Progetto DPC-ReLUIS 2022-2024 WP2

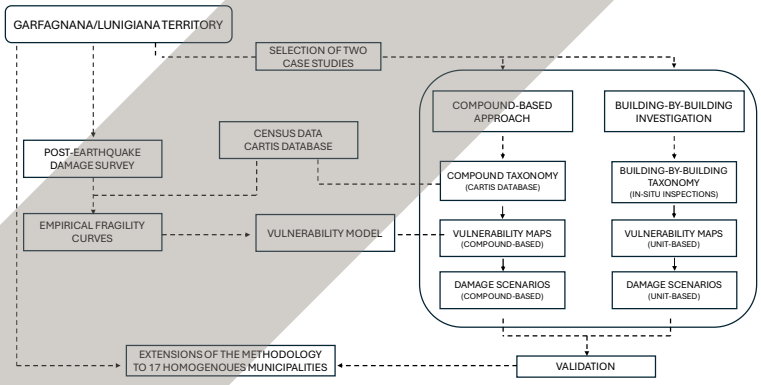
PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

Compound-based approach for large scale seismic vulnerability assessment: application to the Garfagnana area in Tuscany (Tasks 2.3.2, 2.2.3, 2.3.7)

Vieri Cardinali, Elisabetta Di Rienzo, Marco Tanganelli, Mario De Stefano

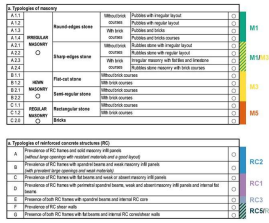
A rapid procedure for vulnerability and risk analysis at urban scale has been presented and validated with respect to a homogeneous territorial area. The research has been carried out through the tasks 2.1, 2.2 and 2.7. The methodology is addressed at defining fast evaluations taking advantage of a division of the territory in compounds based on historical evolution and development of the urban clusters. A compound-based taxonomy realized according to the CARTIS methodology has been adopted as exposure model. The vulnerability models have been validated with respect of recent seismic events for both masonry and RC buildings. Hence, a modified macroseismic vulnerability model for compound evaluations has been used. The simplified procedure has been evaluated with respect to a unit-based analysis where every structural unit has been specifically investigated through a macroseismic approach. The comparisons between the compound-based (CB) and the building-by-building (BB) evaluation is obtained in terms of damage scenarios through binomial distributions. The procedure has been validated assessing two distinct urban centers located in the Garfagnana area, Tuscany (Italy). The results show that the simplified procedure allowed matching the forecasted damage states, limiting the required information and the time of the investigation. The evaluation has been finally extended to the territorial area of Garfagnana and part of the Lunigiana, analyzing a total of 17 municipalities where the CARTIS taxonomy is available. Herein, fragility curves have been derived according to unified classes for a territorial evaluation. The research proves the effectiveness of the procedure in evaluating the seismic vulnerability of large areas, presenting a rapid tool useful for administrators and stakeholders in the management of urban areas.

METHODOLOGY

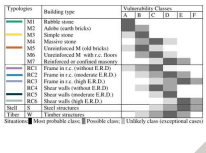


Flow-chart of the research

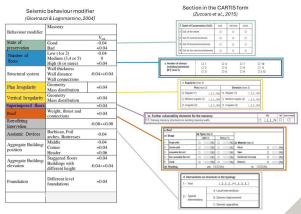
Building typologies: CARTIS form

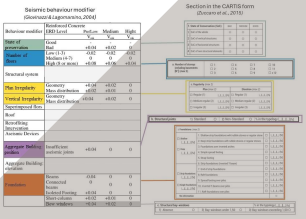


Building typologies: EMS-98



Correlation between the CARTIS taxonomy and the macroscale vulnerability model





Correlation between the CARTIS taxonomy and the vulnerability modifiers (Giovinazzi & Lagomarsino 2004)

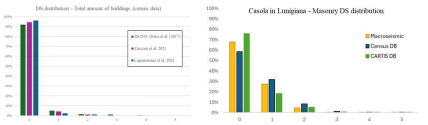
VALIDATION

Validation of masonry vulnerability model accounting on post-earthquake surveys (Lunigiana 2013)

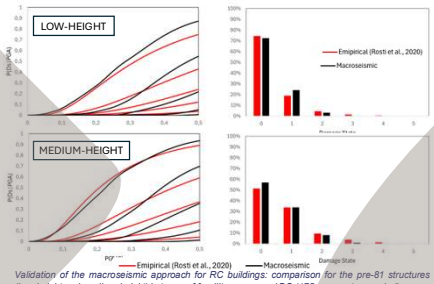
In 2013 an earthquake of magnitude 5.2 hit the Lunigiana territory. As a result, partial and minor damage occurred to the buildings, especially in the municipality of Casola in Lunigiana. Complexly, over 3000 post-earthquake damage inspections (AeDES surveys) have been conducted and collected in the Da.D.O. platform. Although the limited intensity of the ground motion, estimated around a macroseismic intensity of grade V-VI, the available information has allowed the obtainment of empirical correlations between the AeDES surveys and the buildings of the Lunigiana territory.

Validation of the RC vulnerability model accounting on post-earthquake surveys (L'Aquila 2009)

Concerning the RC structures, the available data from the Lunigiana earthquake were too limited to obtain vulnerability and fragility curves, therefore, a validation taking advantage of territorial data is not carried out. The typologies of RC buildings in the Garfagnana area have been correlated to the classifications provided in Rosti, et al. (2021) with respect of the 2009 L'Aquila earthquake. The comparison between the empirical fragility curves from Rosti et al. (2021) and the macroseismic ones adopted for this work are reported on the right panel. Although the fragility curves coming from the binomial distribution follow different trends from the real ones, there are reasonable similarities. In particular, these values have been validated considering the damage scenarios assuming PGA values for a return period of 475 years (life limit state SLV). On the right panel the Ds distributions for 0.202 g are shown; for this acceleration the damage distributions are comparable, while the fragility curves tend to have more differences especially towards higher IM values.



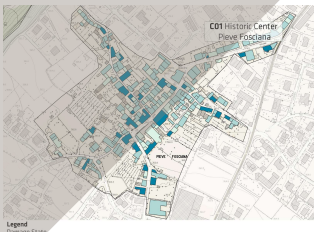
On the right - DS distribution for the Lunigiana 2013 based on the census data; on the right, Casola in Lunigiana – comparison in terms of damage scenarios between the macroseismic vulnerability approach and the real DS of masonry buildings

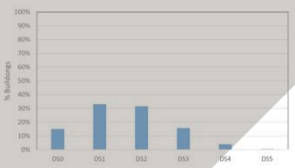


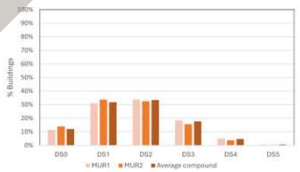
Validation of the macroseismic approach for RC buildings: comparison for the pre-81 structures (low-height and medium-height) in terms of fragility curves and DS (475 years return period)

Validation of the Compound-based procedure

To validate the CB approach, a more refined vulnerability assessment has been adopted. A building-by-building (BB) evaluation has been carried out for two distinct municipalities, Pieve Fosciana and Villa Collemandina. Herein, the different structural units have been identified and analyzed separately. This work has required external visual inspections, as to recollect each building to a univocal building typology according to the macroseismic taxonomy (Grünstal, 1998). The validation of the CB procedure is done in terms of cumulative distribution comparisons, stepping back from a BB scenario to a compound one. When the extensive procedure is applied, the comparison has been done merging the damage distribution and obtaining a mean distribution.







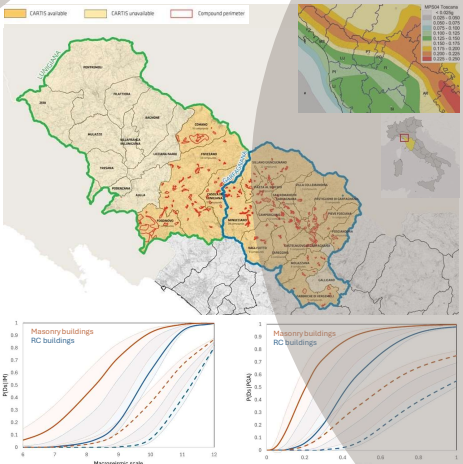
Validation of the CB procedure; on top, building-by-building damage scenarios for the historical center of Pieve Fosciana; below, histograms of the DS for SLV according to the mean value of the single buildings (left panel), the distribution of the different characterization and their weighted mean (right panel)

APPLICATION

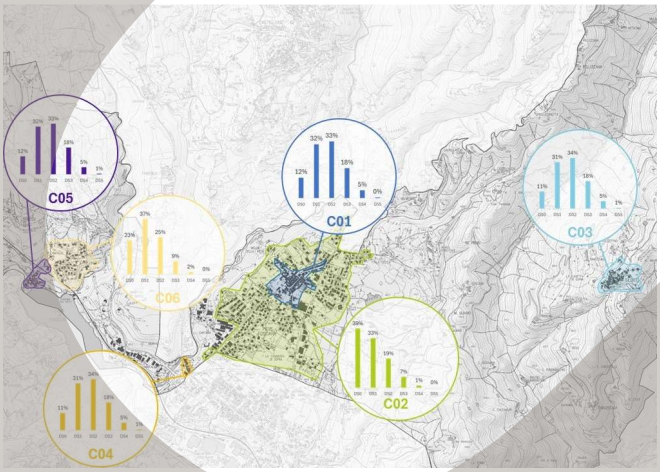
The rapid procedure has been finally applied to a large territorial area, including the whole Garfagnana territory and part of the Lunigiana. Complexly, a total of 17 municipalities have been investigate, i.e. the administrative divisions where the CARTIS taxonomy is available through the Plinivs database. The analysis has regarded 214 compounds, for a total of 515 characterizations, representing over 17000 residential buildings on the territory. The rapid procedure has permitted obtaining vulnerability and fragility curves for each characterization of each compound of the area. The results of the analysis are obtained at a compound level, nevertheless, in order to provide more general outcomes, they have been merged together considering a singular wider distinction: masonry buildings and RC structures.

In this research, the different information have been managed into a geographic information system GIS database, which allows to plot and visualize the different collected information based on the scale of interest. The outcomes of the research allow to obtain important information for the management of the urban areas, e.g. providing the number of buildings associated with each. These aspects are important to orient policies towards prioritization strategies, as to deal with the post-earthquake planning. At the same time, the presented data allow to gather useful information during the rescue activities after a seismic event, to prioritize the interventions as to propose suitable plans for the connection and the infrastructure management.

These results point out that although the medium-high seismicity of the territory, the frequent recurrence of seismic motions has made the population aware of the hazard, especially in the last century and after the reconstructions of the 1920 Garfagnana earthquake. Nevertheless, the vulnerability assessment shows that the territory is expected to suffer a certain damage in case of seismic events, with relevant consequences in terms of direct/indirect losses and functionality interruptions.



Above, availability of the CARTIS taxonomy within the different municipalities. Below, Fragility curves for the two considered limit states D2 (continuous lines) and D4 (dotted lines).



Pieve Fosciana - CB assessment - DS for 475 years return period considering a soil type A