Seismic insurance market for the Italian building stock

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ABSTRACT
The life-cycle cost can be regarded as a benchmark variable in decision making problems involving insurance policy making for existing structures in seismic risk-prone areas. The present study is a preliminary study aiming to calculate the expected insurance premium for RC building stock in Italy subjected to seismic hazard in its service lifetime based on probabilistic loss estimation. A methodology is presented that takes into account the uncertainty in the occurrence of future events due to seismic hazard. The expected insurance premium can then be evaluated based on the time-dependent probabilities that the structure exceeds a set of discrete limit state thresholds. Finally, the methodology is implemented in an illustrative numerical example which considers the Italian portfolio of RC (reinforced concrete) structures discretized in 2 structural typologies and in the 103 Italian provinces. It is demonstrated how the evaluated premium can be affected by the decision to upgrade the structure.

1 INTRODUCTION

Earthquake insurance systems are implemented in many seismic hazard prone countries to reduce losses induced by seismic events and aid the financial recovery of homeowners suffering property damage. Different approaches and solutions have been experienced in Japan, New Zeland, California and Turkey. In Japan and New Zeland earthquake insurance is part of the fire insurance and a re-insurance program is provided by the national government (Brillinger 1993, Yucemen, 2005). Also in California private companies offer seismic insurance, but a state-run earthquake insurance company (CEA) was formed after the Northridge earthquake in 1994, to overcome some difficulties encountered by private companies (Scawthorn et al 2003). In Turkey, the government tried to introduce a compulsory insurance for homeowners, providing a public re-insurance support (Yucemen, 2005). An earthquake insurance system for Italy has been often discussed after seismic events, but studies on this topic are scarce (Amendola et al. 2000).

The objective of the activity here presented is to conduct a preliminary study investigating the feasibility of a seismic insurance system in Italy. In particular, under a set of simplifying assumptions, the insurance premium has been derived for the owners of residential property units.

To do this, Italy has been divided into 103 areas, corresponding to Italian provinces, assumed to be characterized by homogeneous seismic hazard. The population of RC buildings in each of the considered areas has been divided into 2 categories:

- RC (reinforced concrete) structures designed for gravity loading;
- RC structures designed for seismic loading

The total amount of square meters of property units in buildings belonging to each of these categories, in each province, has been obtained from the 2001 Italian building stock census. In particular, in this database, residential buildings are reported for structural typology and year of construction. Hence, RC structures built before 1972 have been assumed to be designed for gravity loading and those built after 1972 have been considered as designed for seismic loading.

Then, two cascade models have been implemented:

- A loss estimation model has been used to evaluate in each of the considered locations and for each of the considered structural typologies, the annual expected loss due to earthquake.
- A monopoly market-full insurance model has been built, accounting for the total number of property units in each of the considered provinces, expected to suffer the economic loss evaluated in the loss estimation model.

By implementing these two models, the analysis resulted in the insurance premiums, to be paid by the owners of the property units of each structural typology in each Italian province, in order to contract an insurance policy covering all the repair/reconstruction costs in case of seismic damage. The insurance premium are reported per square meter of property.

2 LOSS ESTIMATION PROCEDURE

As mentioned above, Italian territory has been divided into 103 areas, corresponding to the Italian provinces in 2001 and in each of them it has been assumed to have an homogeneous hazard. In particular, in each province, the hazard from the Italian Zonation by Istituto Nazionale di Geofisica e Vulcanologia, INGV, in the capital city of the province, has been considered, in terms of PGA.

For each of the considered structural typologies, 4 limit states of damage have been considered: Very light damage (LS1), Light damage (LS2), Moderate damage (LS3) and Severe damage (LS4), according to FEMA 273 (FEMA 273,1997).

Hence, for each structural typology and for each limit state, a fragility function has been introduced reporting the probability that the structure has exceeded a given limit state for a given PGA level. In this preliminary study, the fragility functions existing in literature have been employed. For both categories of RC structures, the fragility functions proposed by Ahmad et al. (Ahmad et al. 2011) have been used. The fragility functions are illustrated in Figures 1-4.

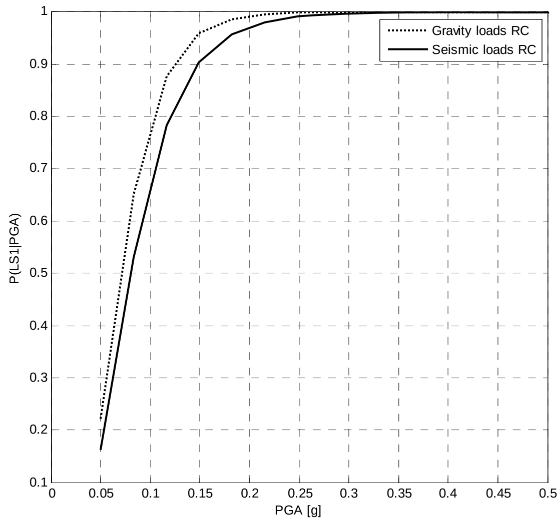

Figure 1– Fragility functions, LS1

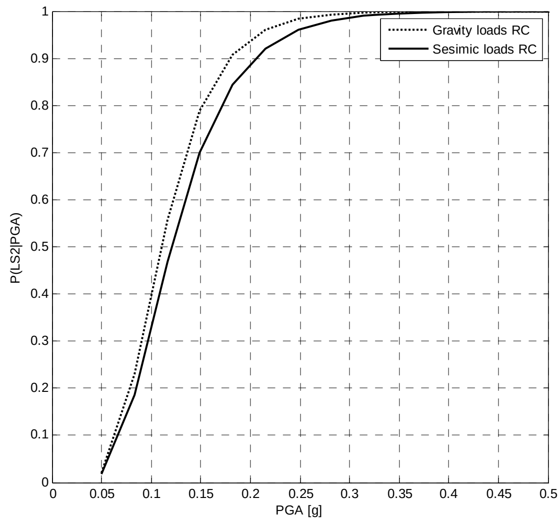

Figure 2– Fragility functions, LS2

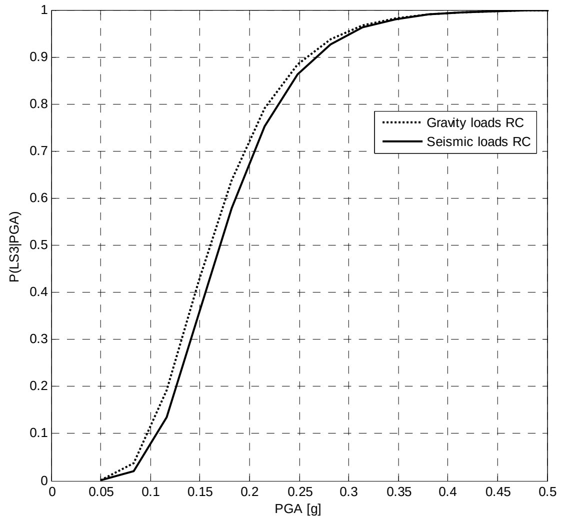

Figure 3– Fragility functions, LS3

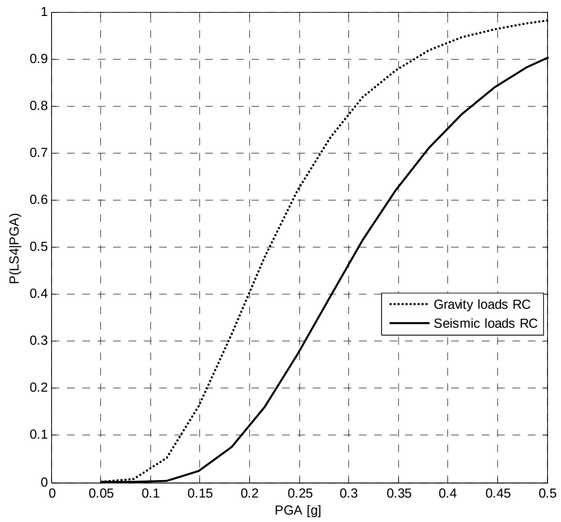

Figure 4– Fragility functions, LS4

The repair/reconstruction cost for each of the considered limit state, has been assumed to be deterministic and is evaluated per square meter of the damaged property unit, as reported in Table 1.

Table 1– Repair/reconstruction cost per limit state

Limit state	Very light damage, LS1	Light damage, LS2	Moderate damage, LS3	Severe damage, LS4
Repair/ reconstruction cost, RC [€/m²]	250	500	750	1500

The expected loss per square meter *E(c)*, in each province and for each structural typology has been evaluated according to the following:

$$E(c)=\sum_{LS=1}^{4} CR(LS)\int\left[P(LS\mid PGA)-P(LS+1\mid PGA)\right]d\lambda(PGA)\Big| \qquad (1)$$

Where for LS=4, *P(LS+1|PGA)=0.*Being *CR(LS)* the repair/reconstruction cost for each limit state, *P(LS|PGA)* the fragility function for the given limit state and *λ(PGA)* the site specific PGA hazard expressed in terms of the annual rate of exceeding a given PGA. The total expected loss per province and structural typology is then obtained by multiplying it by the total amount of square meters of each structural typology.

Figure 5 reports the expected loss per square meter as a function of PGA. It can be observed that the values approach to 1500€ corresponding to the *reconstruction cost*.

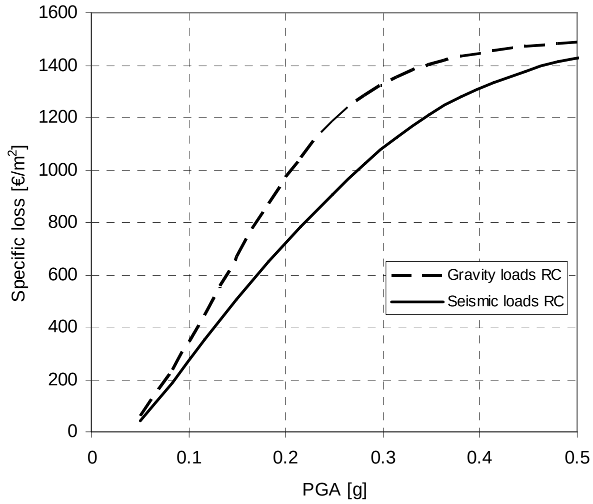

Figure 5– Expected loss per square meter conditioned on PGA

It should be noted that, the expected loss per square meters, for each typology is only influenced by the site specific hazard; whereas the total loss depends also on the total amount of square meters in each province, representing the exposition to the seismic risk. For example, the province of Rome has a larger total loss than the province of Udine for each structural typology, even if the expected losses per square meter in Udine are almost three times those calculated for Rome.

It is also interesting to compare the losses for the two RC categories. It can be observed that, in each province, the expected loss per square meter of the RC structures designed for gravity loading is almost 1.3 times that of the RC structures designed for RC loading. This difference can be interpreted as the loss reduction due to retrofit, assuming that a seismic retrofit operation on an RC structure designed for gravity loading moves the corresponding fragility functions close to those of an RC structure designed for seismic loading. Furthermore, it is interesting to highlight that the annual expected loss for the whole Italian RC building stock due to seismic events is equal to almost 6 billions of euros.

3 SEISMIC INSURANCE MODEL

The output of the loss estimation procedures represents the input for the seismic insurance model, base on the following assumption:

- The insurance policy covers the total loss due to earthquake damages on property units;
- All the property units are covered by an insurance;
- A monopoly market is assumed.

The seismic insurance model is based on the following considerations.

Let us assume a home-owner may incur in a loss Li with probability π_i which reduces his house wealth W_0. However, the home-owner can buy an insurance contract providing him with a transfer x_i whether the loss occurs. The contract price is p, which is the premium paid by the consumer to the insurance company. Assuming risk aversion, the expected utility of the consumer is

$$E\left[U\left(\cdot\right)\right] \equiv \left(1 - \sum_i^k \pi_i\right) U\left(W_1\right) + \sum_i^k \pi_i U\left(W_i\right) \quad (1)$$

where $W_1 = W_0 - p$ and $W_i = W_0 - p - L_i + x_i$, under the assumption that the individual takes the coverage. π_i is the probability that an earthquake of intensity i with $i = 1,\ldots, k$ occurs.

In a monopoly market the insurance company makes a take-it-or-leave-it offer to the home-owner involving the payment x_i to him if the loss L_i occurs. Assuming the insurance company is risk neutral then it maximizes the expected insurance profit:

$$p - \sum_i^k \pi_i x \quad (2)$$

subject to the participation constraint that the consumer accepts the contract

$$E\left[U\left(\cdot\right)\right] \geq \overline{U} \quad (3)$$

where the latter is the maximum level of utility in the absence of insurance. Denoting the Lagrangian with

$$\ell = p - \sum_i^k \pi_i x + \lambda \left\{ E\left[U\left(\cdot\right)\right] - \overline{U} \right\} \quad (4)$$

it follows that the contract consists in the $(x_i; p)$ satisfying the first order conditions

$$\frac{\partial \ell}{\partial p} = 0 \quad \frac{\partial \ell}{\partial x_i} = 0. \quad (5)$$

These conditions implies $x_i = L_i$, that is full insurance and thus $W_i = W_0$.

Assuming W_0 equal to the reconstruction cost (i.e. 1500€/m^2), the results in Tables 2a and 2b are obtained, in terms of insurance premium per square meter p, for each structural typology, in each province. Assuming an average extension of the residential property units equal to 92 m^2, as reported by the 2001 Italian building stock census, the average insurance premium per property unit is also obtained (Tables 2a and 2b).

It can be observed that the maximum values for the insurance premium are obtained in L'Aquila province, whereas the minimum values are obtained in Vercelli, in Piemonte region. It can be also observed that, moving from the RC structures designed for gravity loading to the RC structures designed for seismic loading, i.e. through a retrofit operation, results in a reduction of the premium equal to 30%. It can be also observed that in most seismic areas the insurance premium for the average property unit are quite high (in L'Aquila for the RC structures designed for gravity loading the premium is equal to € 2,478.86), much higher than the average property tax.

Table 2a– Insurance premium per province and structural typology

Provinces	Specific insurance premium p [€/m^2]		Insurance premium for the average residential property unit [€]	
	Gravitiy load designed RC structures	Seismic load designed RC structures	Gravitiy load designed RC structures	Seismic load designed RC structures
Torino	0.21	0.16	19.22	14.35
Vercelli	0.03	0.02	2.58	1.92
Biella	0.06	0.04	5.29	3.93
Verbania	0.08	0.06	7.49	5.58
Novara	0.03	0.02	2.86	2.13
Cuneo	4.45	3.24	409.17	297.77
Asti	0.07	0.05	6.04	4.50
Alessandria	0.43	0.32	39.81	29.88
Aosta	2.06	1.53	189.39	140.94
Varese	0.04	0.03	3.71	2.76
Como	0.06	0.05	5.88	4.38
Lecco	0.24	0.18	22.50	16.85
Sondrio	1.37	1.02	126.21	94.29
Milano	0.18	0.13	16.26	12.16
Bergamo	3.10	2.27	285.24	208.90
Brescia	6.96	4.94	640.32	454.89
Pavia	0.88	0.66	80.91	60.67
Lodi	0.77	0.58	70.79	53.15
Cremona	1.36	1.02	125.28	94.01
Mantova	1.95	1.46	179.51	134.01
Bolzano	0.21	0.16	19.15	14.33
Trento	0.89	0.67	82.34	61.81
Verona	7.83	5.52	720.13	508.04
Vicenza	6.89	4.89	633.42	449.59
Belluno	19.45	13.02	1,789.14	1,197.42
Treviso	5.70	4.08	524.33	375.65
Venezia	0.72	0.54	66.25	49.73
Padova	1.43	1.07	131.39	98.42
Rovigo	0.55	0.41	50.63	37.95
Pordenone	13.50	9.25	1,241.64	851.38
Udine	15.13	10.31	1,392.32	948.51
Gorizia	13.43	9.20	1,235.16	846.20
Trieste	3.93	2.86	361.69	263.56
Imperia	6.08	4.26	559.03	391.49
Savona	0.29	0.22	26.70	20.01
Genova	0.82	0.62	75.46	56.63
La Spezia	4.23	3.10	389.29	284.94
Piacenza	1.99	1.48	182.85	136.35
Parma	5.90	4.27	542.85	392.67
R. Emilia	8.20	5.82	754.25	535.78
Modena	9.07	6.38	834.38	587.22
Bologna	9.85	6.97	906.01	641.26
Ferrara	5.21	3.74	479.27	344.29
Ravenna	9.11	6.40	837.81	588.62
Forlì	16.11	11.14	1,482.23	1,025.18
Rimini	11.44	7.92	1,052.15	728.70
Massa	6.99	5.02	642.63	461.94
Lucca	5.05	3.69	464.84	339.09
Pistoia	8.71	6.21	801.43	570.86
Firenze	5.21	3.81	479.30	350.25
Prato	7.04	5.08	647.23	467.48
Livorno	4.28	3.11	393.95	286.02

Table 2b– Insurance premium per province and structural typology

Provinces	Specific insurance premium *p* [€/m^2]		Insurance premium for the average residential property unit [€]	
	Gravitiy load designed RC structures	Seismic load designed RC structures	Gravitiy load designed RC structures	Seismic load designed RC structures
Pisa	4.01	2.94	369.12	270.29
Arezzo	8.79	6.29	808.93	578.78
Siena	6.32	4.58	581.40	421.30
Grosseto	0.67	0.50	61.57	46.17
Perugia	14.83	10.30	1,364.79	947.88
Terni	10.03	7.14	923.19	657.05
Pesaro	10.96	7.58	1,008.56	697.14
Ancona	9.60	6.66	882.86	612.40
Macerata	11.29	7.86	1,038.67	723.17
Ascoli Piceno	12.03	8.42	1,106.72	774.69
Viterbo	5.88	4.27	540.96	392.87
Rieti	12.45	8.73	1,145.33	803.04
Roma	4.48	3.30	411.97	303.47
Latina	1.03	0.77	94.43	70.84
Frosinone	9.07	6.46	834.37	594.31
L'Aquila	26.94	18.04	2,478.86	1,659.80
Teramo	12.47	8.71	1,146.97	801.57
Pescara	5.71	4.14	525.65	381.17
Chieti	8.51	6.03	782.54	554.55
Isernia	25.49	16.91	2,344.78	1,555.52
Campobasso	19.30	12.96	1,775.48	1,191.92
Caserta	5.56	4.06	511.31	373.31
Benevento	22.61	15.00	2,079.97	1,380.02
Napoli	8.92	6.26	820.38	575.70
Avellino	12.89	8.88	1,186.16	817.18
Salerno	2.58	1.92	237.08	176.91
Foggia	5.89	4.28	541.44	393.50
Bari	0.69	0.52	63.75	47.86
Taranto	1.15	0.86	106.14	79.56
Brindisi	0.11	0.08	9.85	7.36
Lecce	0.18	0.13	16.31	12.22
Potenza	14.49	9.91	1,333.17	911.42
Matera	5.80	4.16	533.56	382.60
Cosenza	26.92	17.79	2,476.79	1,636.87
Crotone	7.66	5.40	705.02	497.18
Catanzaro	22.09	14.73	2,032.72	1,355.09
V. Valentia	25.79	17.05	2,372.41	1,568.30
R. Calabria	26.22	17.31	2,412.05	1,592.69
Trapani	0.20	0.15	17.95	13.45
Palermo	9.96	6.92	916.57	637.03
Messina	22.34	14.83	2,055.45	1,364.07
Agrigento	0.30	0.22	27.52	20.63
Caltanissetta	0.93	0.70	85.47	64.17
Enna	1.61	1.21	148.10	110.91
Catania	16.48	11.19	1,516.30	1,029.68
Ragusa	14.84	9.87	1,365.71	907.98
Siracusa	14.50	9.67	1,334.45	889.21
Sassari	0.17	0.13	15.47	11.56
Nuoro	0.17	0.13	15.47	11.56
Oristano	0.17	0.13	15.47	11.56
Cagliari	0.17	0.13	15.47	11.56

4 LIMITS OF THE CURRENT RESEARCH AND FUTURE ACTIVITIES

Authors want to emphasize that this simulation represents a preliminary research effort and that it has been conducted under simplifying assumptions that are going to be removed in future work. In particular:

- It was assumed that for the entire territory within each province the seismic hazard is constant and is equal to that of the capital city; a more refined discretization of Italian territory based on seismic zonation can be introduced;
- Italian RC building stock was discretized in just 2 typologies. Also in this case, a more refined discretization is necessary, accounting for building height, regularity/ irregularity, age, retrofitting/ maintenance operations, etc. Masonry structures must be included.
- The costs per square meter to be incurred in case of damage, per each limit state need to be considered as dependent on the location of the structures and on the structural typologies;
- A full insurance-monopoly market was assumed; more complex cases need also to be considered, as deductible percentage, limits to the covered loss, private/public re-insurance mechanisms, etc.
- The whole Italian RC building stock was assumed to be covered by an insurance policy; this hypothesis could be removed and public incentive to contract the insurance policy need also to be introduced in the simulation.

5 CONCLUSIONS

In this preliminary study a seismic insurance system has been built for Italian RC building stock, accounting for the site specific hazard in (the capital city of) each of the 103 Italian provinces and discretizing the building portfolio in 2 structural typologies (i.e. RC structures designed for gravity loading and RC structures designed for seismic loading). A loss estimation model and an insurance model have been applied resulting in the annual expected loss and in the annual insurance premium for each property unit owner in each Italian province. The obtained results showed a very different insurance premium among the different Italian provinces as a result of the different seismic hazard. Furthermore, in each province, a significant difference between the considered structural typologies was observed, as a result of the different fragility functions/seismic vulnerability. In particular, tone can appreciate the influence of retrofitting operations in reducing the expected lossand as a consequence, the insurance premium to be paid in order to have covered the economic loss due to seismic events.

Finally, it is emphasized that this study represents a preliminary effort in analyzing the feasibility of a seismic insurance system, extended to all the Italian RC building stock. Further investigations need to be conducted in order to introduce more detailed hypothesis and to obtain a more sophisticated simulation.

6 REFERENCES

Ahmad N., H. Crowley, R. Pinho, 2011, “Analytical fragility functions for reinforced concrete and masonry buildings aggregates of euro-mediterranean regions – UPAV methodology” Internal report, Syner-G Project, 2009/2012.

Amendola, A., Ermoliev, Y., Ermolieva, T., “Earthquake Risk Management: A Case Study for an Italian Region”, Proceedings of the Second EuroConference on Global Change and Catastrophe Risk Management: Earthquake Risks in Europe IIASA, Laxenburg, Austria, 6–9 July, 2000

Brillinger, D. R., Earthquake risk and insurance. Environmetrics, 4 , 1993, 1–21.

FEMA 273 “NEHRP Guidelines for the seismic rehabilitation of buildings”, Washington, USA, 1997

Palm, RI, Hodgson, ME, Blanchard, RD, Lyons, DI “Earthquake Insurance in California: Environmental Policy and Individual Decision-Making.” Westview press, 5500 central ave., boulder, co 80301 (USA). 1990.

Scawthorn, C., Kunreuther, H., and Roth Jr, R.: 2003, Insurance and financial risk transfer, In: W.-F Chen. and C. Scawthorn (eds.), Earthquake Engineering Handbook, CRC Press, Chapter 32.

Yucemen M. S. Probabilistic Assessment of Earthquake Insurance Rates for Turkey, Natural Hazards, 2005, 35: 291–313