Structural safety

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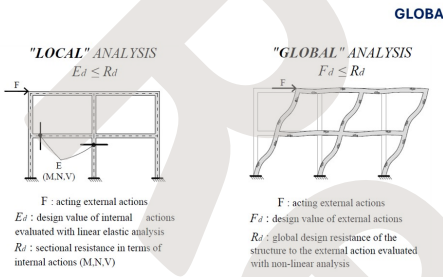
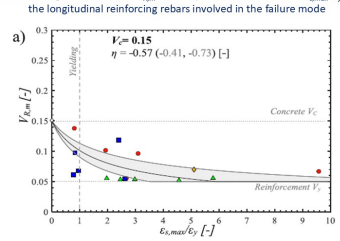
Safety assessment of reinforced concrete structures by NLNAs

The safety and reliability of reinforced concrete (RC) structures are vital to maintain functional and efficient structures and transport infrastructure, which are essential for social cohesion and economic efficiency. Across Europe, many infrastructures exceed their designed service life and are subject to external stresses (e.g., traffic loads, environmental impacts) greater than anticipated, alongside more severe environmental degradation due to climate change. This progressive deterioration calls for comprehensive safety assessments of existing structures. Advanced methodologies for safety verification, such as non-linear numerical analysis (NLNAs), have been developed to meet these needs, as prescribed by modern design codes. The Global Resistance Format (GRF) offers a framework that accounts for uncertainties in structural response, including *aleatory uncertainties* - those intrinsic to materials and geometric properties - and *epistemic uncertainties* arising from incomplete knowledge or modeling assumptions. GRF's approach considers load-bearing capacity, ultimate load, and other indicators of global structural performance, incorporating partial safety factors to accommodate the two families of uncertainties. Analysts (i.e., engineers, practitioners) employ diverse "modeling hypotheses" when performing NLFEAs, encompassing choices in equilibrium equations, kinematic compatibility, and constitutive laws for materials. Addressing structural safety through these advanced, robust assessment techniques can inform sustainable intervention strategies, enabling a systematic approach to enhancing the durability and reliability of aging transport infrastructure. The development of such approaches is critical in mitigating risks of structural failure and sustaining the efficiency of European transport networks in the face of aging and increasing environmental challenges.





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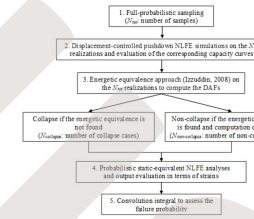
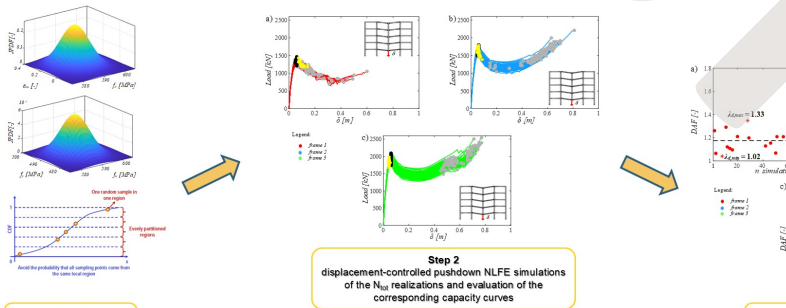
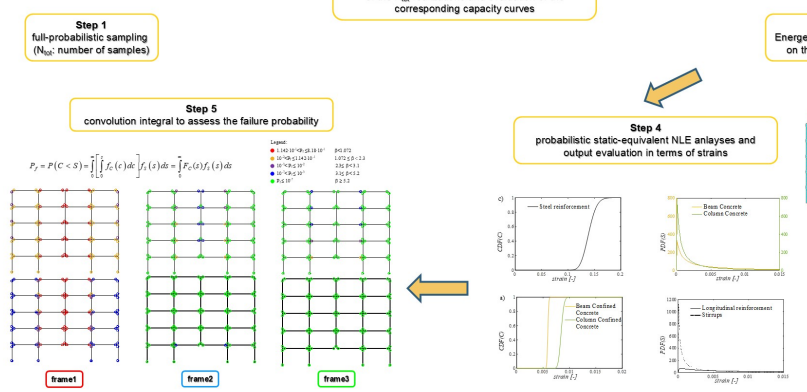
Robustness and global approach

Terrible events like the terrorist attack of 2001, which caused the total collapse of the so-called Twin Towers and thousands of victims, represented a shock for the entire community, not only for the consequences due to the structural collapse of the buildings, but mostly for human losses. In the past decades, such catastrophic phenomena on strategic structures caused by exceptional events, brought architecture, engineering and construction experts to show a growing interest towards structural robustness. European code rules and many international guidelines have been integrated by specific sections regarding structural robustness with suggestions or general requirements. In this way, it has been more and more clear that risk analysis should become part of strategies for collapse prevention against low-probability high-consequence (LPHC) events to investigate both socially acceptable and technically feasible solutions. The actual code rules do not provide any requirement of a progressive collapse risk assessment as well as associated reliability levels for buildings or bridges. This study aims at covering this gap in the specific case of reinforced concrete buildings designed in seismic area and subjected to progressive collapse phenomena implying the removal of a supporting column.

A strain-based **5-step procedure** for the probabilistic robustness assessment of 2D reinforced concrete (RC) moment resisting (MR) frames designed in a highly seismic zone is proposed. Considering the removal of the central supporting column as failure scenario, the probabilistic outcomes of three different frames are compared: the frame 1 designed according to the current standards, whereas the frame 2 and frame 3 designed with specific robustness improvements. In detail, the frame 2 adopts a continuous longitudinal reinforcement of the beams over the supports together with side face rebars, the frame 3 derives from the frame 2 assuming the same reinforcement amount in all the floors and symmetric between the upper and lower chord. The results provide the reliability levels of the three RC MR frames showing the safety advantages when robustness improvements are adopted with respect to standard seismic design: the failure probabilities are strongly lower in the spans close to the collapse scenario, the safety level increases in any structural element for increasing distance from the collapse phenomenon reducing the progressive consequences.







E. Miceli, D. Gino, P. Castaldo (2025). Reliability assessment of robustness for reinforced concrete moment resisting frames, Developments in the Built Environment, 100639 (DOI: https://doi.org/10.1016/j.dibe.2025.100639)

E. Miceli, P. Castaldo (2024): Robustness Improvements for 2D Reinforced Concrete Moment Resisting Frames: Parametric Study by Means of NLFE Analyses, Structural concrete : Journal of the FIB *Structural Concrete*, 25(1), pp. 9–31 https://doi.org/10.1002/suco.202300443