PhD Open Days

A new holistic approach for the rehabilitation of existing reinforced concrete structures

DOCTORAL PROGRAM IN CIVIL ENGINEERING

RAFAELA ALMEIDA (rafaela.almeida@tecnico.ulisboa.pt)

Abstract
The PhD thesis focuses on developing a Holistic Methodology for Performance Assessment (HMPA) of the existing Reinforced Concrete Structures (RCS). Integrating three crucial performance indicators: seismic vulnerability assessment, energy efficiency, and life cycle analysis. Into a unified framework that aims to enhance the overall understanding and decision-making process related to the selection of reinforcement types for individual buildings.

Motivation
In the European Union (EU), existing buildings account for approximately 40% of energy consumption and 38% of CO2 emissions, with around 40% situated in regions with moderate to high seismic activity [1]. In Portugal, RCS make up about 60% of its real estate, and it is estimated that over half of this stock was not designed under modern seismic regulations (Figure 1). Additionally, approximately 70% was not designed considering energy regulations [2].

While the identification of priority regions for seismic reinforcement based on existing seismic risk has been previously studied, it is not yet correlated with regions requiring energy reinforcement. Pohoryles et al. [3] made the first attempt to identify priority regions in the EU for combined seismic and energy reinforcement by correlating seismic hazard with climate indicators. However, this approach is deemed insufficient as the identification of priority regions heavily depends on combining seismic risk regions with regions having high energy needs.

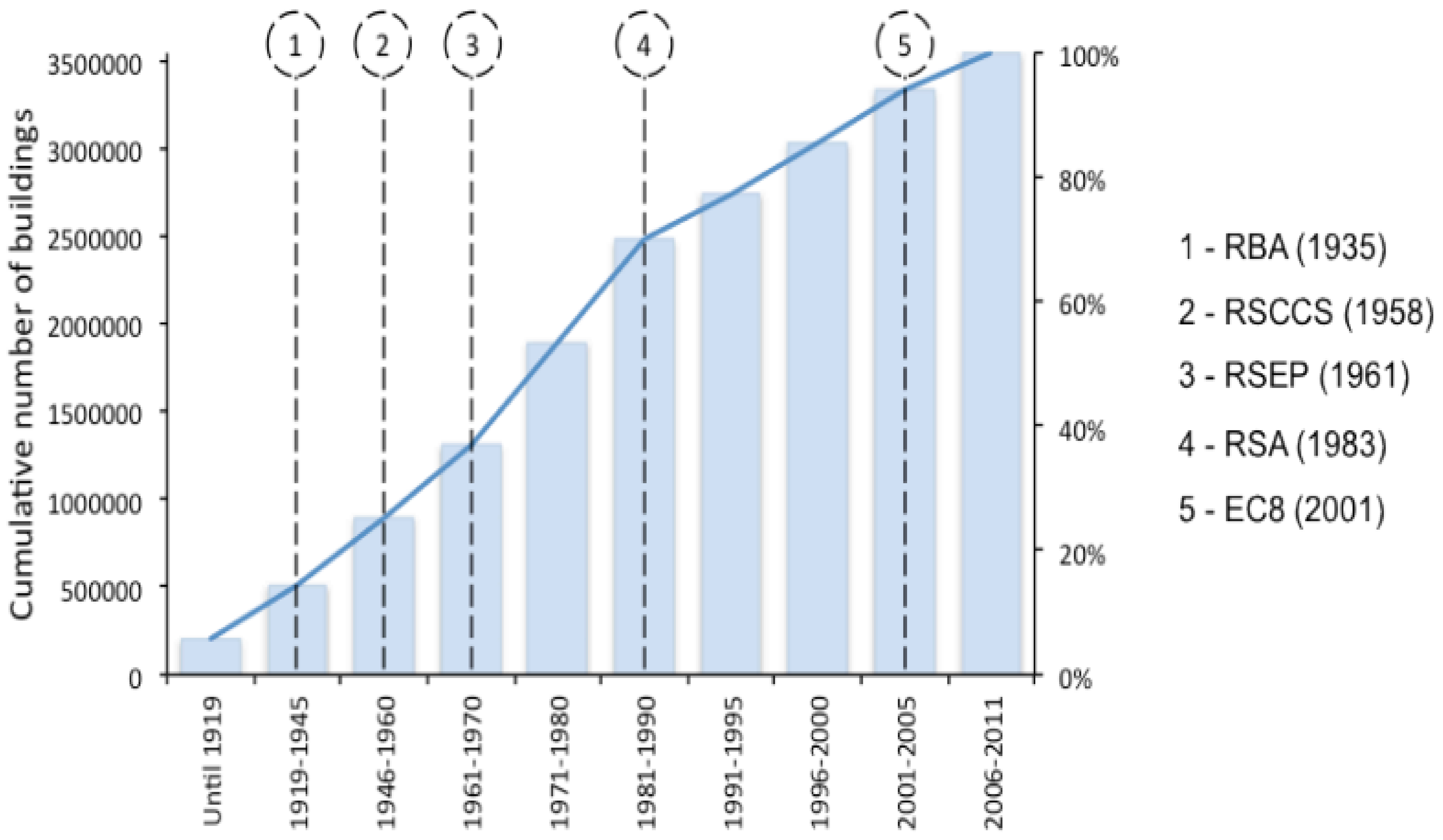

Figure 1- Cumulative distribution of buildings in Portugal to period of construction, at the time of the 2011 Building Census [3]

Building envelopes play a pivotal role in causing significant structural damage, collapses, casualties, and economic losses, exemplified by recent events, presented in Figure 2, in Turkey. Where an estimated 50% of post-earthquake costs are attributed to building repairs [4].

Energy, seismic, and life cycle assessments of buildings are usually conducted in isolation, without correlation. Usually, dynamic hygrothermal simulations can be used to evaluate various indicators like daily, monthly, seasonal, and annual energy consumption, along with specific points. Life cycle assessments typically focus on studying costs, encompassing initial costs, energy, water, operation, maintenance, repair, and replacement, among other factors. Concerning seismic safety assessment, it involves thoroughly examining structures and infrastructure to evaluate their resilience to seismic forces. This process includes analyzing factors such as the structural integrity, potential vulnerabilities, and adherence to seismic building codes. The goal is to identify areas that may be prone to damage during an earthquake and implement measures to enhance the overall seismic safety of buildings.

Figure 2- Non-structural damage in the envelopes of a residential building in Turkey (6th February 2023) [4]

Methodology and Future Developments
This project aims to propose and validate a novel performance assessment methodology for RCS building structures that combines the three performance indicators (structural, energy and life cycle). It is expected that this methodology will facilitate the identification and optimization of the integrated retrofitting required based on the building characteristics. A parametric study will be performed to evaluate and compare the impact of integrated, instead of independent, retrofitting on RCS at the country level, addressing the critical need for modernization in sustainability, efficiency, and resilience.

Primary objectives are: (i) Characterization of pre-1983 Portuguese building stock, prioritizing regions with high seismic risks and significant heating/cooling needs. Analyze energy consumption and seismic risk data, identifying RCS types. (ii) Development of HMPA for RCS, simultaneously evaluating the integration of the 3 indicators in economic terms. (iii) Evaluation of independent and integrated retrofitting on RCS, using techniques available in the literature and corresponding data to numerical model calibration. Compare with the non-retrofitted building condition. (iv) Assess retrofitting impacts at micro and macro levels, considering implications for individual buildings and broader contexts. (v) Development guidelines for HMPA implementation and propose policy measures to encourage holistic renovation interventions in the future.

The objectives of this project align with the Sendai Framework Action Plan for DRR 2015-2030, the United Nations SDG 2030 Agenda, the new European Bauhaus, the Paris Agreement of 2021, the new Urban Agenda for sustainable cities, and the First Circular Economy Action Plan.

References
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