UNIVERSITÀ DEGLI STUDI
DI NAPOLI FEDERICO II

The implicit seismic risk of code-conforming structures in Italy

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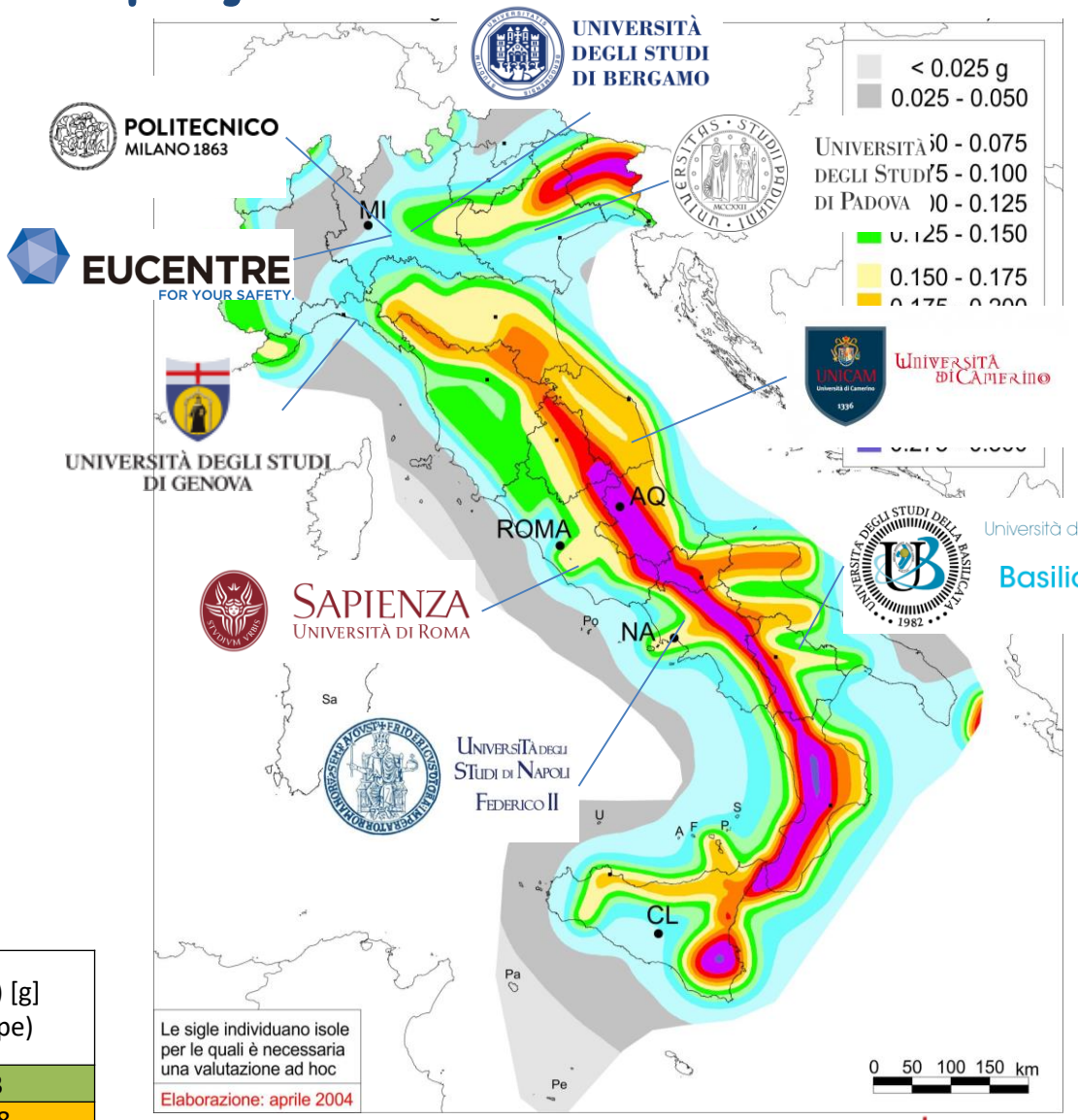
RINTC project 2015-2017

1. Evaluate the failure rate (global collapse and usability-preventing damage) for code-conforming buildings in Italy.

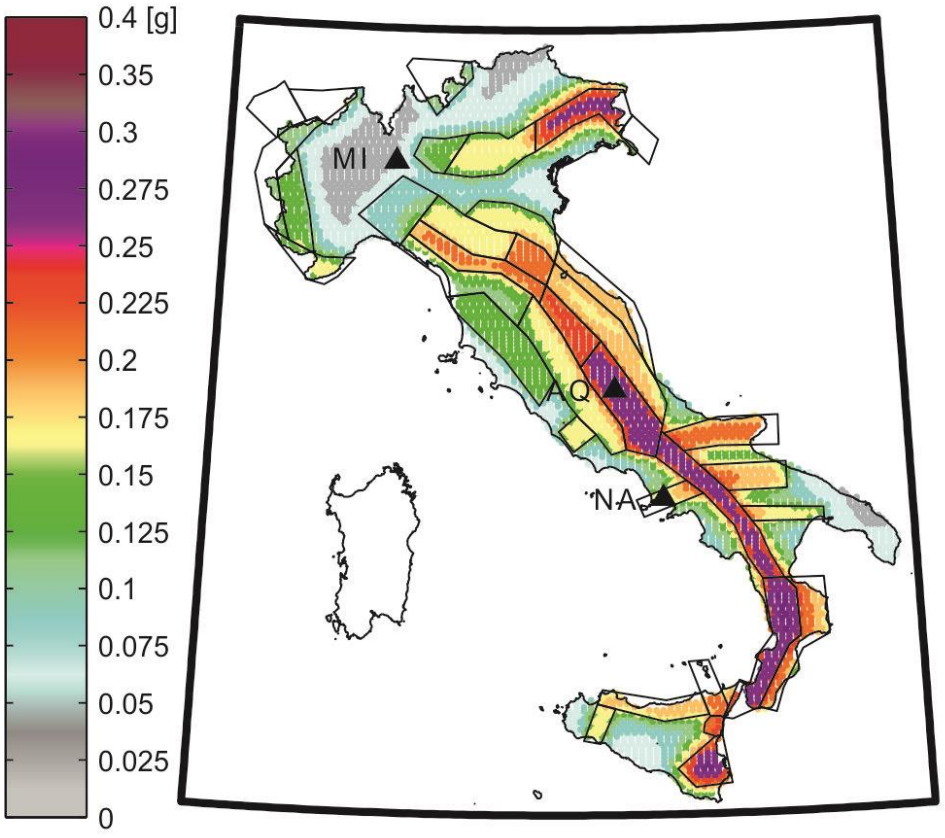
2. Five structural typologies were considered: URM, RC, PRC, Steel, BI.

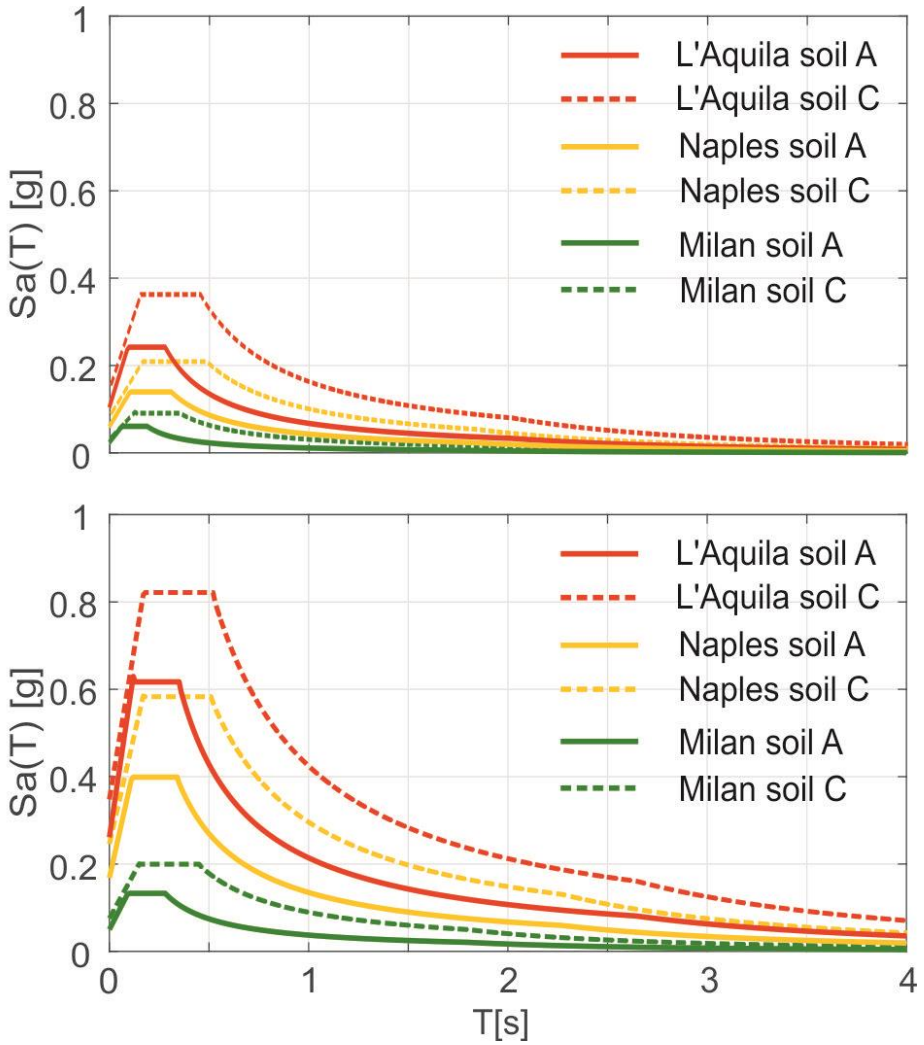
3. Design was for five sites and two EC8 soil classes (A and C).

Site	PGA (475) [g] (Soil A-type)	PGA (475) [g] (Soil C-type)
Milano	0.0495	0.0743
Napoli	0.1668	0.24338
L'Aquila	0.2607	0.3451

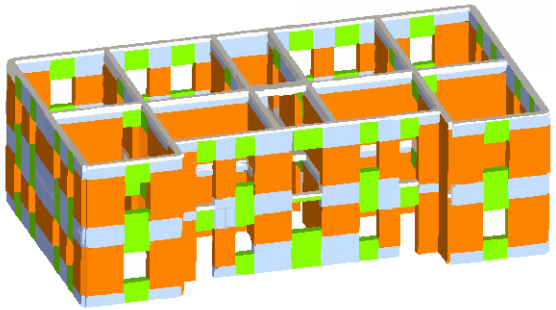


Sites and limit states

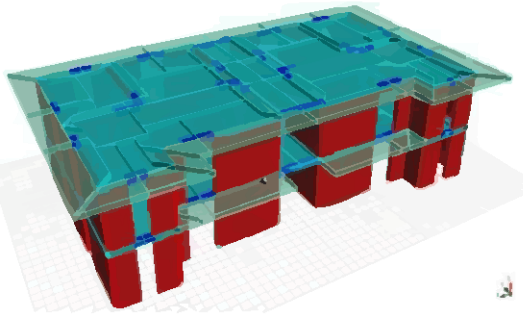




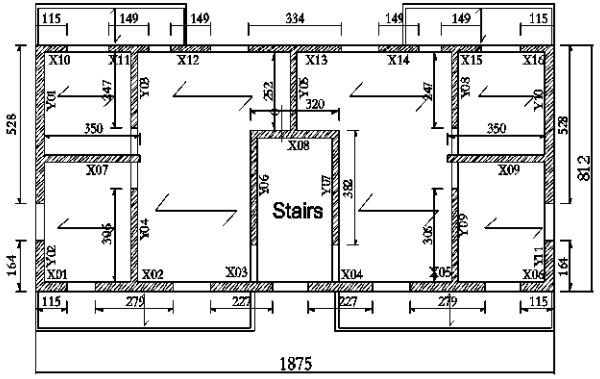
Masonry buildings (50+ structures)



(a)



(c)



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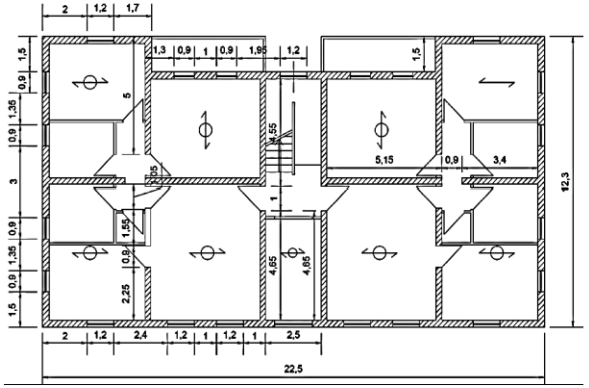
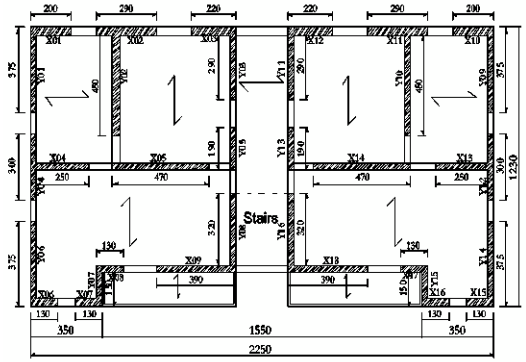
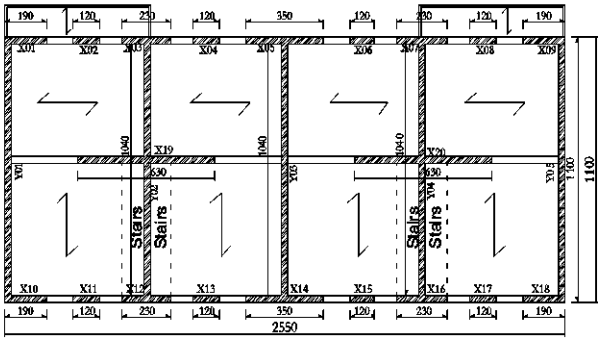


(b)



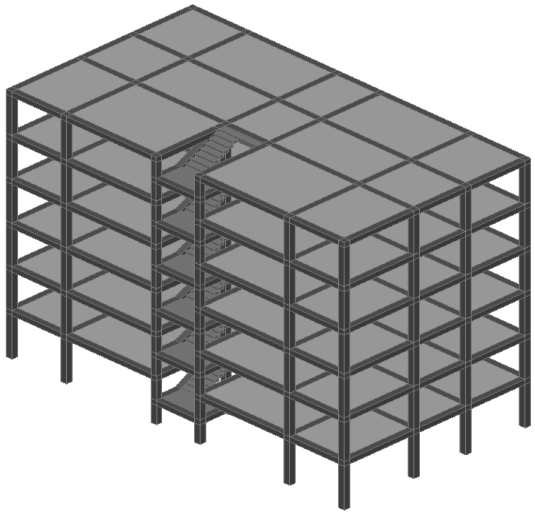
(d)

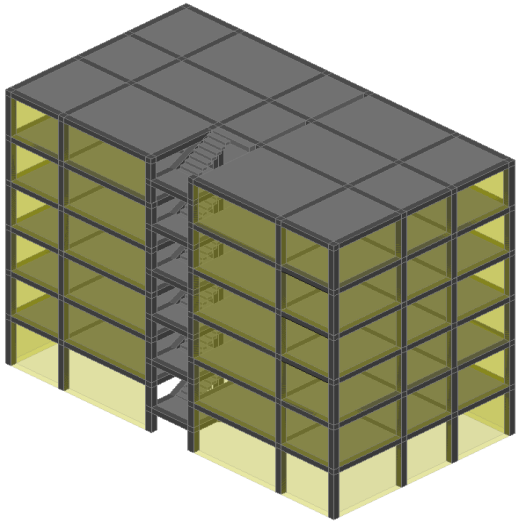


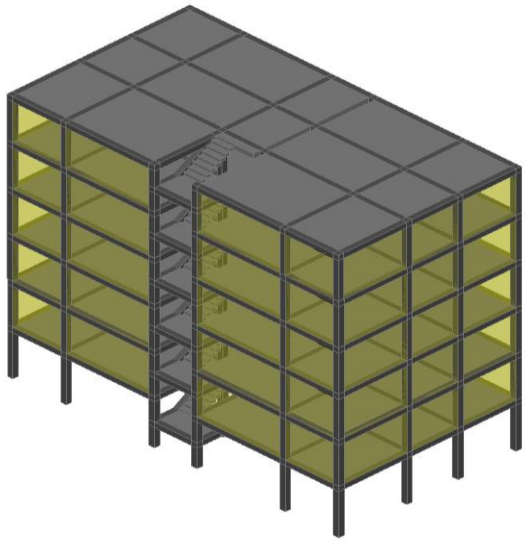
(f)

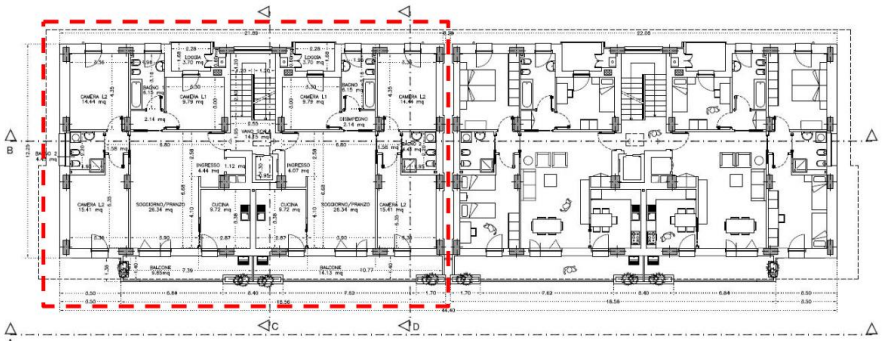
1. Two and three stories buildings.
2. Regular and irregular.
3. Design with simple building, equivalent frame (q=3.6), and non-linear static approaches.

Reinforced concrete buildings (50+ structures)



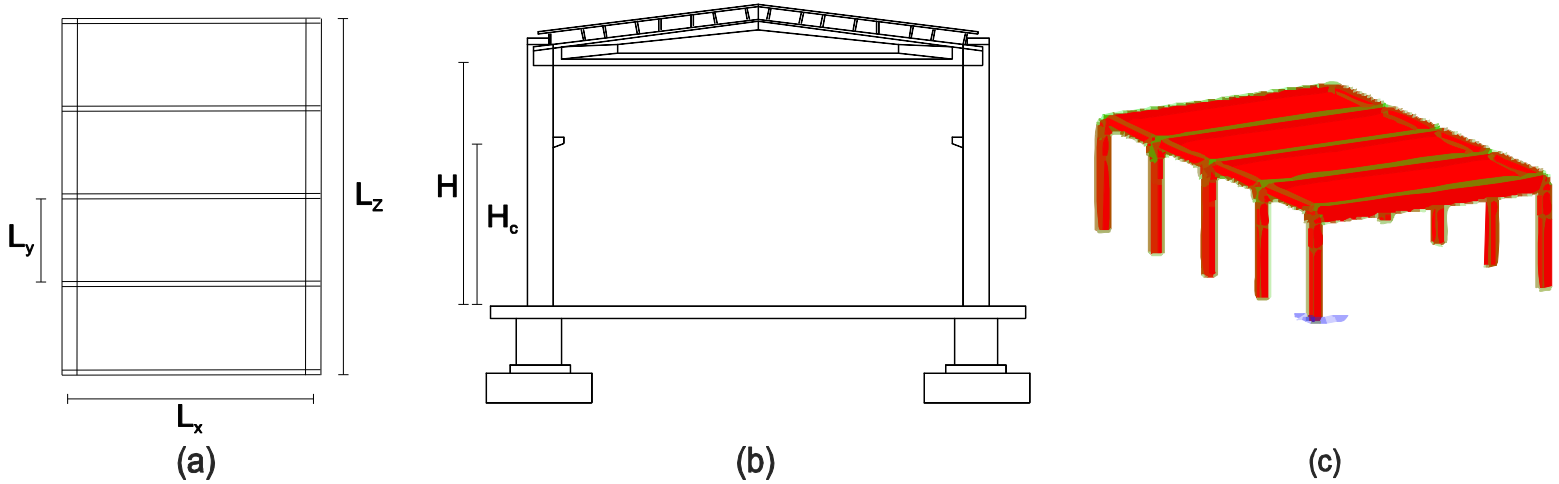






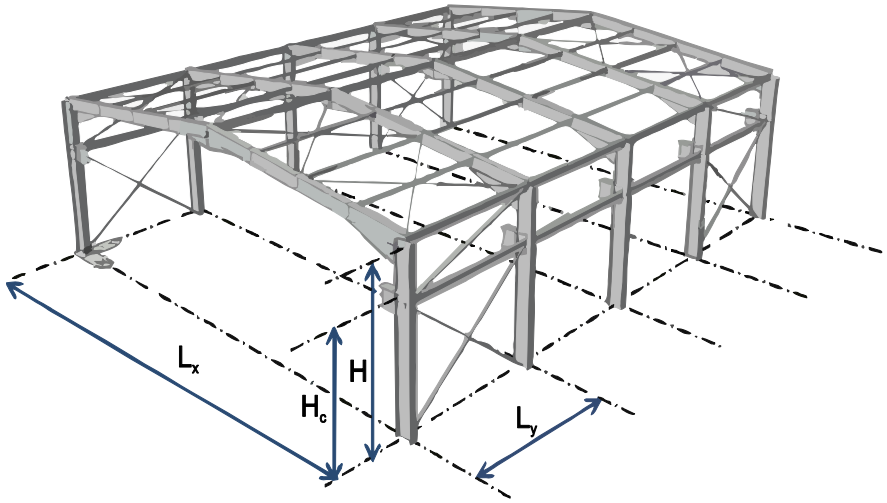
1. Three, six and nine stories.
2. Moment resisting frames and concrete-walls structures.
3. Designed with modal analysis (q=3.9).

Industrial precast reinforced concrete buildings (20+ structures)



Geometry	Lx [m]	Ly [m]	H [m]	Hc [m]
1	15	6	6	4.5
2	20	8	6	4.5
3	15	6	9	7.5
4	20	8	9	7.5

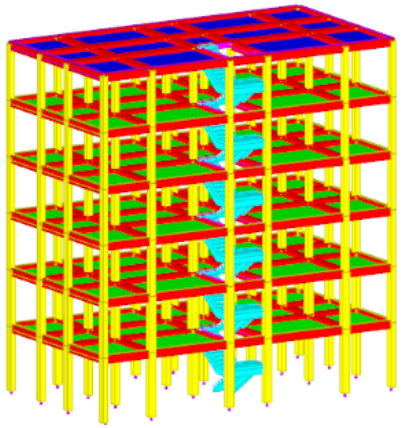
Steel industrial buildings (50+ structures)

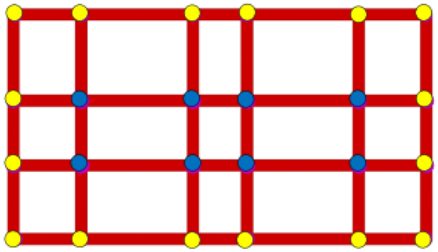


	Snow	Wind	EQ	EQ
Sito	q_s [kN/m²]	q_v [kN/m²]	$a_{g,SLV}$	$a_{g,SLD}$
Milano	1.20	0.39	0.050	0.024
L'Aquila	1.31	0.61	0.261	0.104
Napoli	0.48	0.46	0.168	0.060

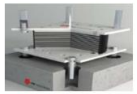
Geometry	Lx [m]	Ly [m]	H [m]	Hc [m]
1	20	6	6	4.5
2	20	8	6	4.5
3	30	6	9	6
4	30	8	9	6

Base-isolated buildings (20+ structures)





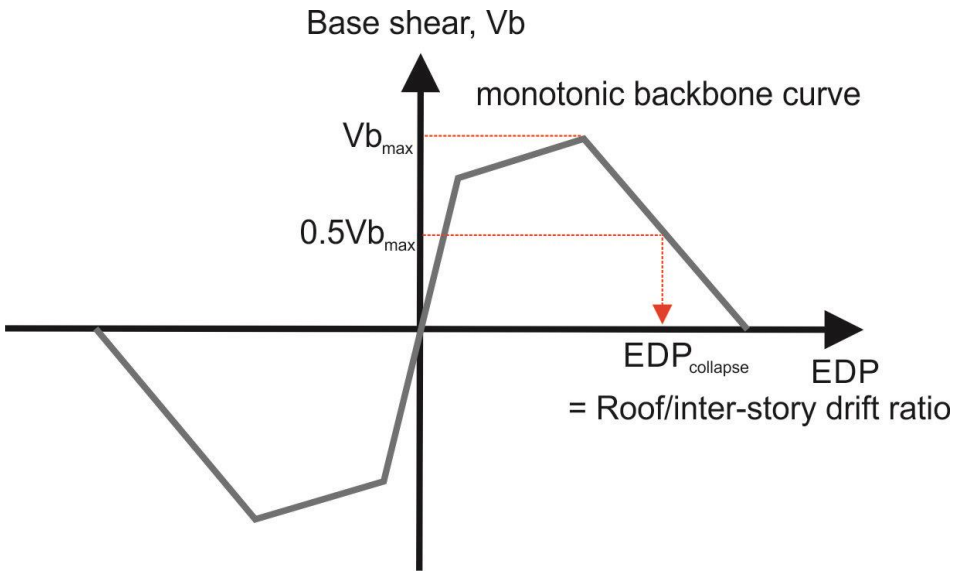

SLITTA


HDRB

1. High-damping rubber bearings (HDRB).
2. HDRB and sliders (hybrid system).
3. Friction pendulums.

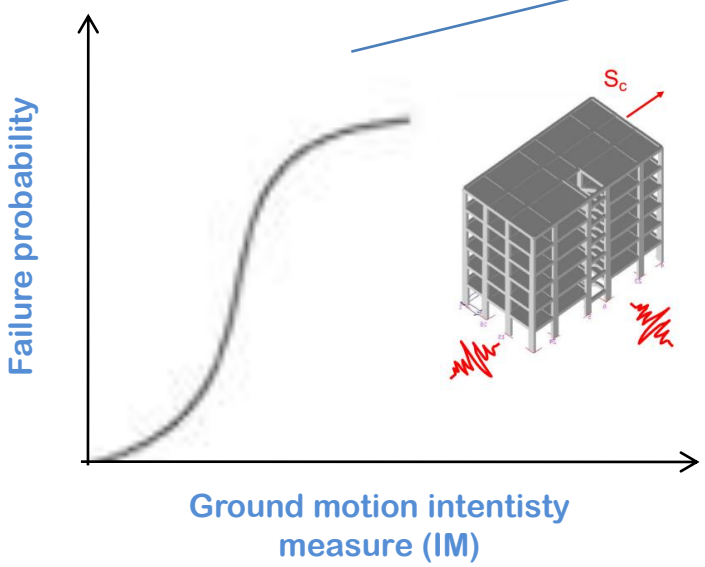
Failure criteria

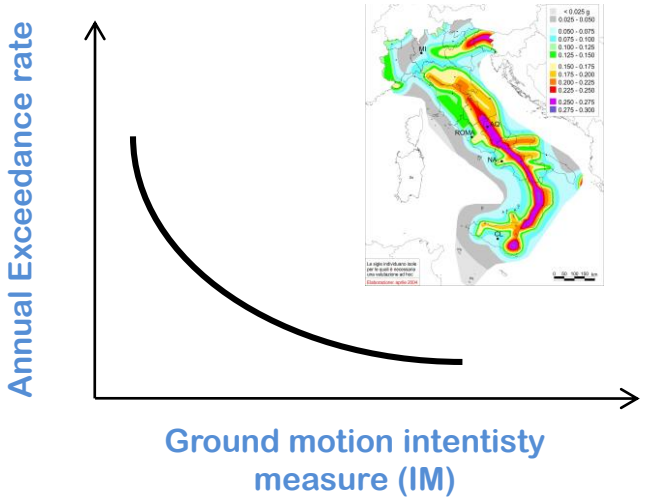
Global collapse



Risk computed in the performance-based earthquake engineering framework

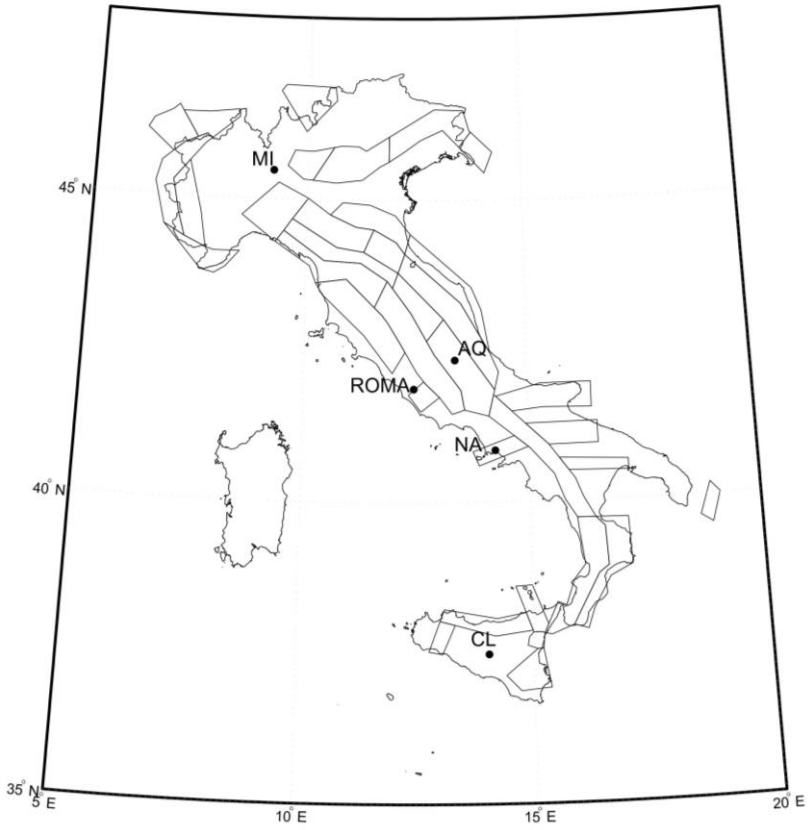
Annual failure rate $\lambda_f = \int_{sa} P\left[f \left| Sa(T) = sa \right] \right] \cdot \left| d\lambda_{Sa(T)>sa} \right|$

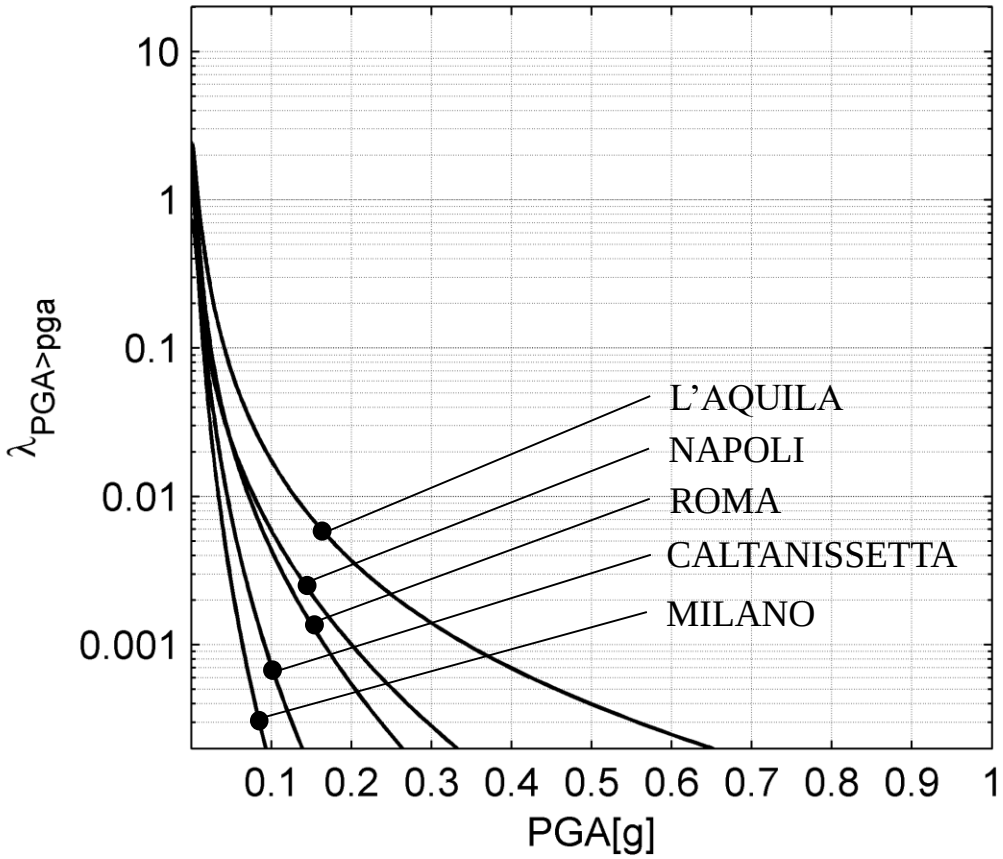




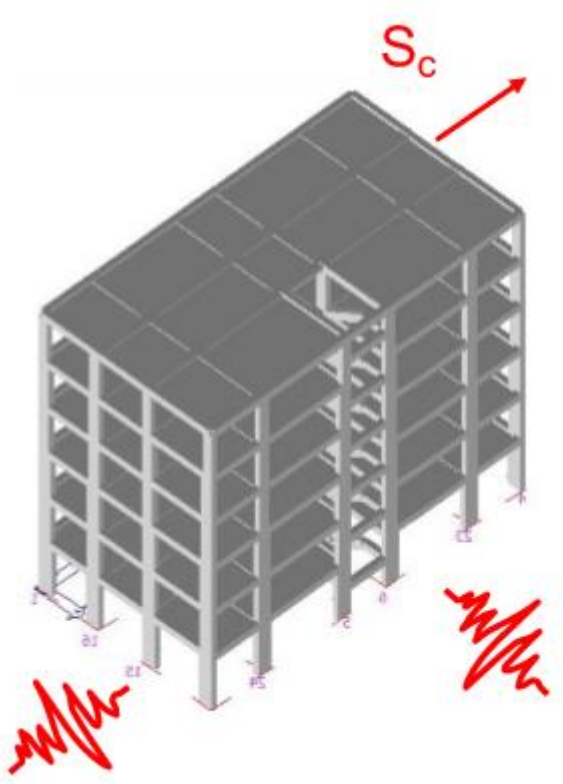
Hazard analysis at all sites (hazard curves stopped at IM with 100,000 years return period)

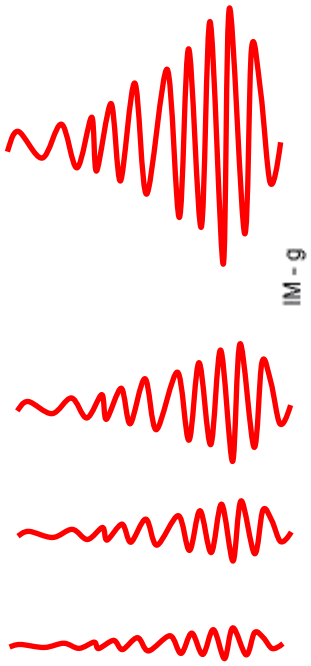
$$\lambda_{Sa(T)>sa} = \sum_{R_{min}}^{R_{max}} \sum_{M_{min}}^{M_{max}} P\left[Sa(T) > sa \mid m,r\right] \cdot \nu_{M=m,R=r}$$

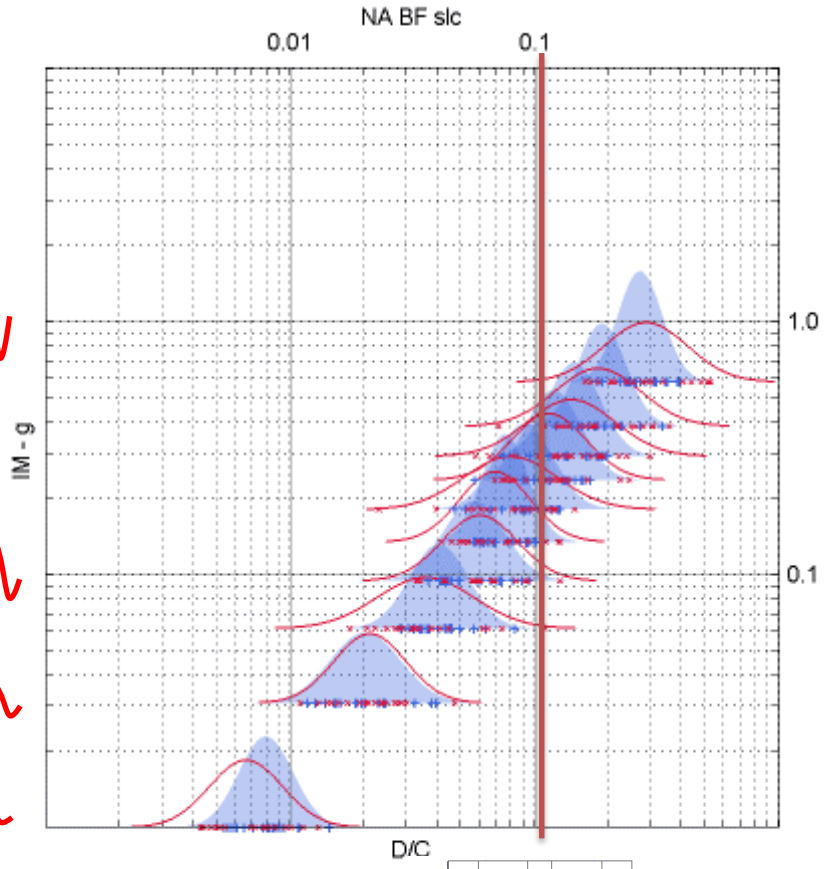




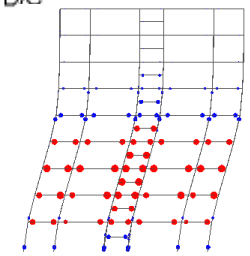
Multi-stripe nonlinear dynamic analysis (recods selected according to the conditional spectrum approach)



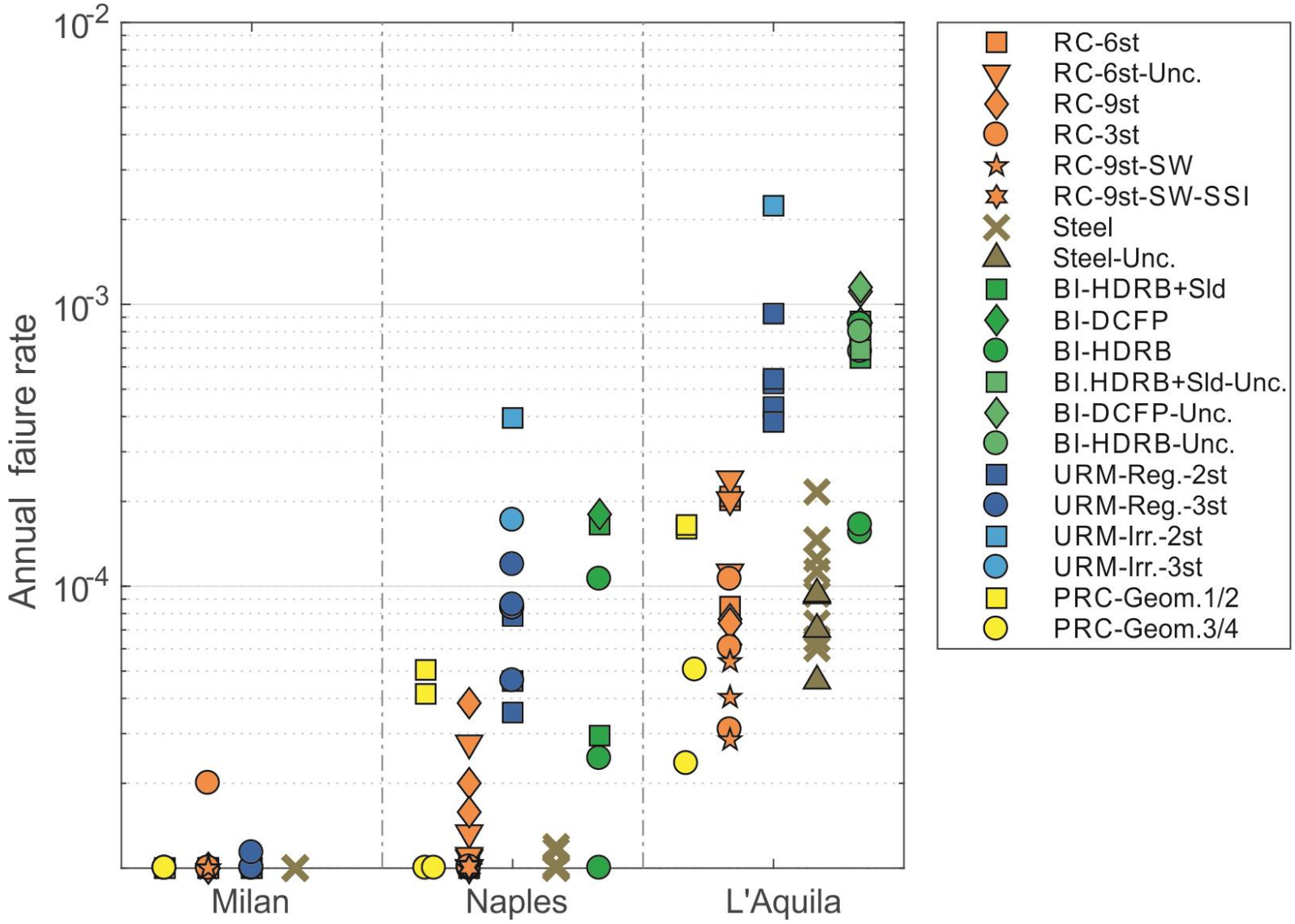




$$P\left[f \left| Sa(T) = sa \right. \right] = \left\{ 1 - \Phi \left[\frac{\log\left(edp_f\right) - \mu_{\log\left(EDP \left| Sa(T)=sa \right.\right)}}{\sigma_{\log\left(EDP \left| Sa(T)=sa \right.\right)}} \right] \right\} \left(1 - \frac{N_{col,Sa(T)=sa}}{N_{tot,Sa(T)=sa}} \right) + \frac{N_{col,Sa(T)=sa}}{N_{tot,Sa(T)=sa}}$$

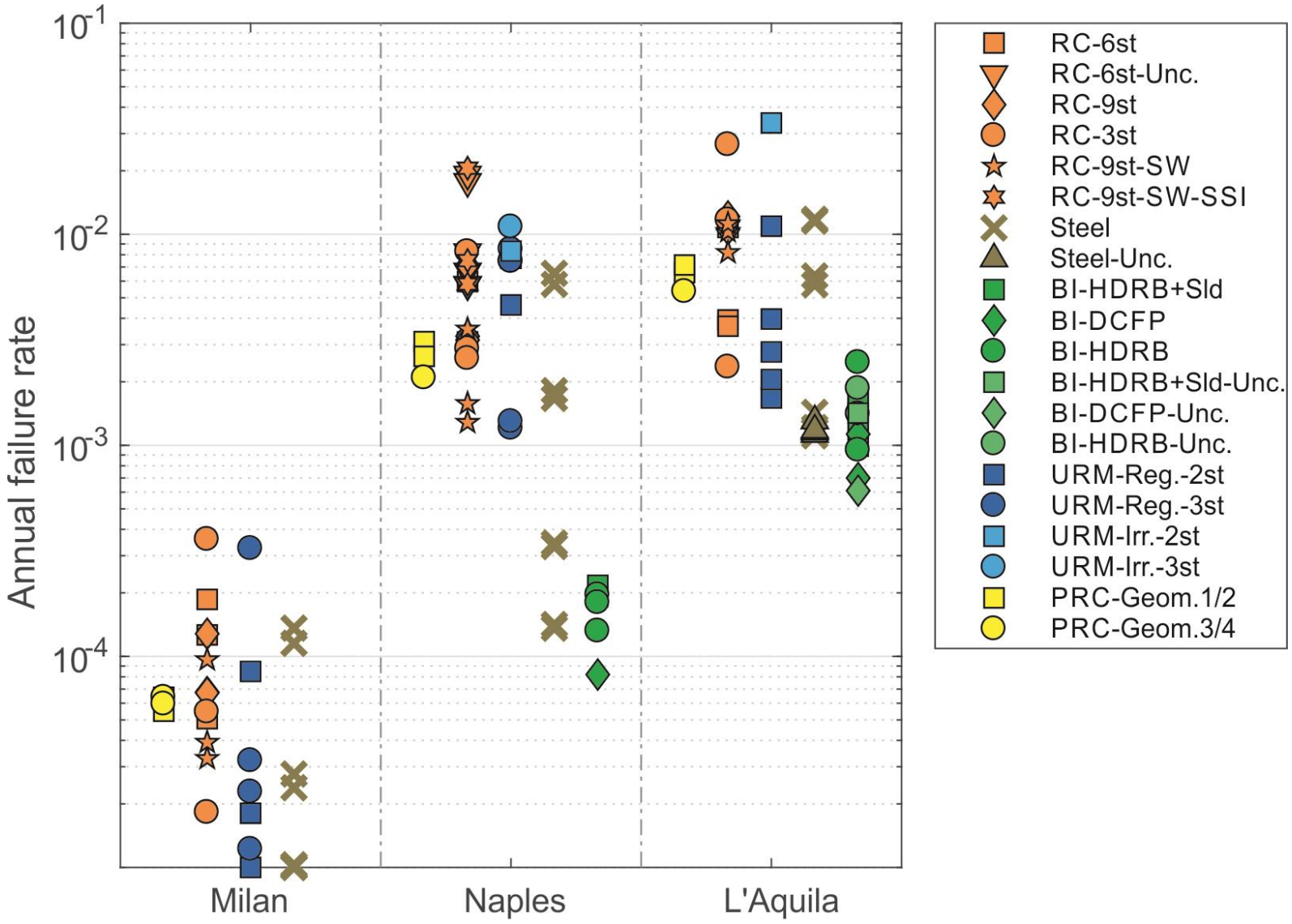


Global collapse – soil type C results for three sites*



*Iervolino I., Spillatura A., Bazzurro P. (2018) Seismic reliability of code-conforming Italian buildings. Journal of Earthquake Engineering. (in press)

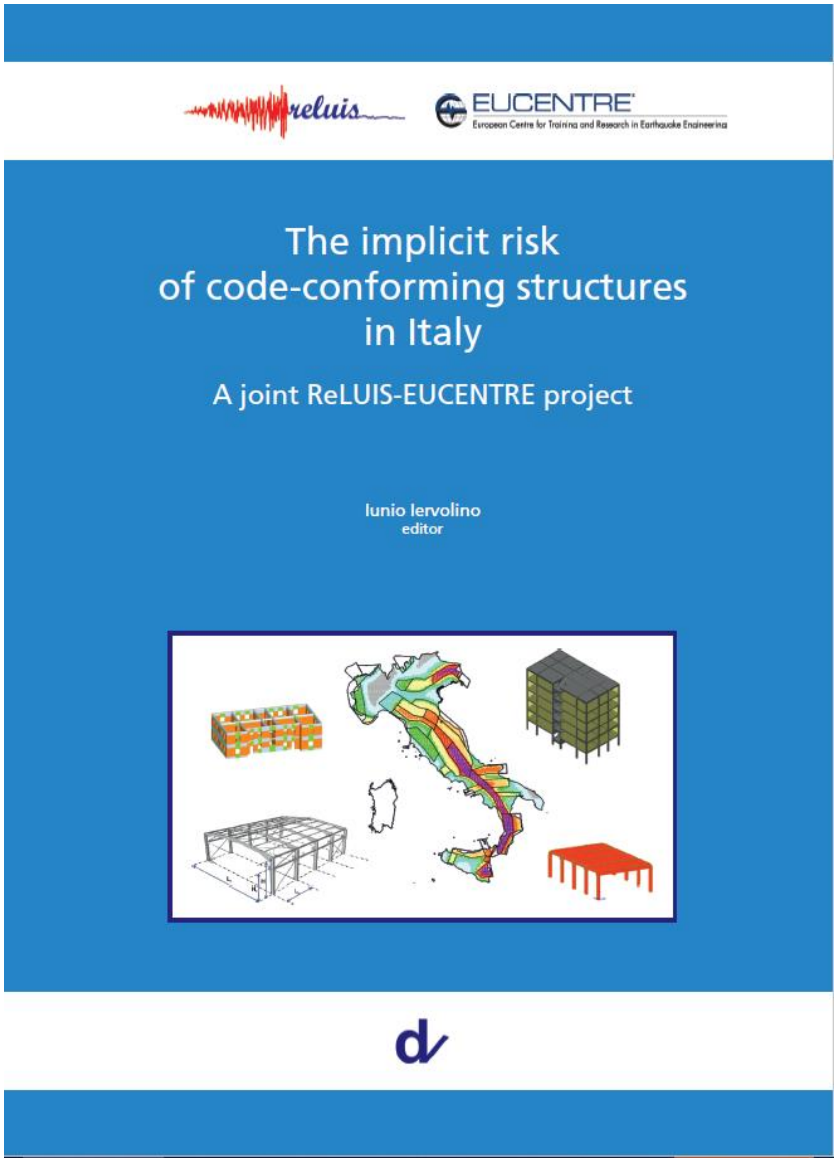
Usability preventing damage – soil type C results for three sites*



*Iervolino I., Spillatura A., Bazzurro P. (2018) Seismic reliability of code-conforming Italian buildings. Journal of Earthquake Engineering. (in press)

Part two - conclusions

1. Despite the homogeneity of design seismic actions and engineering choices, the seismic structural reliability tends to decrease with the seismic hazard of the sites.
2. For the less hazardous sites, the failure rates are so low that only an upper bound to the actual failure rate can be provided.
3. On the other hand, the failure rates of buildings at the most hazardous of the sites are, in some cases, comparable to the annual rate of exceedance of the design ground motion intensity.
4. Modelling uncertainty and soil-structure-interaction have a relatively minor impact on the estimation of failure risk.
5. The global collapse failure rates of base-isolated structures are relatively high, those for usability-preventing damage are relatively low.



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