Reconstruction Cost and Insurance Refunding Empirical Evidences for Long-span-beam Buildings Struck by the 2012 Emilia-Romagna Earthquake

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ABSTRACT: From the 2012 Emilia-Romagna earthquake much can be learnt in terms of seismic economic consequences. The public institutions' need for comparable and accessible data, to be used within the reconstruction process, is the reason why researchers can finally put their hands on a vast, consistent and reliable seismic damage and loss database. In particular, after the 2012 seismic sequence, the local administrative authority, Regione Emilia-Romagna, started collecting relevant information regarding consequences occurred to structures and infrastructures, public housing, cultural heritage and business facilities. For what concerns the latter, the so-called SFINGE database was assembled in more than 6 years of reconstruction process. In SFINGE, among other things, reconstruction costs and insurance refunding were documented. In this paper, the author presents some results obtained by exploring such database, processing and checking data on thousands of buildings. In particular, long-span-beam structures were taken into consideration: for them, empirical evidences are plotted and summarized. Study results can be included within the state of the art of seismic performance assessment tools.

Keywords: 2012 Emilia earthquake, consequence curves, business facilities, seismic insurance, long-span-beam buildings.

1 INTRODUCTION

The seismic sequence that, in May 2012, struck a highly industrialized area of Northern Italy, provoked vast damage to structures and infrastructures, cultural heritage and business activities. During the events (also known as Emilia-Romagna Earthquake), 28 people lost their life, and at least 300 were injured; at the same time, more than 40-thousand workers, from more than 3700 different enterprises, faced temporary lay-off (R E-R, 2012a). Assessed loss grand total within the affected area reached EUR 13.2 billion, of which at least 2.41 are related to enterprises (ARR, 2018). Soon after the emergency phase, the local administrative authority, Regione Emilia-Romagna, launched an extensive reconstruction campaign, divided into 3 subprograms: one for private housing – "MUDE", see (R E-R, 2012c) –, one for infrastructures and cultural heritage – "FENICE", see (R E-R, 2012b) –, and one for business activities – "SFINGE", see (R E-R, 2012d). In this paper, the focus is on data belonging to SFINGE's database. Such database hosts, among other things, vast and reliable information regarding the occurred damage, the reconstruction costs, and details about insurance refunding.

2 CONSEQUENCES OF THE EMILIA-ROMAGNA EARTHQUAKE

2.1 Reference framework

After May 2012, numerous reports and scientific papers were dedicated both to the Emilia-Romagna seismic sequence – see INGV (2015), Galli (2012), Scognamiglio (2012), Mucciarelli (2014) – and its effects – for example, Parisi (2012) and Rossetto (2012); in particular, for what concerns structural performance, special emphasis was paid to a specific class of structures widely adopted in industrial facilities, i.e. long-span-beam precast RC buildings (hereby referred to as LSB). Such buildings, for a description see also Bonfanti (2008), have precast beams of length typically between 10 and 20 m; columns can be prefabricated or not, and made in RC or masonry. Concrete panels or infill brick walls define the structures' perimeter. In general, both the seismic overcapacity, as well as the global ductility of these buildings, can be considered quite limited. An example of damaged LSB structure is given in Figure 1. Studies about this structural typology during the 2012 seismic sequence can be found in Savoia (2012), Casotto (2014), Magliulo (2014), Liberatore (2013), and Buratti (2017). On one hand, some of those works were written taking into consideration field inspection reports and on-site failure observations; on the other hand, database regarding *non-damaged* structures were used as a source of information. Recently, innovative results about actually damaged buildings were obtained by exploring data in the Emilia-Romagna's SFINGE database (Rossi, 2019a): interestingly, in this case, data are available at large scale about *actually damaged* structures, with thousands of relevant entries properly classified and organized in a database. The author of this paper accessed SFINGE's (non-sensitive) information, under a special scientific agreement between RWTH Aachen University and Regione Emilia-Romagna (Pres. R E-R, 2015), within the research project DatA ESPerT (Rossi, 2016). On one hand, Regione Emilia-Romagna provided the author with an electronic worksheet summarizing the main data records. On the other hand, during scientific visits at Emilia-Romagna's headquarters, the author interrogated SFINGE, having direct access to its entire archive. In this paper, as a first step, the author summarizes the main results of the information discovery sessions performed (see also: Rossi, 2019a); furthermore, precious insights regarding the insurance refunding data are reported in the text.

Figure 1. Example of LSB damaged building in Emilia-Romagna (source: Agenzia regionale per la ricostruzione – Sisma 2012).

2.2 Consequence variables

After the 2012 earthquake, in order to properly manage the bottom-up refunding process, the Italian public authorities decided to take three reference variables as main input of every SFINGE application: experienced loss (L), induced cost (C), and insurance refunding (I). Such variables' values were used – casa by case – so to determine the actual amount of money to be finally granted by the state to the business owner (G) (see also Rossi, 2019a). On one hand, L can be considered as the economic value that was destroyed by the earthquake; it is assessed by the applicant before reconstruction works start, by means of official price lists, market price levels and expert judgement. On the other hand, C is the money actually spent during the reconstruction works – and is obtained by summing up all the expenses actually documented in receipts; C includes money for reconstruction works, machineries repair actions, goods repurchase, and business relocation. In other words, L can be considered as a first approximation of the actually induced cost C (further details are given in Rossi, 2019b). For what concerns I, it is about the amount of money paid by the insurance companies to the business owners: Such variable was introduced in order to avoid overcompensation to the enterprises. In SFINGE database, the total number of well-documented damaged buildings is 4423. Of these, 2104 are LSB-type, while the rest (2319) are "housing-type". For the sake of brevity, results reported in the second part of this work will refer just to C and I variables, and to the sole LSB-type buildings.

2.3 Consequence classification

In collecting consequence data for SFINGE database, Regione Emilia-Romagna adopted a classification system according to which each enterprise belongs to one business macro-sector among *industry*, *trade*, and *agriculture*. Furthermore, suffered consequences were organized in 5 different main categories: *real-estate*, *business relocation*, *capital goods*, *in-stock products*, and *special food products*. Definitions are given in the following – (the bullet point list is taken from Rossi, 2019a).

- Real estate, or closely related to it (REA): Primary or secondary structural components of buildings (e.g. RC frames and cladding panels), including finishes (e.g. windows or doors) and non-productive systems (e.g. electrical systems).
- Business relocation (REL): Temporary relocation of the enterprise's activities to another site within the affected area. The purchase and rental of temporary structures (e.g. tents), the connection of utilities, and the moving of production facilities are also included in this category.
- Capital goods, except real estate (CAP): Machinery (e.g. metal lathes), tools (e.g. compressors), equipment (e.g. cabinets) and systems for production (e.g. air purification systems); hardware in general.
- In stock goods (STO): Raw material (e.g. glass jars), finished and semi-finished products in storage (e.g. canned food), who lost at least 20% of their initial value.
- Products (PRO): Special food and agriculture products: this is the case of aged cheese and balsamic vinegar. This category – that represents quite an important term on the regional budget – is only related to enterprises in agriculture.

Examples of the different categories are easily available in SFINGE database: In Figure 2a, the reader can see a precast RC building, a part of which collapsed, also damaging external steel stairs (REA). In Figure 2b, a case of production facility relocation (REL) is illustrated: a small business in agriculture is temporary reinstalled in a tent structure. In Figure 3a, a stack of glass jars (STO) fall down over a forklift (CAP); in Figure 3b, a light metal structure hosting aged cheese (PRO) overturned, losing its content and also damaging the lighting system (REA).

(a) (b)

Figure 2. Examples of consequences after the 2012 Emilia earthquake (a) REA (b) REL (source: Agenzia regionale per la ricostruzione – Sisma 2012).

(a) (b)

Figure 3. Examples of consequences after the 2012 Emilia earthquake (a) STO and CAP (b) PRO and REA (source: Agenzia regionale per la ricostruzione – Sisma 2012).

2.4 Consequence data

The information in SFINGE database can be accessed by application file; each application file may contain one or more items of the same type (indeed, as we said, the total number of listed buildings is 4423). Consequence data are reported in Table 1 (taken from Rossi 2019a): in it, the reader can see that real-estate (REA) is the most relevant category, with 73.6% of application files and 82.3% of money amount. Capital goods (CAP), is the second biggest, with circa 10% of both applications files and money amount.

Table 1. Induced costs (C) data summary

C	REA	REL	CAP	STO	PRO	Total
Number of files	2 847	453	372	180	17	3 869
% of total	73.6%	11.7%	9.6%	4.7%	0.4%	100%
Money amount (10^3 €)	2 032 460	85 422	251 785	50 785	47 643	2 468 094
% of total	82.3%	3.5%	10.2%	2.1%	1.9%	100%

For what concerns insurance refunding, working on the database it is possible to obtain what is reported in Table 2.

Table 2. Insurance refunding (I) data summary

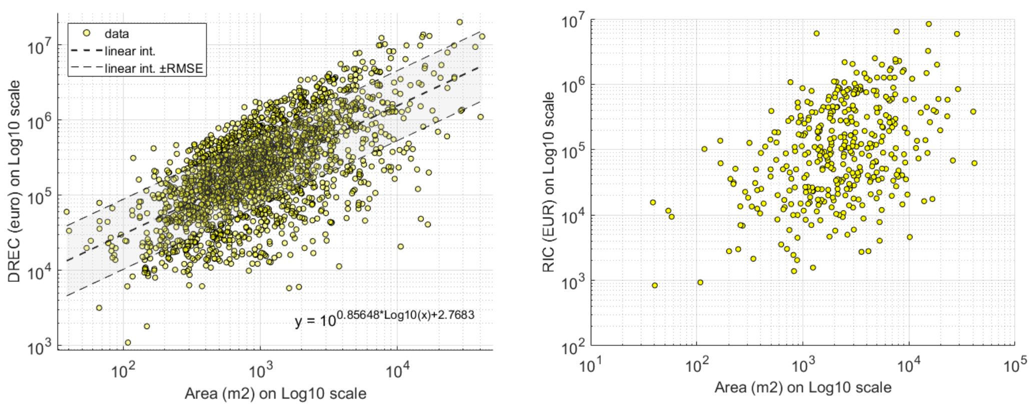
I	REA	REL	CAP	STO	PRO	Total
Number of files	316	8	55	17	2	398
% of total	79.4%	2.0%	13.8%	4.3%	0.5%	100.0%
Total amount (10^3 €)	170 948	4 204	33 404	3 852	13 443	225 852
% of total	75.7%	1.9%	14.8%	1.70%	5.9%	100.0%

From Table 2, the reader can see that, again, most of the economic amount went for real-estate (REA) items; still, capital goods (CAP) is the second most important term. Interestingly, the number of files regarding insurance refunding is circa 10% of the total listed application files; this could be taken as a first-attempt assessment of insurance penetration ratio within the region, for what concerns structures used by enterprises. It is also possible to notice that, while for REA, CAP, STO and PRO the ratio of insurance files to cost files is always between 9.4% and 14.8%, when it comes to business relocation (REL) this is less than 1.8%; the author thinks that, before the earthquake, within the region, enterprise relocation was generally underestimated as a potential source of cost, and therefore, only little insured.

2.5 *Data disaggregation*

At this stage of research, data reported in Table 1 and Table 2 can be furtherly disaggregated – at the level of single damaged item – for the sole REA-LSB subset. This means that, for each LSB structure, it is possible to access information regarding real estate-related consequences (i.e. reconstruction cost and insurance claims). In the following, for brevity, disaggregated REA-LSB cost items are referred to as DREC (or *Direct Real-estate-related Economic Cost*), while the corresponding insurance records are called RIC (*Reported Insurance Claim*). The disaggregation also discloses buildings' total area, making possible to calculate variables' values by square meter.

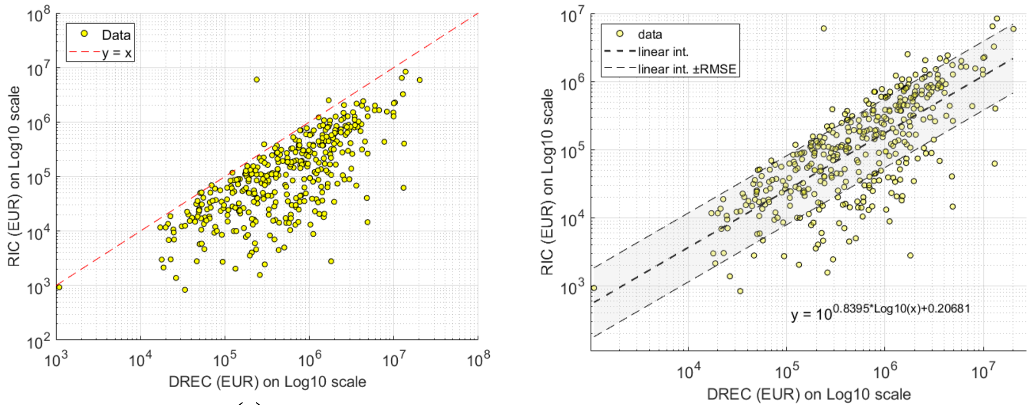
Scatterplots of area-DREC and area-RIC (in Log10 plane) are reported in Figure 4a and Figure 4b respectively. In the first case, a linear proportionality between Log10(area) and Log10(DREC) emerges, despite quite a large dispersion around the interpolation line (Root Mean Square Error – RMSE – being 0.47); the correlation coefficient is 0.59 (0.65 once values are on the Log10 scale). On the contrary, in the second case, when the 392 insurance data points are represented, almost no correlation between the chart's variables emerges (correlation coefficient is 0.28 for the original values and 0.42 on Log10 scale).



(a) (b)

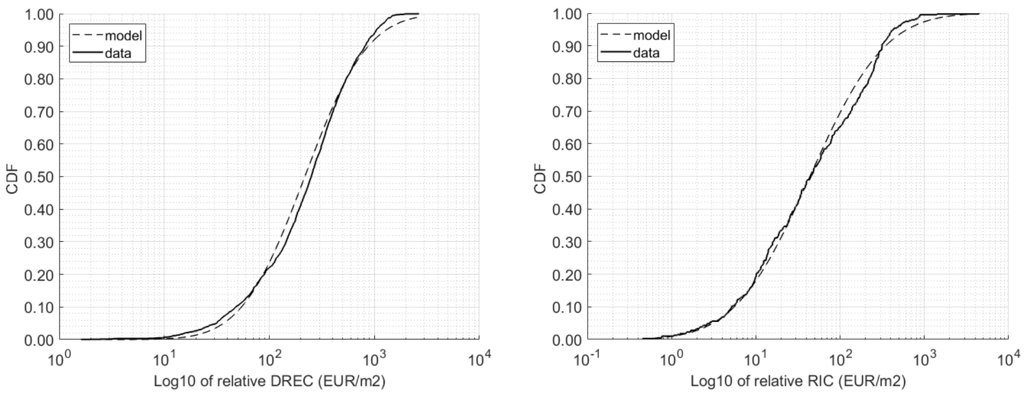
Figure 4. (a) Area-DREC and (b) area-RIC scatterplots, both on Log10 scale.

In Figure 5, the reader can see a DREC-RIC scatterplot: this time, it is possible to notice the emerging proportionality between the reported DREC and the corresponding RIC (the correlation coefficient between the two being 0.70 – and 0.74 with values on Log10 scale). On one hand, in Figure 5a, a dashed red parity line (i.e. y = x) is reported, to highlight how, except few outliers, RIC is always smaller than DREC. On the other hand, in Figure 5b, the focus is put on the emerging linear proportionality between the two variables (RMSE being 0.51). As a further step, so to enhance results portability, variables' values can be divided by the corresponding building's area, so obtaining *relative* DREC and *relative* RIC respectively. Figure 6a and Figure 6b show the Cumulative Distribution Function (CDF) of such variables: Despite not succeeding in the Kolmogorov-Smirnov Test (Massey, 1951), both the curves resemble a lognormal distribution. Distributions' mean and standard deviation (i.e. μ and σ) are given in Table 3.



(a) (b)

Figure 5. DREC-RIC scatterplot, on Log10 with (a) y = x line and (b) linear interpolation ±RMSE.



(a) (b)

Figure 6. Empirical and theoretical cumulative distribution functions (CDF) for (a) relative DREC and (b) relative RIR, both on Log10 scale.

Table 3. CDF main parameters

Variable	μ	σ
Relative DREC	2.34	0.47
Relative RIC	1.64	0.70

Reported results can be adopted in seismic performance assessment of LSB buildings. To this aim, it has to be noticed that, for both the variables – C and I – we just considered data regarding conditions for which non-zero consequences actually occurred. This means that, the probabilities discussed in this paper have to be intended as conditional ones.

3 CONCLUSIONS

The disastrous 2012 Emilia-Romagna Earthquake promptly triggered publicly funded reconstruction programmes, to manage which informative databases were set up by the local administrative authority. The author of this paper accessed such data source (and in particular the so-called SFINGE database), collecting and analysing relevant information regarding damaged enterprises. From research on available data, it clearly emerges how, for long-span-beam buildings, most of the direct economic consequences of the 2012 Emilia-Romagna earthquake – in terms of cost and insurance refunding – were due to real-estate items. In the text, relevant summaries to this regard are reported. Furthermore, scatterplots and cumulative distribution functions are given, so to statistically characterize the analysed seismic economic consequence datasets. Provided information may serve in future seismic consequence assessment of long-span-beam buildings. To this regard, limitations arise for what concerns the necessary correspondence to the Emilia-Romagna seismic sequence, and the local socio-economic context; about this, more can be learnt from existing literature and author’s previous works. Practically speaking, the future user will have to look for similarities in terms of seismic hazard, structural preparedness and values exposure; in this sense, proposed results can be immediately adopted in industrialised areas of other seismic prone Italian regions close to Emilia-Romagna, as Umbria, Marche and Veneto.

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