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A simplified methodology for seismic repair costs assessment in RC buildings: an application to L'Aquila 2009 event

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ABSTRACT

The estimation of direct and indirect losses due to earthquakes is a key issue in the Performance Based Earthquake Engineering framework. The analysis of damage data in literature highlights the key role played by damage to non-structural components on the resulting losses, namely, infills and partitions, in Reinforced Concrete (RC) Moment Resisting Frames (MRF). Therefore, the use of simplified methods leading to the definition of repair costs, fatalities, and repair time due to earthquake, reproducing the influence of infills on the global behaviour of RC frames, is very attractive for insurance and risk management strategies.

In commonly adopted loss computation tools, no specific data related to masonry infill panels, widespread in moment-resisting-frame residential buildings, are available to perform a probabilistic assessment of losses. To fill this gap, specific fragility and loss functions have been recently proposed in the literature. To assess their validity and estimate the relevance of the repair costs due to infills after earthquakes with respect to the total reconstruction process, the present work analyses a subset of Reinforced Concrete residential buildings with masonry infills struck by the 2009 L'Aquila (Italy) earthquake, focusing on "lightly" damaged buildings, where only damage to masonry infills occurred. In such a way, the evaluation of repair costs can be made by neglecting the contribution due to repair activity to other structural components (namely vertical structures, horizontal structures, stairs, roofs).

Based on available data related to these buildings, the observed damage scenario after L'Aquila earthquake is first obtained. Then, a simplified mechanical method – PushOver on Shear Type models (POST) – for seismic vulnerability assessment of infilled RC buildings is used to obtain a predicted damage scenario to be compared with the observed one. The repair costs for infills are estimated given the observed and the predicted damage scenarios, by means of the cost functions at given damage states (DSs) reported in the most recent literature for infill panels. Additionally, the resulting estimated repair costs are compared with the actual repair costs presented in the available literature for the investigated subset of buildings, and the percentage influence of infills on the total repair costs due to earthquakes for residential buildings is lastly computed.

1 INTRODUCTION

In this study a simplified methods for the definition of repair costs accounting for the influence of infills on the global behaviour of RC frames and on its consequence in terms of damage and monetary losses is shown.

Although the structural typology considered herein, namely infilled RC frames, is a very widespread constructive solution, especially in Mediterranean area, the latter is not taken into consideration in the recently methods for losses estimation, for example the ATC (2012) FEMA P-58 simplified seismic performance assessment methodology developed by the US Federal Emergency Management Agency (FEMA).

Moreover, the analysis of damage data in (Dolce, Goretti, 2015) and (Del Gaudio et al., 2016) highlights the key role played by damage to non-structural components, namely, infills and partitions, in Reinforced Concrete (RC) Moment Resisting Frames (MRF). Therefore, the seismic performance assessment of infilled RC frames needs to take into account also infills to estimate expected seismic performance properly.

For these reasons, a simplified mechanical method – PushOver on Shear Type models (POST) (Del Gaudio et al., 2015; Del Gaudio et al., 2016, Del Gaudio et al., 2017, Del Gaudio et al., 2018) – for seismic vulnerability assessment of infilled RC building is used herein to determine repair costs of a dataset of “lightly” damaged residential buildings subjected to the April 6th, 2009 L’Aquila earthquake. More in details, “lightly” damaged buildings are defined herein as those buildings where only damage to masonry infills occurred after L’Aquila earthquake.

To this end, the fragility functions and the unit costs reported in Del Gaudio et al. (2019) for infill panels are used to determine their repair costs after seismic events, starting from the nonlinear response history analyses of buildings evaluated according to “POST” methodology.

The considered database is constituted by Moment Resisting Frame (MRF) residential RC buildings located in the Abruzzi region that after the 2009 earthquake are characterized exclusively by damage to infill panels. In such a way, the evaluation of repair costs can be made neglecting the contribution due to repair activity to other structural components (namely vertical structures, horizontal structures, stairs, roofs). Predicted costs are lastly compared with the costs obtained from the “observed” damage scenario, as explained in the following Sections.

2 OBSERVED DAMAGE AFTER L’AQUILA 2009 EARTHQUAKE

In this work the attention is focused on the L’Aquila 2009 seismic event, whose main characteristic are briefly described in Section 2.1. More detailed information can be found in (Del Gaudio et al., 2018).

After this event, a very extensive post-earthquake survey was performed to evaluate the produced damage to residential buildings and to judge about the usability of those buildings, as recalled in Section 2.2. Thanks to this data collection, a subset of buildings has been investigated herein as explained in Section 2.2, to obtain an “observed” damage scenario (Section 2.3) allowing in the end to obtain the post-earthquake repair costs due to infills, the main aim of this work.

2.1 Seismic input characterization

On April 6th, 2009, an earthquake of magnitude Mw = 6.3 struck the Abruzzo region, kill-ing 308 people. The area near the epicentre, in the neighbourhood of L’Aquila Municipality, was seriously damaged, resulting in a IX–X grade of MCS (Mercalli–Cancani–Sieberg) (Sieberg, 1930) macro-seismic scale. The related ShakeMap in terms of Peak Ground Acceleration (PGA) and spectral ordinates (PSA) (for periods of vibration, T, equal to 0.3, 1 and 3 sec) can be derived by means of the Italian National Institute of Geophysics and Volcanology (INGV) procedure (Michelini et al., 2008). The ShakeMap in terms of PGA is used in this work and shown in Figure 1.

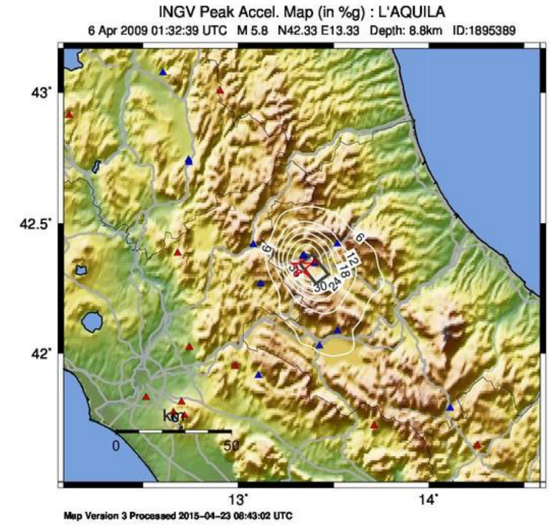

Figure 1: ShakeMap in terms of PGA derived by the Italian National Institute of Geophysics and Volcanology (INGV)

The map is derived by means of the software package ShakeMap® (Wald et al., 2006) using different Ground Motion Prediction Equations and the signals registered by Italian Strong Motion Network (Rete Accelerometrica Nazionale, RAN) and by the Italian National Seismic Network (RSN).

2.2 Analysed subset of lightly damaged buildings

The database of buildings investigated in this work is made up of Moment Resisting Frame (MRF) residential RC buildings located in the Abruzzi region that after the 2009 earthquake have been charged to post-earthquake usability assessment procedure, extracted from Da.D.O. platform (Dolce et al., 2017, 2019). This post-earthquake usability assessment procedure results in the collection of data related to Damage (D) severity (“Null”; “D1: Slight”, “D2-D3: Medium-Severe”, “D4-D5: Very heavy”) and extent (<1/3, 1/3-2/3, >2/3) about a given building, reported in the socalled AeDES (Agibilità e Danno nell’Emergenza Sismica, Usability and Damage in Post-Earthquake Emergency) form (Baggio et al., 2007). Considered damage could affect vertical structures, floors, stairs, roofs, infills, or can be pre-existing damage.

More in details, only buildings characterized exclusively by damage to infill panels are considered, since the aim of this work is the evaluation of repair costs due to infills in RC buildings, neglecting the contribution due to repair activity to other structural components (namely vertical structures, horizontal structures, stairs, roofs). Therefore, only buildings for which the AeDES form reported damage to exterior infills and interior partitions and "Null" damage to all the other structural components are considered for the following analyses. These buildings are defined herein as "lightly damaged buildings". The resulting database is composed by 5095 RC buildings. The related frequency distribution of number of stories, year of construction, plan Area (A) and suffered PGA are reported in Figure 2.

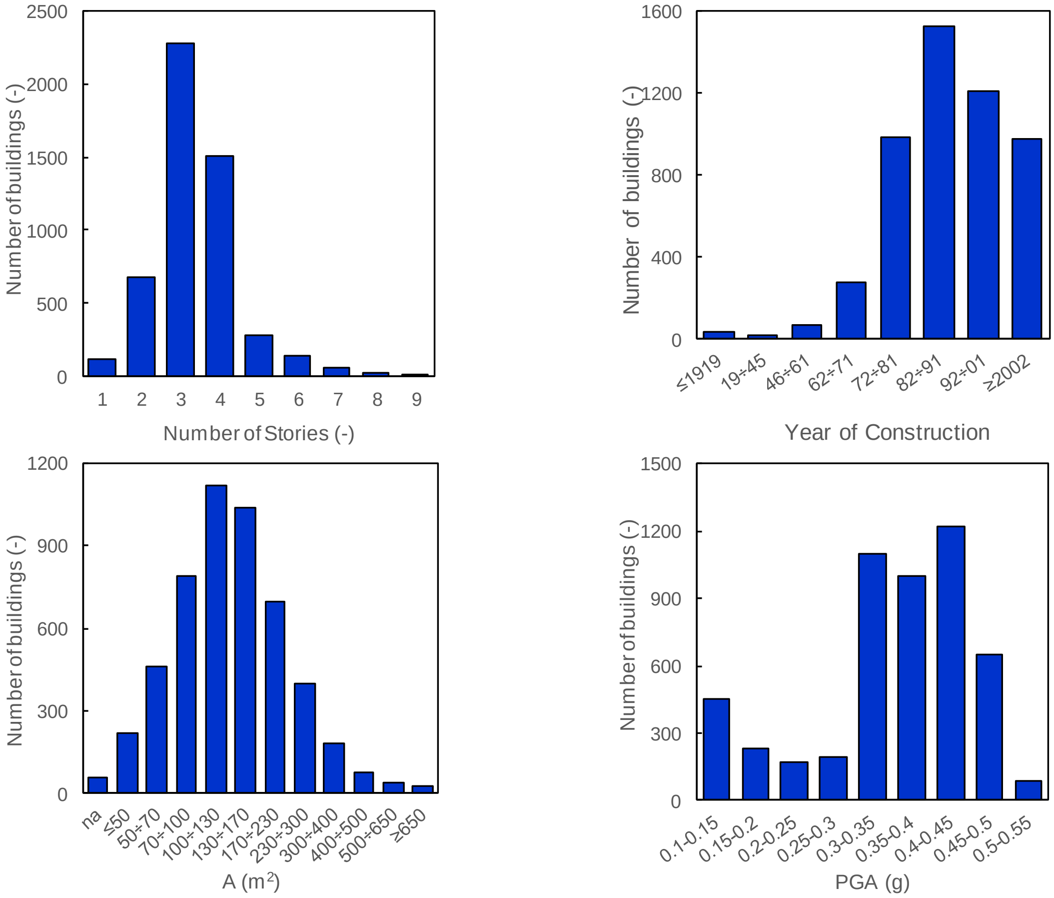

Figure 2: Frequency distribution of number of stories, year of construction, plan area (A), and PGA suffered during L'Aquila 2009 earthquake for the analysed subset of buildings.

2.3 *Observed damage*

Based on data described in the previous section, the observed damage scenario is obtained and shown in this Section. To obtain such a damage scenario some assumptions are necessary, particularly related to the damage metric definition specifically for infill panels.

The definitions of 3 Damage States (DSs) will be considered herein through the observation about the extent and severity of cracking patterns on the panels or about the failure of brick units, according to classification made by European Macroseismic Scale (EMS-98) (Grünthal, 1998), (see Table 1): fine cracks (DS1), large cracks (DS1), collapse (DS3). DS4 and DS5 are also defined in the EMS-98 scale, but they are basically related to damage suffered by RC members (for RC buildings). Therefore, due to the scope of the present work, these two DSs will be neglected in the following. Information about extent and severity of damage reported by AeDES survey forms (Baggio et al., 2007), essentyally descend from EMS-98. Thus, a certain degree of correlation can be found between these two damage scales, assuming the correspondence synthetically reported in Table 1.

Table 1: Correspondence of damage level according to EMS-98 and AeDES form.

EMS-98		**OBSERVED: AeDES form**	
DS0	No Damage	**D0 - Null Damage**	
DS1	Negligible to Slight damage: *Fine cracks in partitions and infills.*	**D1: Slight**	<1/3
			1/3 – 2/3
			>2/3
DS2	Moderate damage: *Cracks in partition and infill walls*	**D2-D3: Medium - Severe**	<1/3
			1/3 – 2/3
			>2/3
DS3	Substantial to Heavy damage: *Large cracks in partition and infill walls, failure of individual infill panels*	**D4-D5: Very Heavy**	<1/3
			1/3 – 2/3
			>2/3

Starting from the damage metric reported in Table 1, the collected buildings with damage to infills can be classified in DS1, DS2, or, DS3, depending on the information reported on the related AeDES form. The resulting "observed" damage scenario is shown in Figure 3, reporting the number of buildings in each considered DS, where the DS of the whole building is assumed as the maximum observed damage level identified in the AeDES form for that building. In summary, 2406 buildings present no damage to infills and partitions (and no damage to vertical structures, roofs, stairs, etc.). A total of 1943 buildings fall down damage level DS1, 555 are in DS2, and a smaller portion (191 buildings) presents a damage level DS3.

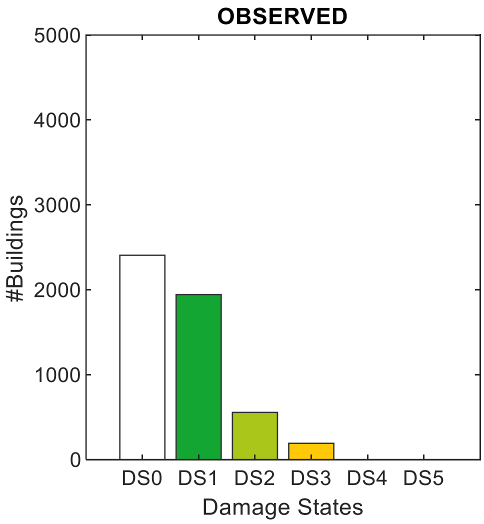

Figure 3: Resulting "observed" damage scenario.

3 REPAIR COST ESTIMATION DUE TO INFILLS FROM OBSERVED DAMAGE

The repair cost estimation performed herein belongs to the "component-level" loss predictions (Cremen, and Baker, 2019). Only repair costs due to infills are analysed and presented, to show their percentage incidence on the total repair costs – generally assumed as predominant in literature – and to provide a lower bound for the actual repair costs for infilled RC buildings. More in details, the repair costs estimation provided in this section is directly derived from the "observed" damage scenario reported and commented in the previous section, as explained in the following.

Repair costs for infill panels are taken from (De Risi et al., 2019), where a list of macro-activities have been considered, determining for each of them the main operations in repairing the damaged panel after a seismic event and corresponding unit costs from Price List of Public Works in Abruzzi Region (B.U.R.A. 2017). The infill typology considered herein is the double leaf cavity masonry wall with (hollow + hollow) panel, constituted by (12×25×25)cm hollow clay brick (void percentage > 55%) for exterior leaf and (8×25×25)cm hollow clay brick (void percentage > 55%) for interior leaf, with thermal insulation, generally widespread in L'Aquila region (Ricci et al., 2011). The corresponding repair costs are reported in Table 2. Note these values can be considered as expected (mean) values of economic losses for restoring a damaged infill partition after an earthquake. A dispersion value around them may be considered due to variability related to different professional practices or to different unit costs in different geographical areas or considering uncertainty in contractor pricing strategies. However, this aspect is not investigated in the present work.

Table 2: Repair costs (C^{TOT}_{DSi}) for double leaf hollow clay bricks.

	C^{TOT}_{DS1} (€/m²)	**C^{TOT}_{DS2} (€/m²)**	**C^{TOT}_{DS3} (€/m²)**
solid panel	77.0	105.3	285.8
panel with window	73.0	101.3	331.4
panel with door	69.2	97.4	374.9
interior partitions	51.3	73.5	199.9

To obtain a realistic repair cost prediction for a whole building starting from the values reported in Table 2, the equivalent length of interior infill panels ($L_{int,x}$ and $L_{int,y}$) along the two main orthogonal directions (x and y) is determined by assuming that the geometric percentage of interior infills (with thickness $s_{w,int}$) was equal to the 50% (Del Gaudio et al., 2017) of the geometric percentage of exterior infills (with thickness $s_{w,ext}$), as shown in Eq.s (1) and (2):

$$s_{w,int}\left(L_{int,x}\right)=0.5\left[s_{w,ext}\left(2L_x\right)\right]\rightarrow L_{int,x}={}^{s_{w,ext}}\!/_{s_{w,int}}\,L_x \quad (1)$$

$$s_{w,int}\left(L_{int,y}\right)=0.5\left[s_{w,ext}\left(2L_y\right)\right]\rightarrow L_{int,y}={}^{s_{w,ext}}\!/_{s_{w,int}}\,L_y \quad (2)$$

where $s_{w,int}$=80mm and $s_{w,ext}$ is assumed to be 200 mm. As a consequence, the ratio between $L_{int,x}$ and $L_{int,y}$ results coherent with the plan aspect ratio (PR = L_x/L_y).

The total repair cost estimation due to infills in a RC building obviously starts from the above described repair costs related to a single infill panel, but additionally requires the definition of some Random Variables (RVs) to identify the complete configuration of the damaged infills throughout the whole building. The necessary RVs, assumed here with uniform probability density functions, are listed below:

- Plan Area (*A*), assumed as a continuous RV within the ranges reported in the AeDES form;
- Plan aspect Ratio (PR), assumed as a continuous RV within the range [1; 2.5] (according to Del Gaudio et al., (2018));
- Damage Extent (DE), assumed as a continuous RV within the ranges [0; 1/3[, [1/3; 2/3[, [2/3; 1] (as in the AeDES form);
- Presence of Opening (OP), assumed as a discrete RV among the cases “no opening”, “window”, “door”.

Therefore, for each building belonging to the collected database, starting from its own *A* range and DE extent range from the related AeDES form, 1000 random samples are generated in a Monte Carlo simulation approach, thus assuming A_j, PR_j, DE_j, OP_j with j = 1,…,1000. Then, the following cascading quantities can be defined for each sample *j*:

- Longitudinal (L_{xj}) and Transversal (L_{yj}) plan length: $L_{xj} = A_j / PR_j$; $L_{yj} = A_j / L_{xj}$;
- Exposed infills area (S): Plan perimeter (P) × Building height (H) (the latter defined as the number of stories (n_s) multiplied by the inter-story height, h, assumed equal to 3 meters); namely, $S_j = P_j \times H = 2(L_{xj} + L_{yj}) \times n_s \times 3m$;
- Damaged infills area at DS_i (S_{DSij}): Exposed infills area × Damage extent at the damage level DS_i, namely, $S_{DSij} = S_j \times DE_{ij}$;
- Repair cost at a given DS_i (RC_{DSij}): Damaged infills area at DS_i × Repair cost at that DS_i, namely, $RC_{DSij} = S_{DSij} \times C^{TOT}_{DSi}$;
- Total repair cost TRC, as the sum of RC_{DSi}, for i = 1,…,3 averaging among all the j^{th} simulations.
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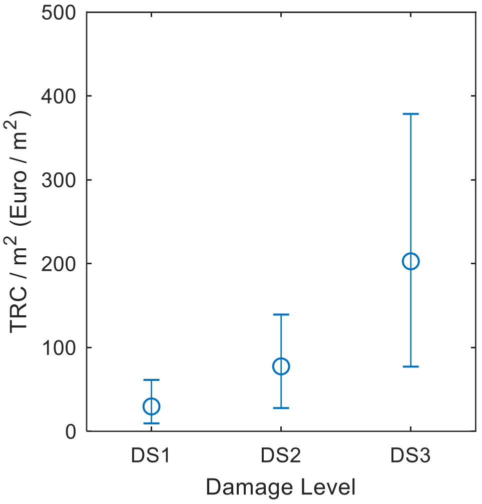


Figure 4: Repair cost estimation due to infills from observed damage.

The result of this procedure is shown in Figure 4, in terms of TRC per plan area unit in Euro

(€)/m^2 and depending on the maximum observed DS. Median, 16th and 84th percentiles are shown in Figure 4 for each maximum DS, and reported in Table 3. This repair cost estimation obtained from observed damage will be compared with the predicted repair cost estimation obtained from a mechanical-based predicted damage scenario, as explained in the following sections.

Table 3: Median, 16th and 84th percentiles for observed TRC.

TRC (€/m^2)	**Median**	**16th percentile**	**84th percentile**
DS1	29.6	9.5	61.3
DS2	77.4	27.7	139.2
DS3	202.7	77.1	378.5

4 DESCRIPTION OF THE “POST” METHODOLOGY

In this work, a component-based approach for the definition of repair costs due to earthquake starting from the pushover analysis performed trough the simplified mechanical method POST (PushOver on Shear Type models) is shown. The original POST methodology has already been presented in previous studies for urban-scale seismic vulnerability and fragility assessments, both applied at single building level (Del Gaudio et al., 2015; Del Gaudio et al., 2016, Del Gaudio et al., 2017, Masi et al., 2017) and at class-oriented level (Del Gaudio et al., 2018).

Basically, the POST methodology allows deriving non-linear static response of the building via static pushover analysis, using a simulated design procedure similar to Verderame et al., (2010). The Approximate Incremental Dynamic Analysis (IDA) curve of the multi-linearized capacity curve of the equivalent Single-Degree-of-Freedom (SDoF) system is derived from the SPO2IDA tool (Vamvatsikos and Cornell, 2006). The influence of infill panels is taken into account both in building response and damage definition according to EMS98 classification.

The approach, used herein for a subset of 5095 RC buildings damaged only to infill panels/partitions after L’Aquila 2009 earthquake, allows to determine repair costs to non-structural components from fragility functions and unit costs specifically derived for infills made up of hollow clay bricks reported in (Del Gaudio et al., 2019).

Table 4: Correspondence of damage level according to EMS-98 and predicted damage by means of the “POST” methodology.

EMS-98		**PREDICTED: “*POST*”**
DS0	No Damage	$IDR < IDR_{DS1} = \log n(\mu = -2.81, \beta = 0.9)$
DS1	Negligible to Slight damage: *Fine cracks in partitions and infills.*	$IDR \begin{cases} \geq IDR_{DS1} = \log n(\mu = -2.81, \beta = 0.9) \\ < IDR_{DS2} = \log n(\mu = -1.11, \beta = 0.4) \end{cases}$
DS2	Moderate damage: *Cracks in partition and infill walls*	$IDR \begin{cases} \geq IDR_{DS2} = \log n(\mu = -1.11, \beta = 0.4) \\ < IDR_{DS3} = \log n(\mu = -0.50, \beta = 0.4) \end{cases}$
DS3	Substantial to Heavy damage: *Large cracks in partition and infill walls, failure of individual infill panels*	$IDR \geq IDR_{DS3} = \log n(\mu = -0.50, \beta = 0.4)$

POST method require the exploitation of a Monte Carlo simulation procedure, generating a “virtual population” of buildings with input parameters sampled from statistical distributions properly defined. In this study, these “virtual population” is generated extracting number of storeys, plan surface and age of construction from the joint distributions collected from the surveys of the 5095 RC buildings making use of the “simulated annealing” method (Vorechovsky and Novak, 2009).

Further random variables considered in this study belong to the following types (for further details see Del Gaudio et al., (2018)):

- *Geometrical-typological characteristics*: number of storeys, age of construction, building area;
- *Material properties*: compressive strength of concrete, steel yield strength and infill material characteristics;
- *Modelling parameters*: Uncertainties in definition of non-linear behaviour of both RC columns and infill panels.

- *Displacement thresholds*: according to capacity models of Del Gaudio et al., (2019), as reported in Table 4;
- *Spectral shape*: The uncertainty in definition of spectral shape obtained from INGV ShakeMaps according to Bird et al., (2004), as done in Del Gaudio et al., (2017).
- *Record-to-record variability.* Uncertainty related to seismic ground motion is considered from 16- and 84%-fractiles IDA curves.

Therefore, the procedure adopted herein (see Figure 5) to determine the damage distribution along the height of the building from pushover analysis made through POST method is constituted by the following steps for each j^{th} run of Monte Carlo procedure:

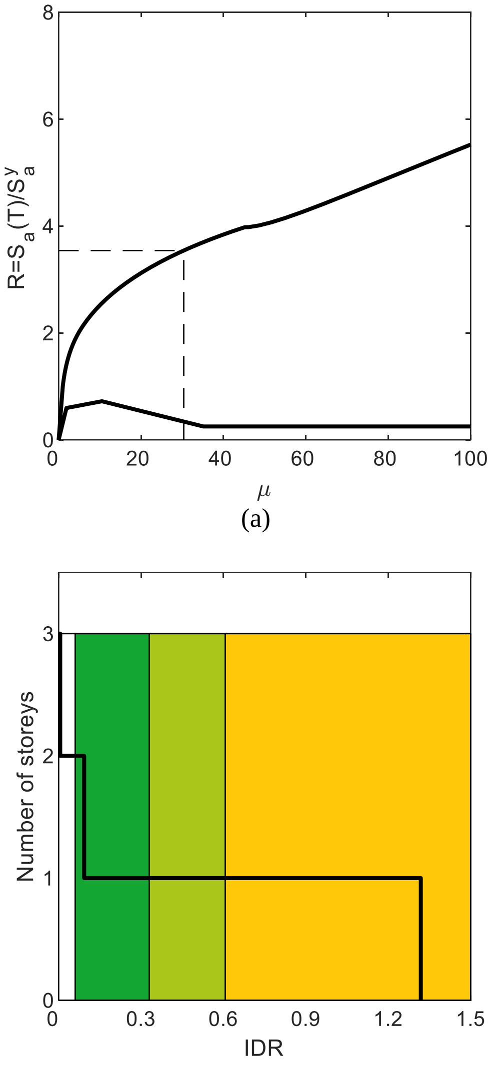
i. definition of a PGA value extracted for each considering buildings from the INGV ShakeMap, considering also its uncertainty. Note a distribution of PGA values is obtained from logarithmic mean and standard deviation value obtained from the ShakeMap, for a given location (latitude and longitude of the building);

ii. definition of the spectral ordinate value from the elastic pseudo-acceleration spectra (which is one of the considered random variables) anchored to the abovementioned PGA value as a function of the effective period of the buildings;

iii. definition of the roof displacement value from the simplified IDA and IDR distribution along the height of the buildings from the pushover analysis. In the present study, a class-oriented approach is adopted. Thus, unlike the PGA value specifically derived for each building, the pushover analysis for each direction and the corresponding IDA curves are derived for classes of building's height;

iv. Definition of damage distribution by comparing the IDR value obtained from the pushover analysis with the ones reported in Table 5. In such a way, together with the maximum damage level, also the co-existing less severe damage levels can be evaluated. The former is used to detect damage distribution for the considered sample of buildings, whereas the latter is essential to perform a realistic loss estimation, by summing up all the repair activities for the different damage levels to which the infills are subjected.

Note that, similarly to what done in Section 3, an equivalent length of internal infills has been evaluated by assuming that the latter results in a geometric percentage equal to 50% of the external ones in each direction. Moreover, the TRC is evaluated also assuming the presence of opening as a discrete RV among the cases "no opening", "window", "door".



(a)

(b)

Figure 5: Conceptual derivation of damage distribution: simplified IDA curve as a function of multi-linearized pushover curve (a), distribution of IDR along the height of the building from the pushover analysis and comparison with the IDR threshold for each DS (b).

Figure 6 shows the damage distribution resulting from the application of the abovementioned procedure (steps *i-iv*) for all the 5095 RC buildings considered in this study. A quite good agreement with observed damage scenario can be observed, both for what concern maximum damage (Table 5). A slight underestimation (of about 10%) of DS0 and DS1 and an overestimation of DS2 and DS3 (980 predicted-versus-555 observed at DS2; 246 predicted-versus-191 observed at DS4) can be observed in the predicted damage scenario compared to the observed one.

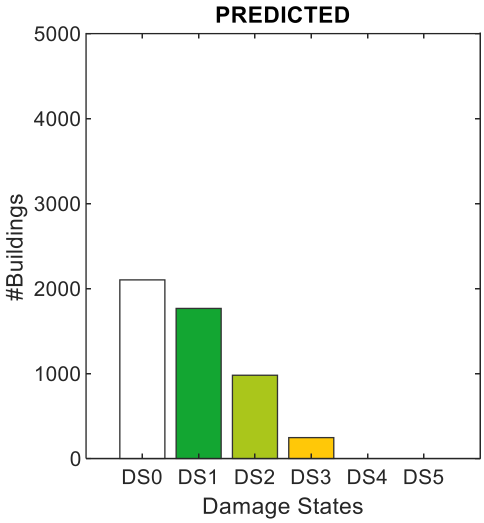


Figure 6: Resulting "predicted" damage scenario.

Table 5: Comparison between observed and predicted damage scenarios.

	Observed	Predicted	Predicted/Observed
DS0	2406	2102	0.87
DS1	1943	1767	0.91
DS2	555	980	1.77
DS3	191	246	1.29

5 REPAIR COSTS ESTIMATION DUE TO INFILLS FROM PREDICTED DAMAGE ACCORDING TO "POST" METHODOLOGY

The predicted repair costs are estimated herein following a "component-level" approach and considering only repair activities and corresponding elementary costs due to infills. The predicted repair costs are then compared with the one obtained in Section 3. The values of economic losses for restoring a damaged infill partition after an earthquake reported in Table 2, respectively for external and internal infills, are adopted.

Thus, in order to obtain the distribution of TRC, a further step, beyond *i-iv* reported in the previous Section, has to be added in the Monte Carlo simulation technique starting from the definition of the damage distribution related to the j^{th} run:

i. Evaluation of damaged infills area at DS_i as the number of infills ($n_{infills}$) in which IDR_j from the pushover analysis is greater that IDR_{DSi} of Table 4 both for longitudinal and transversal direction, $S_{DSij} = n_{infills}(IDR_j \geq IDR_{DSi}) \times A_{infills}$
ii. Evaluation of Repair costs at a given DS_i: Damaged infills area S_{DSij} × Repair cost at that DS_i (from Table 2, respectively for external and internal infills), namely, $RC_{DSij} = S_{DSij} \times C_{DSi}$;
iii. Evaluation of Total repair cost TRC, by summing up all the repair cost of the infills (external and internal) of the building both in longitudinal and transversal direction.

The result of this procedure is shown in Figure 7, in terms of TRC per plan area unit in Euro (€)/m^2 and depending on the maximum predicted DS. Median, 16th and 84th percentiles are shown in Figure 7 for each maximum DS, and reported in Table 6.

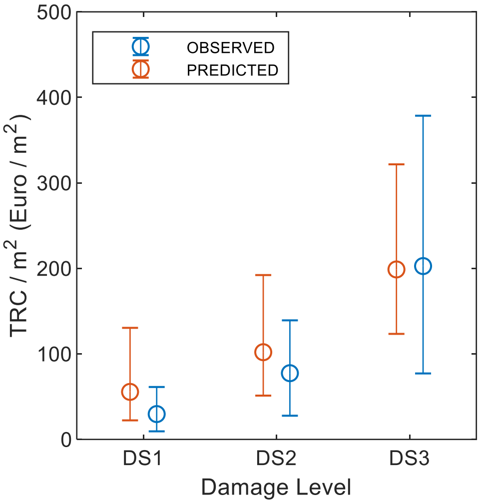


Figure 7: Predicted versus observed loss estimation due to infills.

Table 6: Median, 16th and 84th percentiles for predicted TRC.

TRC (€/m^2)	Median	16th percentile	84th percentile
DS1	55.6	22.3	130.5
DS2	102.0	51.2	192.2
DS3	198.8	123.4	321.7

It can be observed that predicted median TRC overestimates the observed one for what concerns DS1 (55.6 versus 29.6 €/m^2) and DS2 (102.0 versus 77.4 €/m^2), whereas it is in very good agreement for DS3 (198.8 versus 202.7 €/m^2). Given the degree of approximation, necessary for large-scale analyses, the observed-versus-predicted comparisons can be judged as a good promising result.

6 CONCLUSIONS

In present work, a component-based loss estimation approach for the definition of repair costs due to infills after earthquakes was shown, starting from the pushover analysis performed trough the simplified mechanical method POST (PushOver on Shear Type models). The results of pushover analysis were used to determine the distribution or interstorey displacement corresponding to the value of intensity measure (spectral ordinate) to which a given building was subjected during the earthquake. For each structural and non-structural components these interstorey displacements were directly compared to displacement thresholds, determining the corresponding distribution of damage and repair losses for the whole building, by simply summing up the relative costs for the corresponding repairing activities. In this work, only damage and repair cost to non-structural components, namely, infills and partitions, in Reinforced Concrete (RC) Moment Resisting Frames (MRF) are considered, due to the key role highlighted by recent seismic events.

The considered database was constituted by 5095 MRF residential RC buildings located in the Abruzzi region subjected to post-earthquake surveys after the 2009 L'Aquila Earthquake and characterized only by damage to infill panels. In such a way, the evaluation of repair costs was made by neglecting the contribution due to repair activity to other structural components (namely vertical structures, horizontal structures, stairs, roofs).

The total cost of restoration considered in this study is obtained considering the unit costs for a list of considered macro-activities relative to the main operations in repairing a single infill panel damaged during a seismic event obtained from the Price List of Public Works in Abruzzi Region for double leaf cavity masonry wall with (hollow + hollow) panels. The actual total repair cost is evaluated applying the aforementioned total cost of restoration from the information on damage severity and extent acquired by post-earthquake AeDES survey forms for the considered subset of buildings.

Similarly, predicted total repair cost was evaluated, applying the aforementioned total cost of restoration starting from the information on damage severity and extent mechanically determined through the pushover analysis performed by means of POST methodology.

The comparison between observed and predicted damage scenario highlights a good agreement both for maximum global damage and for what concerns the severity and extent of damage locally evaluated for all the infill panels of buildings. In addition, also the evaluation of average predicted total repair costs as a function of maximum observed DS detected in buildings result in good agreement with actual repair cost, highlighting an overestimation for what concerns the slighter Damage States (DS1 and DS2) and a very good agreement for the most severe Damage State (DS3).

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