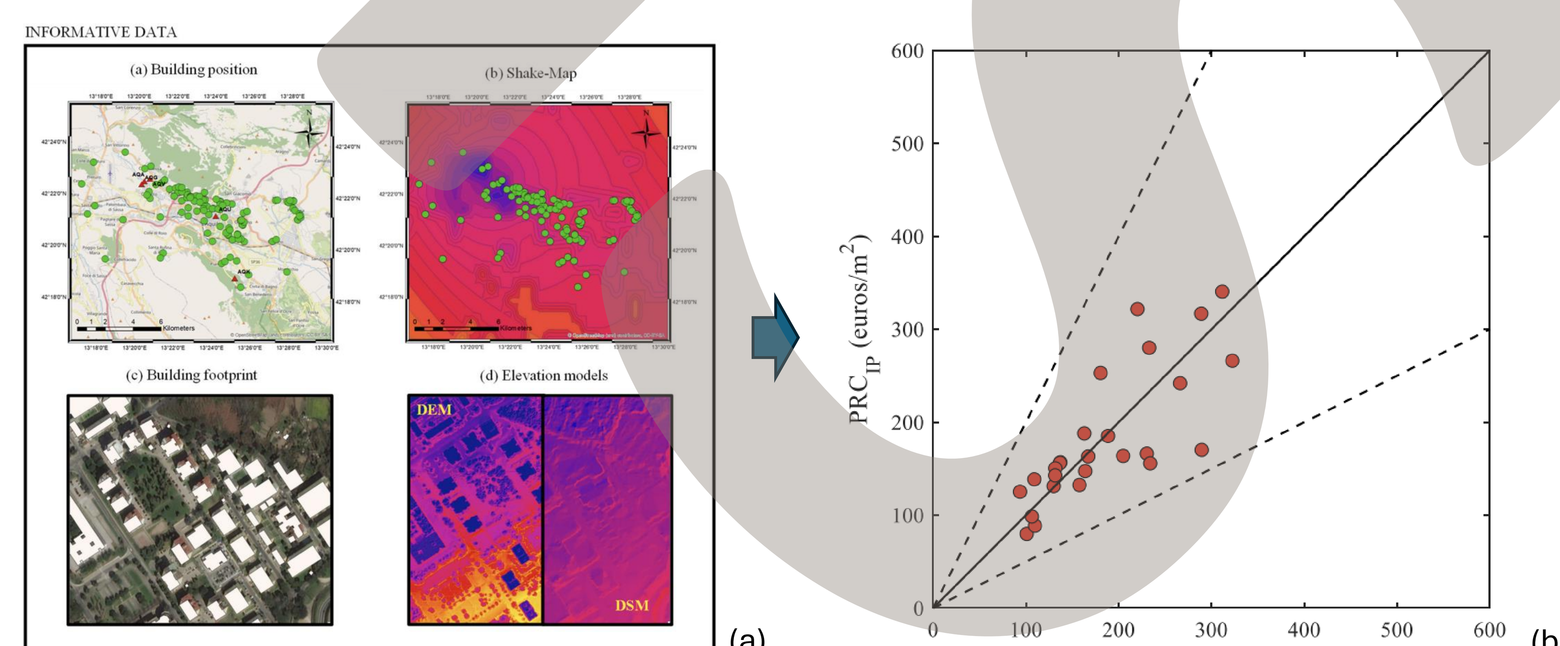

Figure 5. (a) Remote-sensing procedure to retrieve building features at the large scale and (b) comparison between predicted and actual repair costs for a subset of 27 residential buildings.

ReLUIS 2019-2021
[1] Gaetani d'Aragona, M., Polese, M., & Prota, A. (2020). Stick-IT: A simplified model for rapid estimation of IDR and PFA for existing low-rise symmetric infilled RC building typologies. Engineering Structures, 223, 111182.
[2] Gaetani d'Aragona, M., Polese, M., Di Ludovico, M., & Prota, A. (2021). The use of Stick-IT model for the prediction of direct economic losses. Earthquake Engineering & Structural Dynamics, 50(7), 1884-1907.
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[3] Gaetani d'Aragona, M., Polese, M., Di Ludovico, M., & Prota, A. (2022). Large scale loss assessment using stick-it model: A comparison with actual cost data. Soil dynamics and earthquake engineering, 160, 107363.
[4] Gaetani d'Aragona, M., Polese, M., & Prota, A. (2022). Stick model for as-built and retrofitted infilled RC frames. Engineering Structures, 268, 114735.
[5] Gaetani d'Aragona, M., Polese, M., & Prota, A. (2024). Seismic fragility curves for infilled RC building classes considering multiple sources of uncertainty. Engineering Structures, 321, 118888.