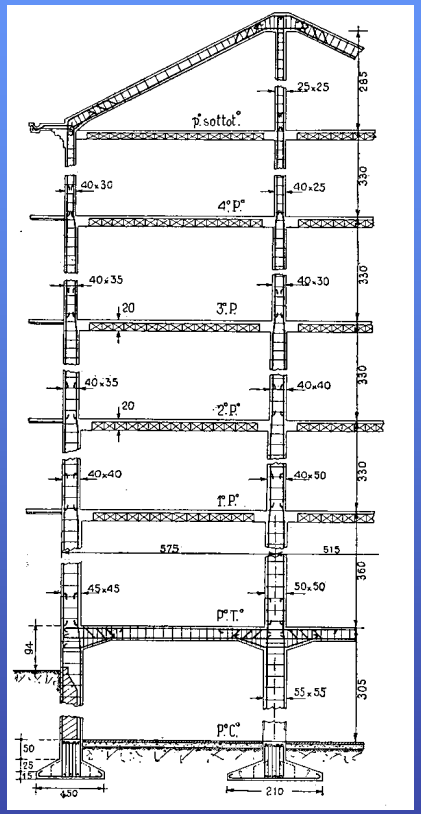
Simplified Analytical (mechanical-based) Procedure for post-earthquake SAFETY and LOSS assessment of buildings

.



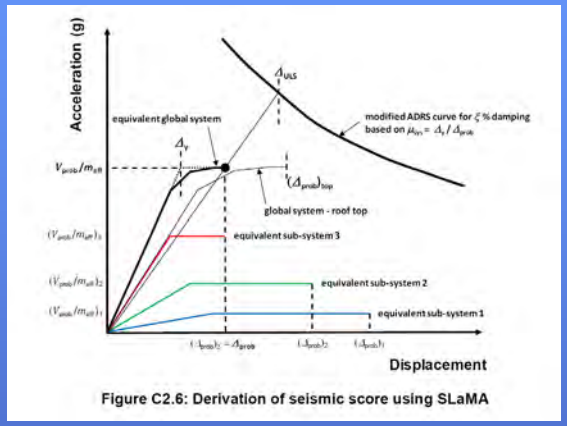


Figure C2.6: Derivation of seismic score using SLaMA

Percentage of New Building Standard (%NBS)	Letter grade	Relative risk (approx)
>100	A+	< 1 time
80–100	A	1–2 times
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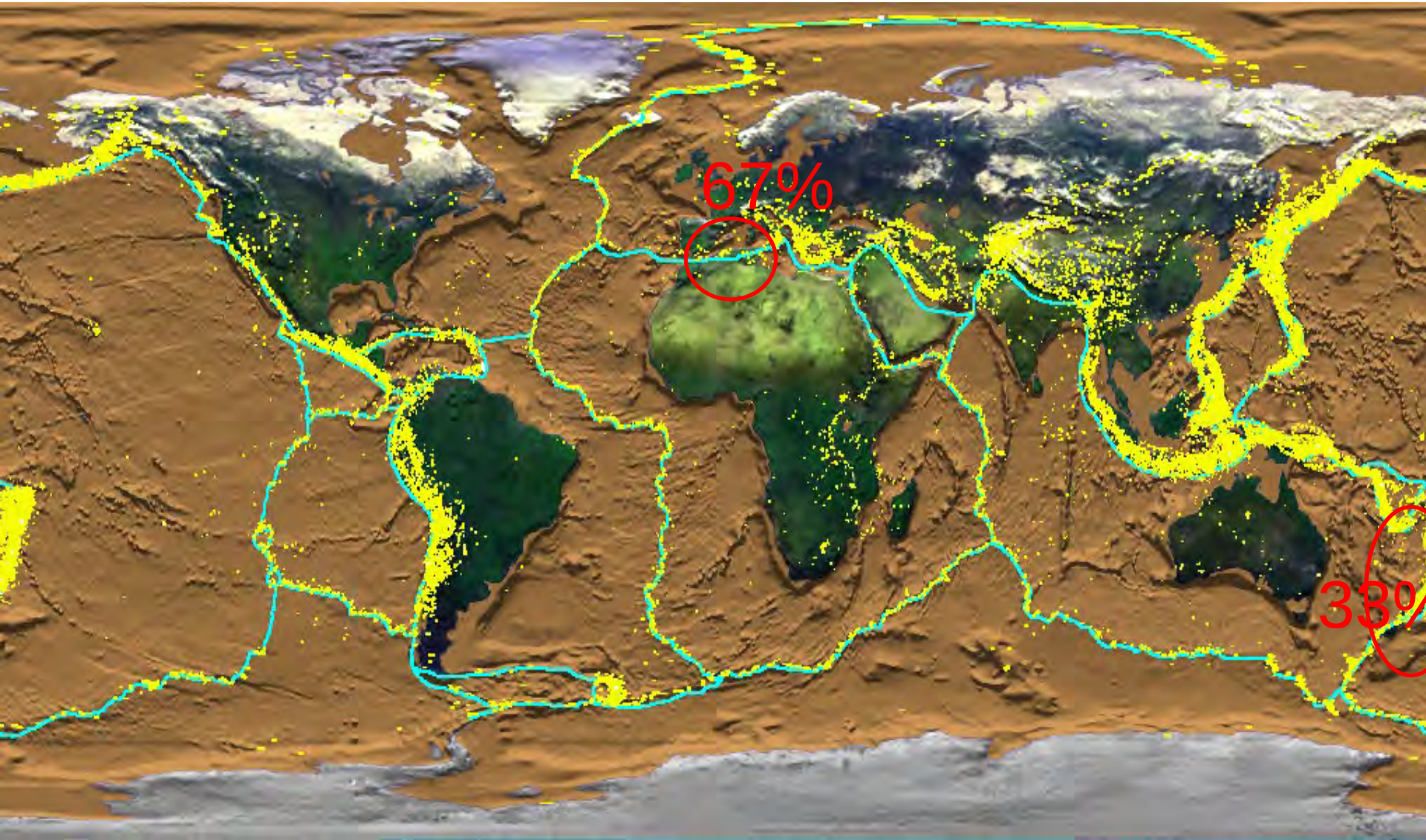
20–33	D	10–25 times
<20	E	> 25 times

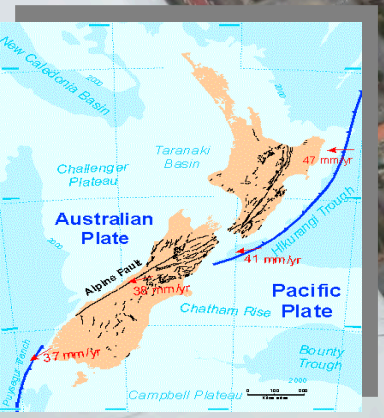
Prof. Ing. Stefano Pampanin

Sapienza Università di Roma

A Common Problem Worldwide



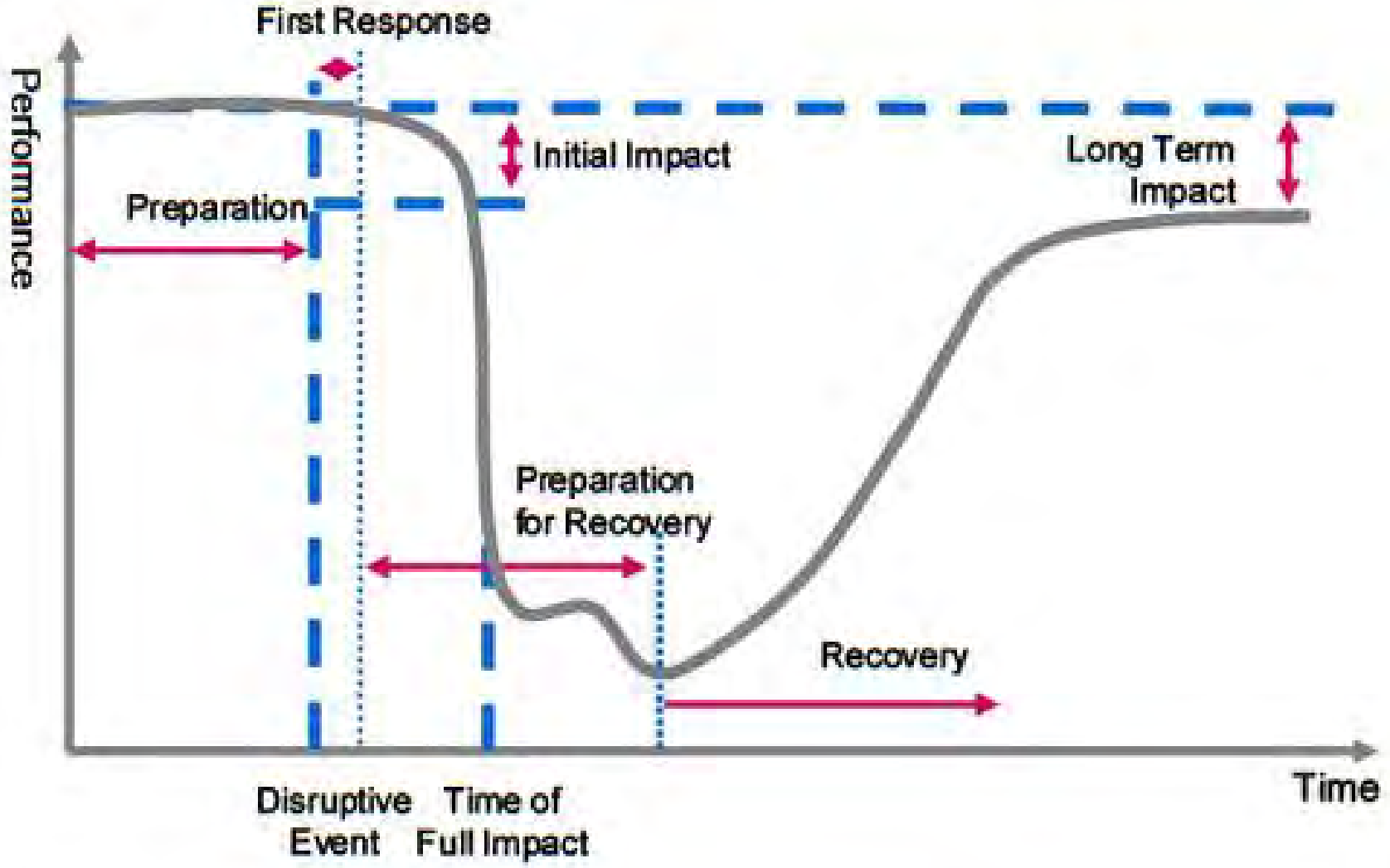
Rebuilding a SAFER and RESILIENT community



40 Billion NZ$
(25% GDP)

Photo courtesy of
Kam Yuen Weng and Umut Akguzel

The Concept of Resilience



I costi dei terremoti in Italia

Importo attualizzato 2014 (milioni di euro)

Periodo di attivazione degli interventi

10 anni

121.608
milioni di euro
il costo totale (1968-2012)

* Dati a consuntivo sulle risorse effettivamente stanziate dallo Stato

** Previsioni di spesa delle autorità locali preposte alla ricostruzione

Fonte: Centro studi del Consiglio nazionale degli ingegneri

250 miliardi di euro

il costo totale degli interventi dal Dopoguerra, considerando non solo terremoti ma anche frane e alluvioni

70%

degli edifici italiani non sono costruiti secondo le regole antisismiche

60%

degli edifici italiani è stato costruito prima del 1974, anno di entrata in vigore delle prime regole antisismiche

50%

delle scuole non è antisismica

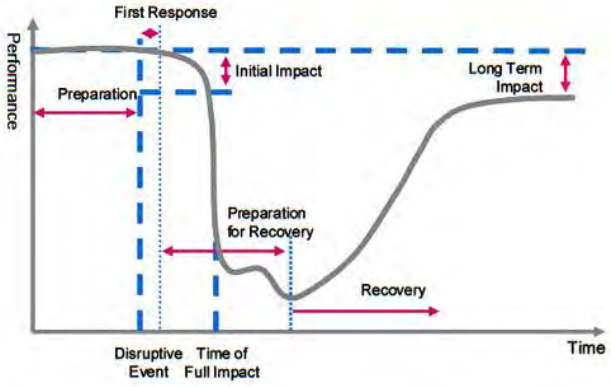
+5/8%

l'incremento medio del costo delle costruzioni antisismiche rispetto a quelle «normali»

360 miliardi di euro

la stima del costo dell'adeguamento sismico degli edifici italiani secondo Oice, associazione delle organizzazioni di confindustria

Corriere della Sera



MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

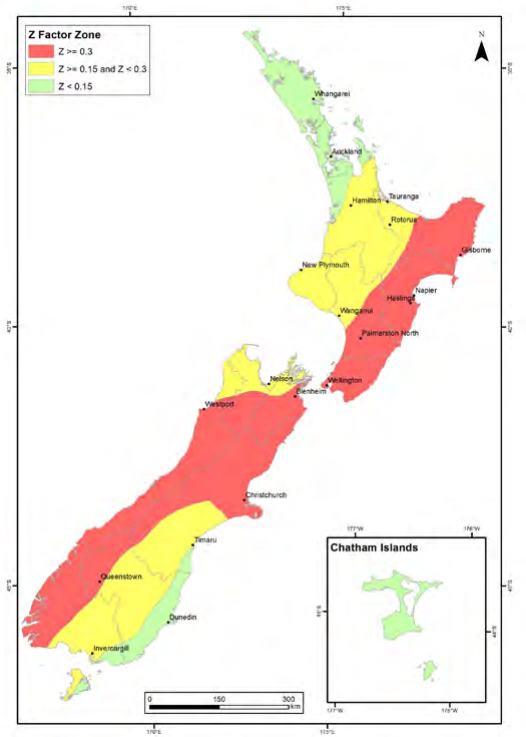
New Framework for managing earthquake-prone buildings in New Zealand

Ministry of Business, Innovation and Employment, 2016

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

New framework for managing earthquake-prone buildings

(Mandatory - effective from 1 July 2017)

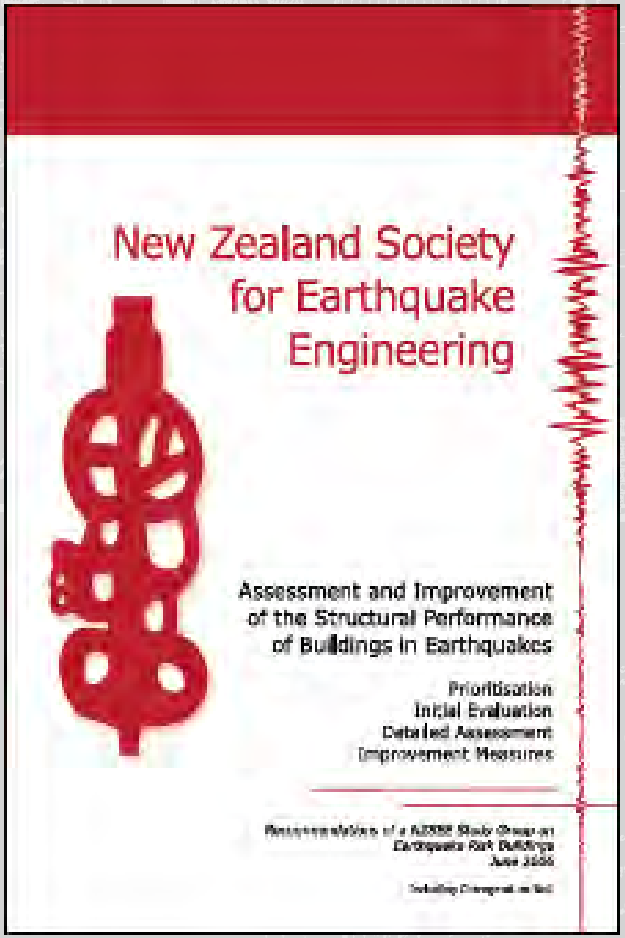


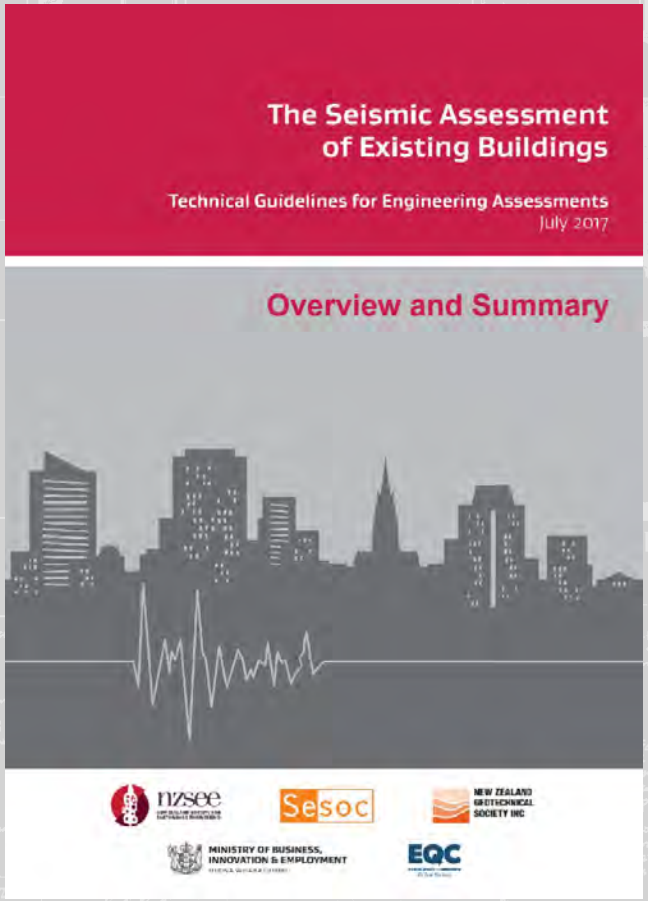
Risk-Based Approach

Seismic risk area	TAs must identify potentially earthquake-prone buildings within:		Owners must strengthen or demolish earthquake-prone buildings within:	
	Priority	Other	Priority	Other
High	2 ½ years	5 years	7 ½ years	15 years
Medium	5 years	10 years	12 ½ years	25 years
Low	n/a	15 years	n/a	35 years

NZSEE2017 – Seismic Assessment Guidelines

http://www.eq-assess.org.nz/





NZSEE 2006 → **NZSEE2017**

Table 2.2 NZSEE2006 Risk Classifications and Improvement Recommendations

Description	Grade	Risk	%NBS	Existing Building Structural Performance		Improvement of Structural Performance	
						Legal Requirement	NZSEE Recommendation
Low Risk Building	A or B	Low	Above 67	Acceptable (improvement may be desirable)		The Building Act sets no required level of structural improvement (unless change in use) This is for each TA to decide. Improvement is not limited to 34%NBS.	100%NBS desirable. Improvement should achieve at least 67%NBS
Moderate Risk Building	B or C	Moderate	34 to 66	Acceptable legally. Improvement recommended			Not recommended. Acceptable only in exceptional circumstances
High Risk Building	D or E	High	33 or lower	Unacceptable (Improvement required under Act)		Unacceptable	Unacceptable

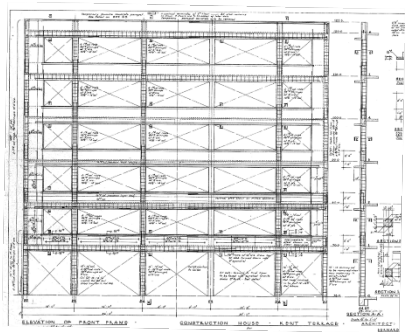
There are many buildings in New Zealand constructed prior to 1976.
The cost to the community of requiring full compliance with current standards would be considerable, and arguably disproportionate to the risk reduction achieved.

Chapter 5
Concrete Buildings

Leader: Stefano Pampanin

Step 1- CAPACITY

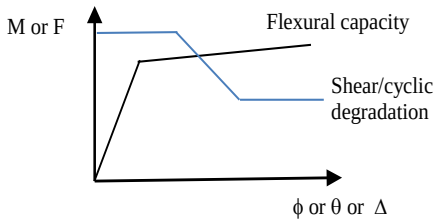
Building data:
- Geometry
- Material properties
- Structural details



1a- Component Level (beam, column, joint)

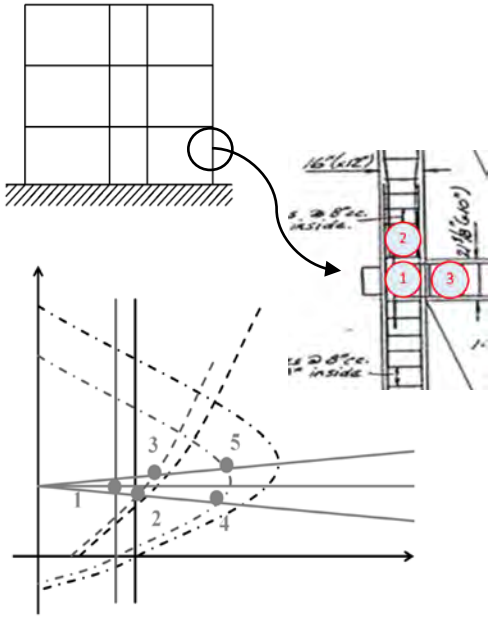
Evaluate strength and deformation capacity:
-Flexure, Shear, Flexure-shear interaction
- Cyclic degradation; Lap splices failure; Bi-directional effects

Outcomes (capacity curves):
Moment-curvature/rotation and/or Force-Displacement



1b- Subassembly Level

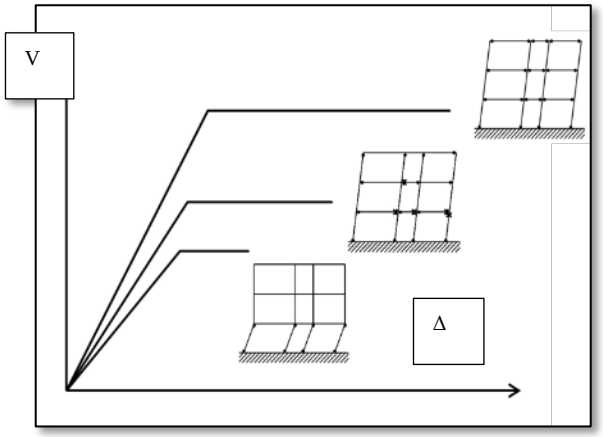
Evaluate the Hierarchy of Strength and sequence of events at a subassembly level



1c - Structural System Level

Identify the global mechanism

Evaluate the Global Capacity Curve (Force-Displacement)



Evaluation of Safety (Risk) Index (% New Building Standard o IS-V)

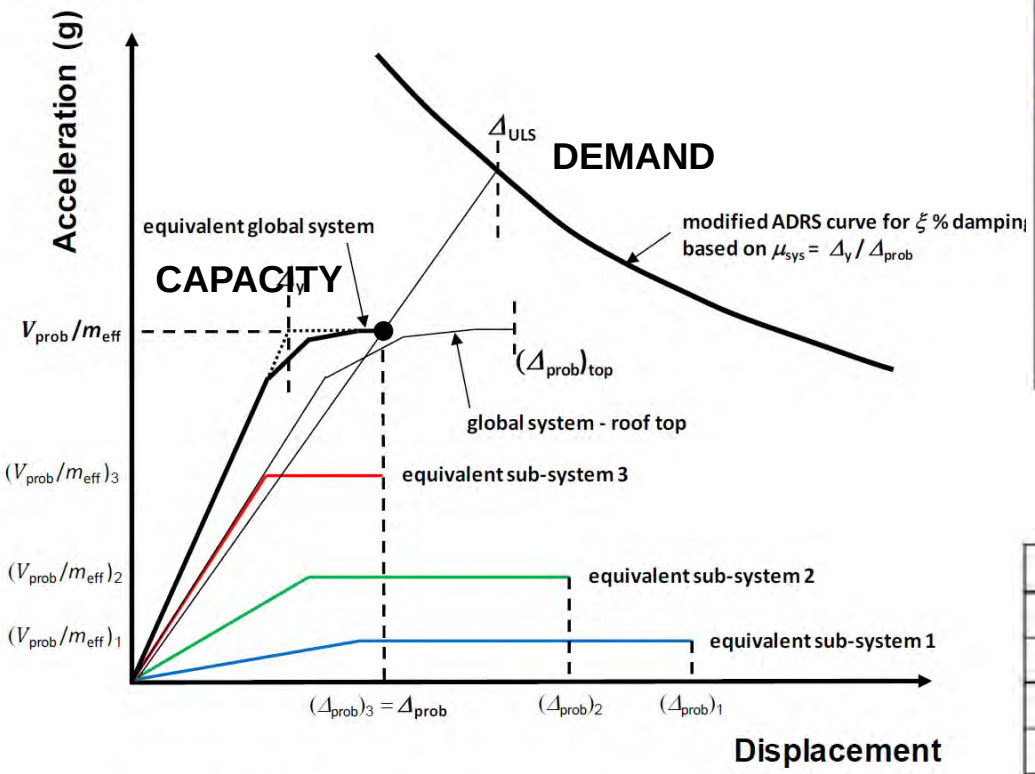


Figure C2.6: Derivation of seismic score using SLaMA

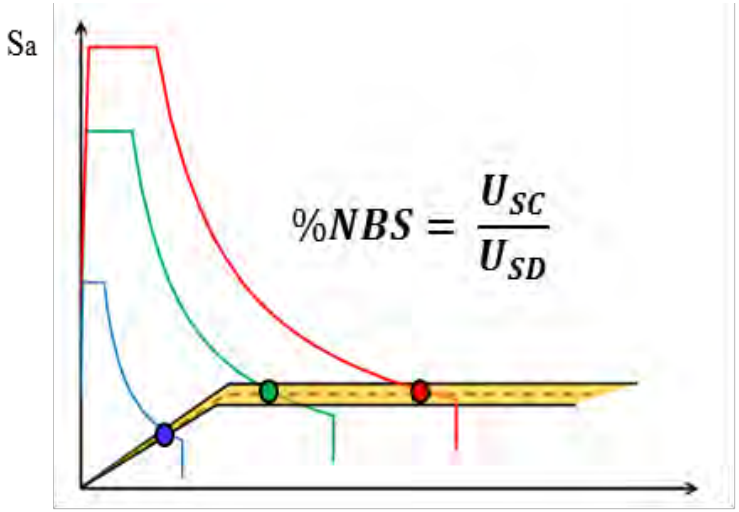
%NBS (NZSEE2006-2017)

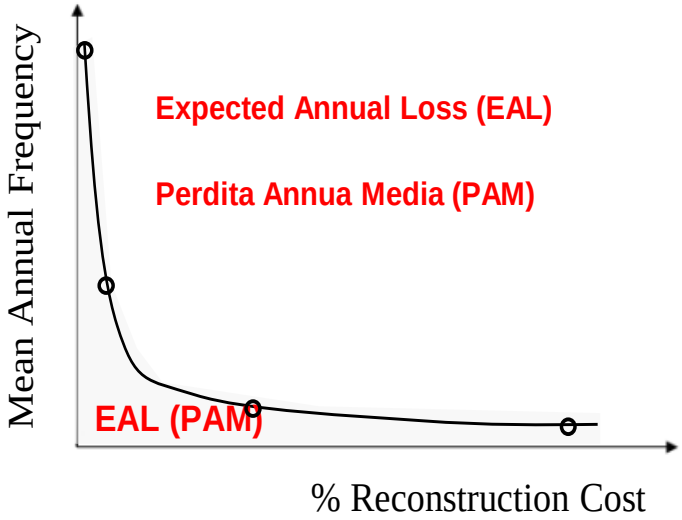
Percentage of New Building Standard (%NBS)	Letter grade	Relative risk (approx)
>100	A+	< 1 time
80–100	A	1–2 times
67–80	B	2–5 times
33–67	C	5–10 times
20–33	D	10–25 times
<20	E	> 25 times

IS-V (ITA2017)

Indice di Sicurezza	Classe IS-V
100% < IS-V	A^{+}_{IS-V}
100% ≤ IS-V < 80%	A_{IS-V}
80% ≤ IS-V < 60%	B_{IS-V}
60% ≤ IS-V < 45%	C_{IS-V}
45% ≤ IS-V < 30%	D_{IS-V}
30% ≤ IS-V < 15%	E_{IS-V}
IS-V ≤ 15%	F_{IS-V}

Evaluation of Losses (1/2)





Performance Evaluation
Capacity Curve vs. Demand

Evaluation of Shaking Intensity for different Limit States
$\boldsymbol{PGA_C}(LS_i)$
(IO, DC, LS, CP)

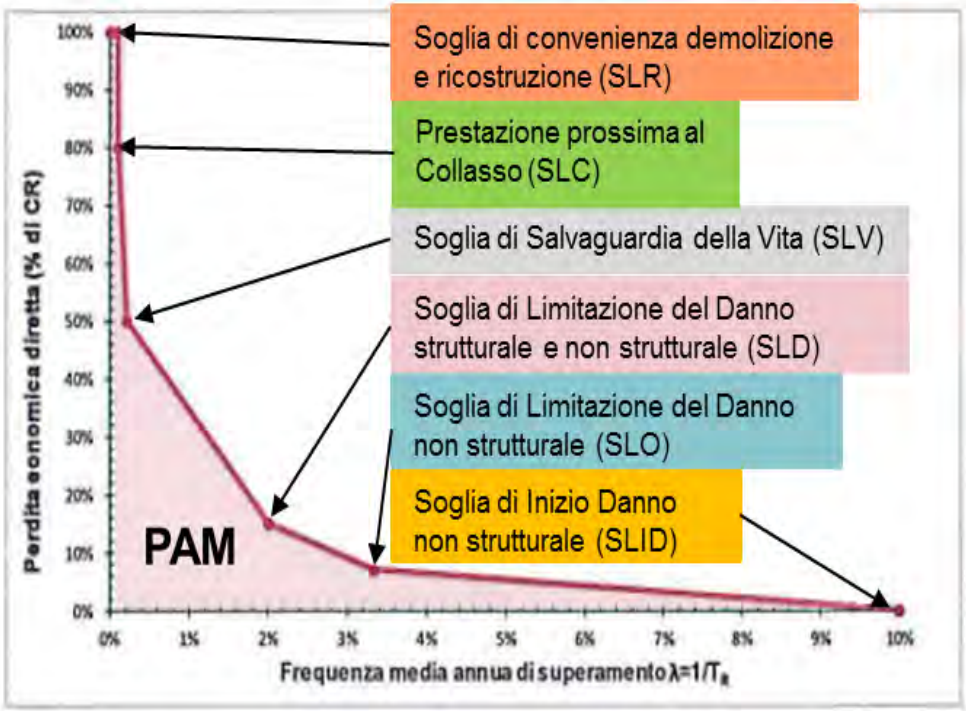
Evaluation of Return Periods $\boldsymbol{T_{rC}}$
$T_{rC} = T_{rD}(PGA_C / PGA_D)^{1/0.41}$

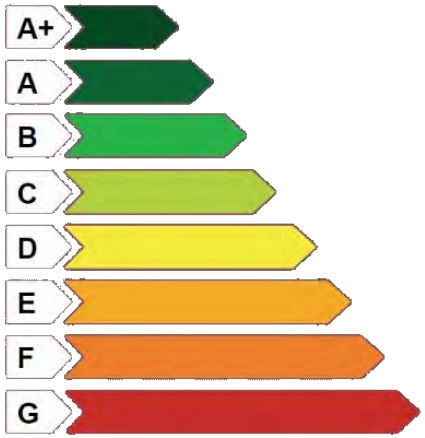
Mean Annual Frequency (MAF):
$\boldsymbol{\lambda} = 1/T_{rC}$

Curve **RC** vs. $\boldsymbol{\lambda}$
(Reconstruction Cost)

Expected Annual Loss
EAL = Area under the curve

Evaluation of Losses - EAL/PAM and Risk Class (2/2)





Stato Limite	CR(%)
SLR	100%
SLC	80%
SLV	50%
SLD	15%
SLO	7%
SLID	0%

SLC= Collapse Prevention

SLV= Life safety

SLD= Damage Control

SLO= Operational

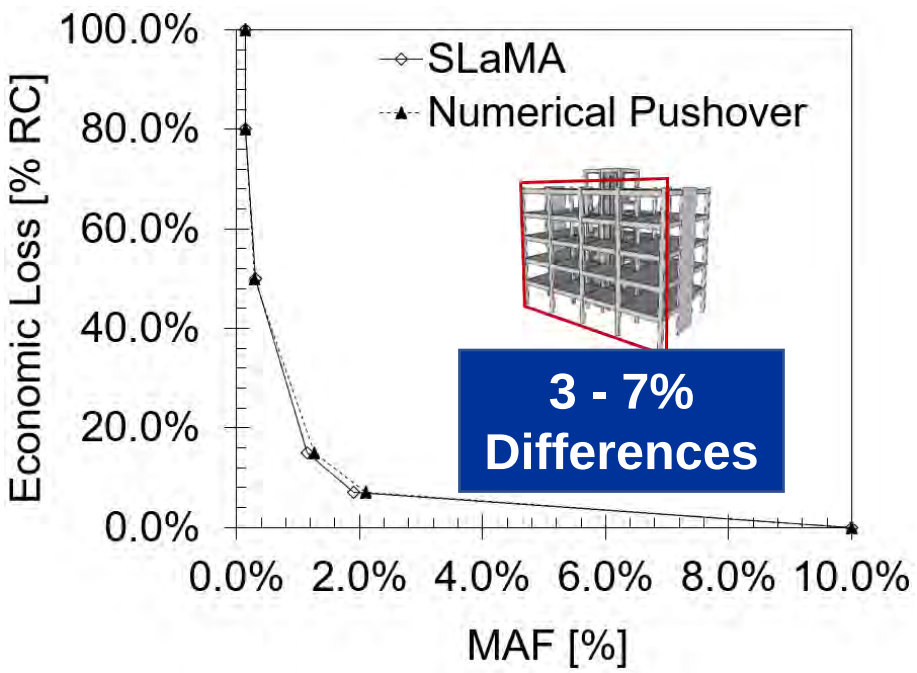
ITA2017 Matrix – IS-V(=%NBS), Risk Class, EAL/PAM

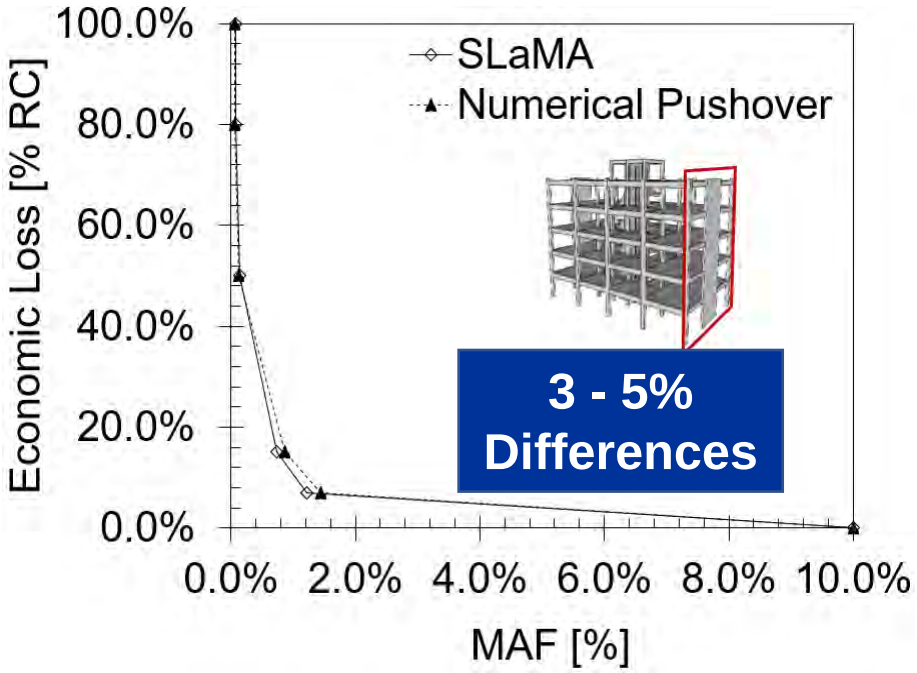
IS-V Class	IS-V ranges	EAL Class	EAL ranges
$A^{+}_{IS\text{-}V}$	IS-V >100	A^{+}_{PAM}	EAL ≤0.5%
$A_{IS\text{-}V}$	80%≤ IS-V< 100%	A_{PAM}	0.5%< EAL ≤1.0%
$B_{IS\text{-}V}$	60%≤I S-V< 80%	B_{PAM}	1.0%< EAL ≤1.5%
$C_{IS\text{-}V}$	45%≤ IS-V< 60%	C_{PAM}	1.5%< EAL ≤2.5%
$D_{IS\text{-}V}$	30%≤ IS-V< 45%	D_{PAM}	2.5%< EAL ≤3.5%
$E_{IS\text{-}V}$	15%≤ IS-V< 30%	E_{PAM}	3.5%< EAL ≤4.5%
$F_{IS\text{-}V}$	IS-V < 15%	F_{PAM}	4.5%< EAL ≤7.5%
-	-	G_{PAM}	7.5%≤ EAL

Comparison of Loss Assessment Methodologies

SLaMA vs **PUSH-OVER** vs **TIME-HISTORY**

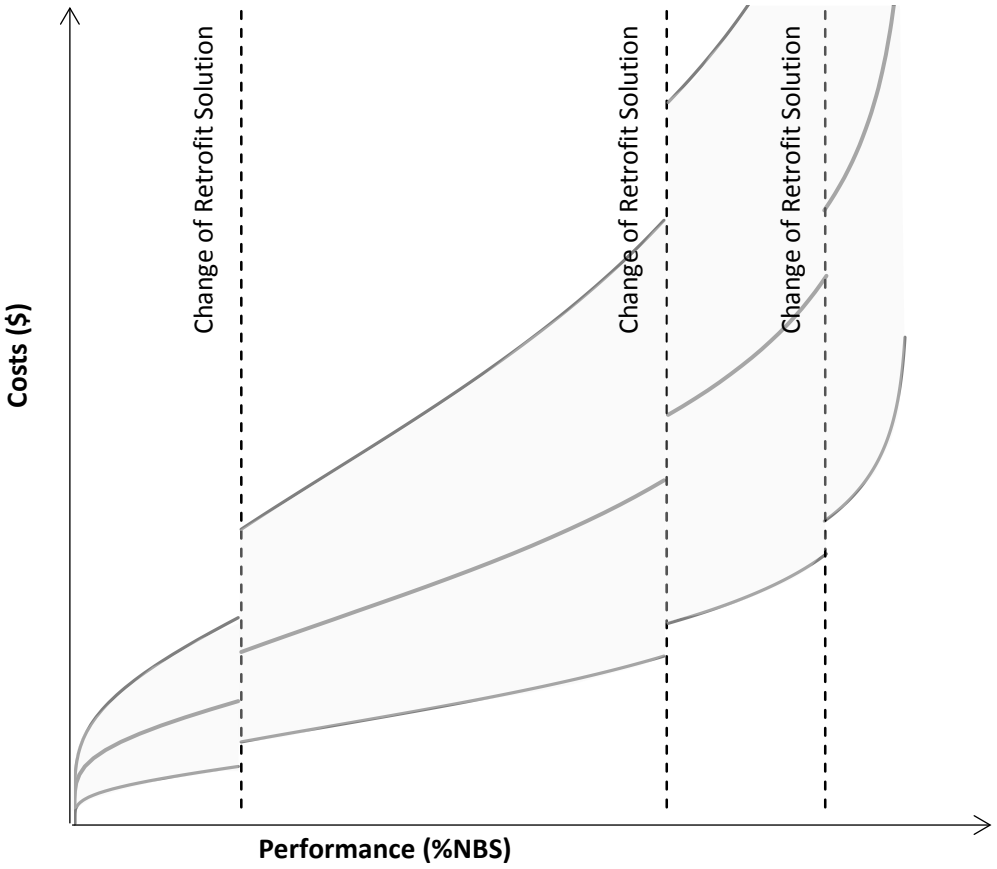
SIMPLIFIED PROCEDURE: *2017 Italian Guidelines for Seismic Risk Classification*

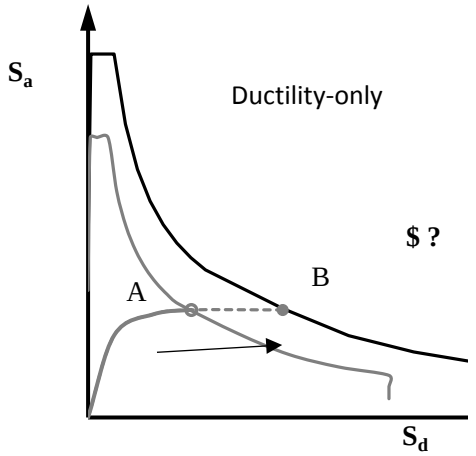


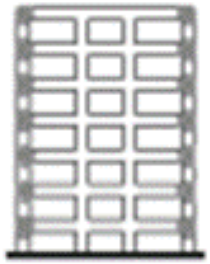


Bianchi, S., Ciurlanti, J,, Pampanin, S., 2019, "*A SLaMA-based analytical procedure for the Cost/Performance-based evaluation of buildings", Compdyn Conference, Crete, Greece*

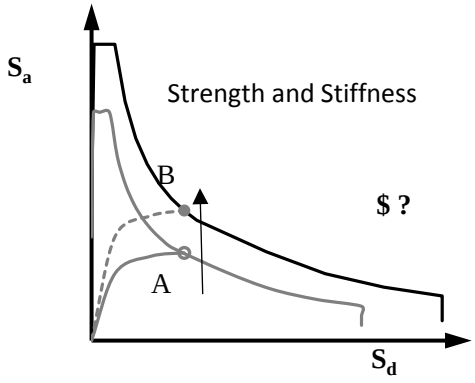
Comparing Alternative Retrofit Options (Multi-criteria Cost-benefit Approach)

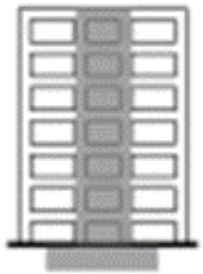






OPTION 2
(FRP)



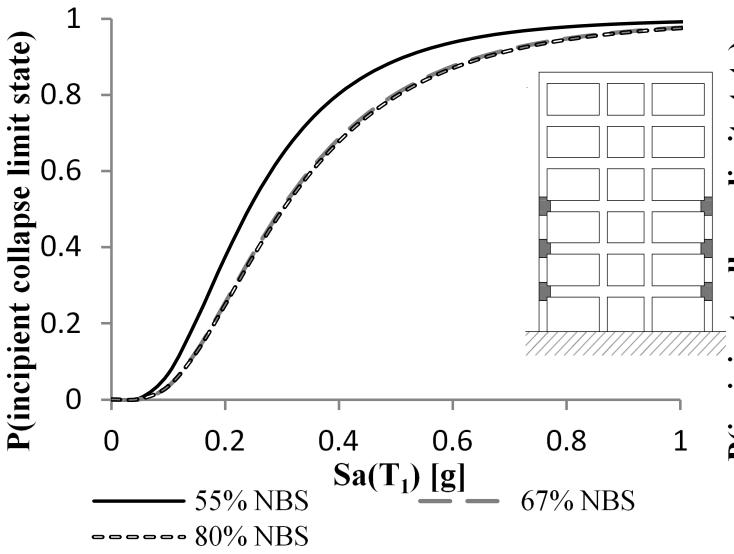


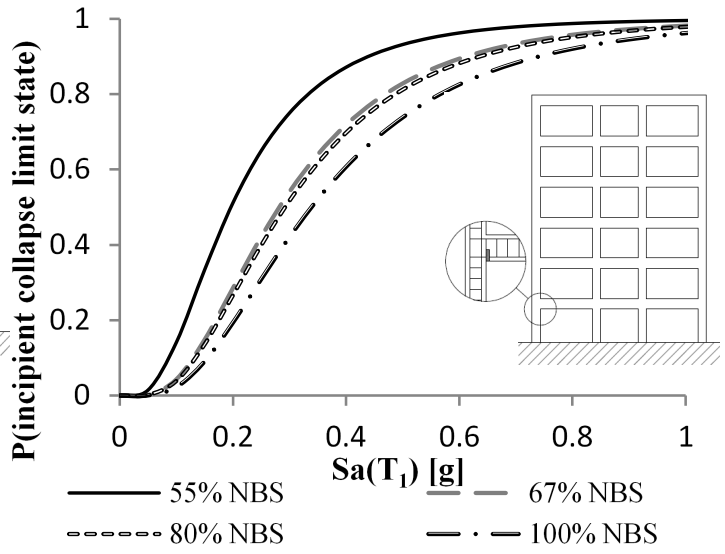
OPTION 3
(Shear Wall)

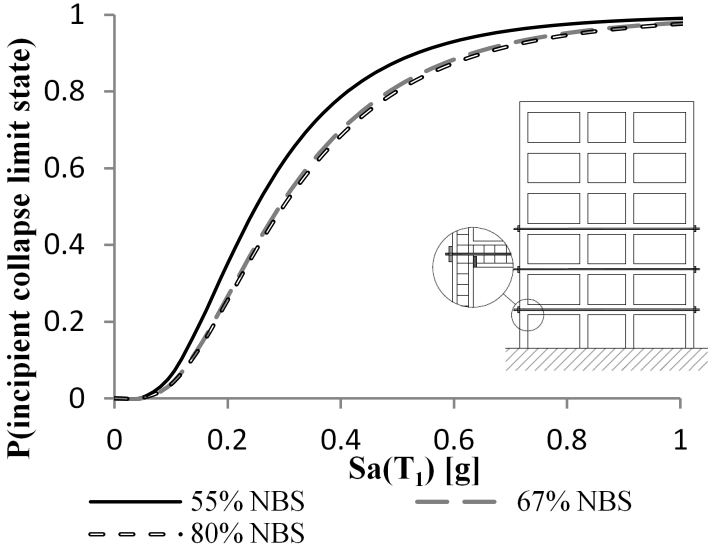
Pampanin, Beetham et al. 2012-

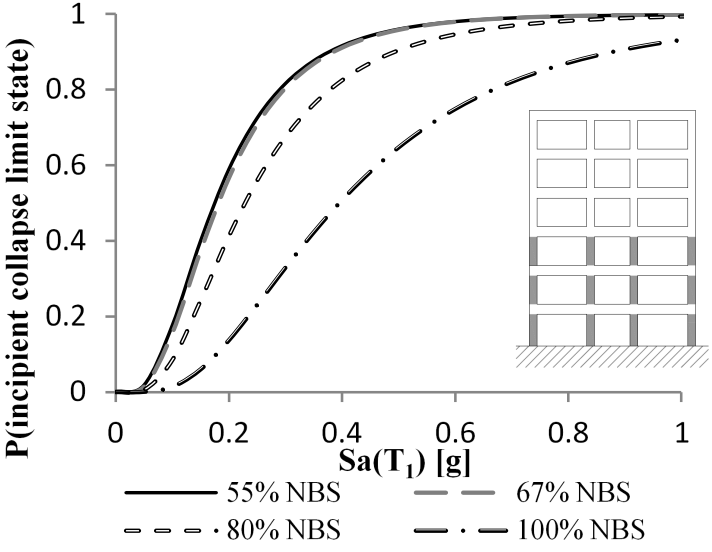
Collapse Fragilities for Alternative Retrofit options

Ligabue, Pampanin, Savoia, 2015



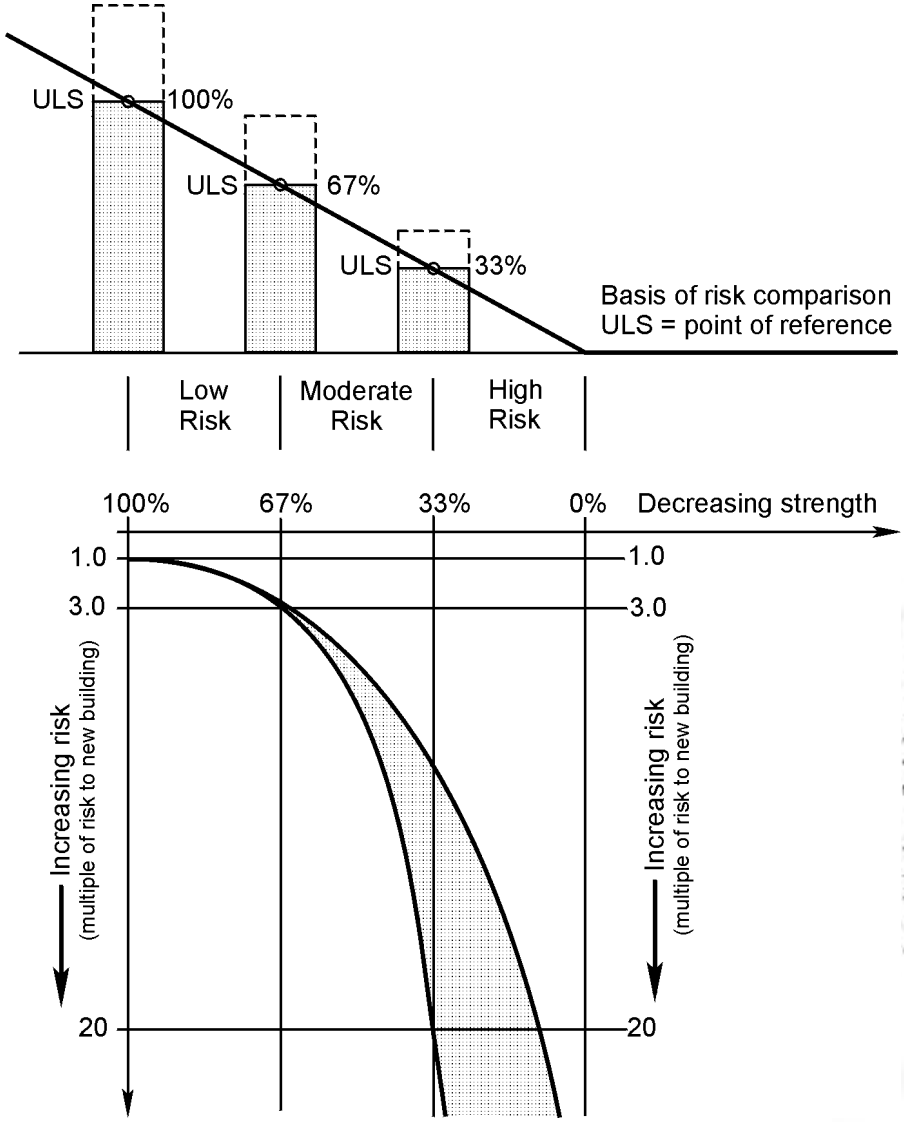


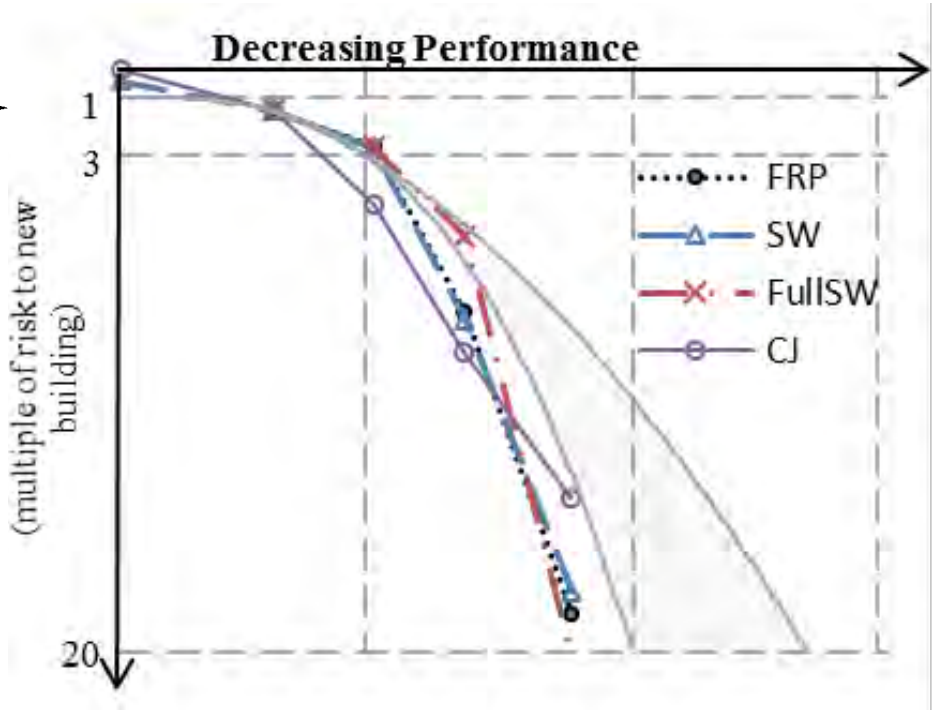




Risk vs. %NBS

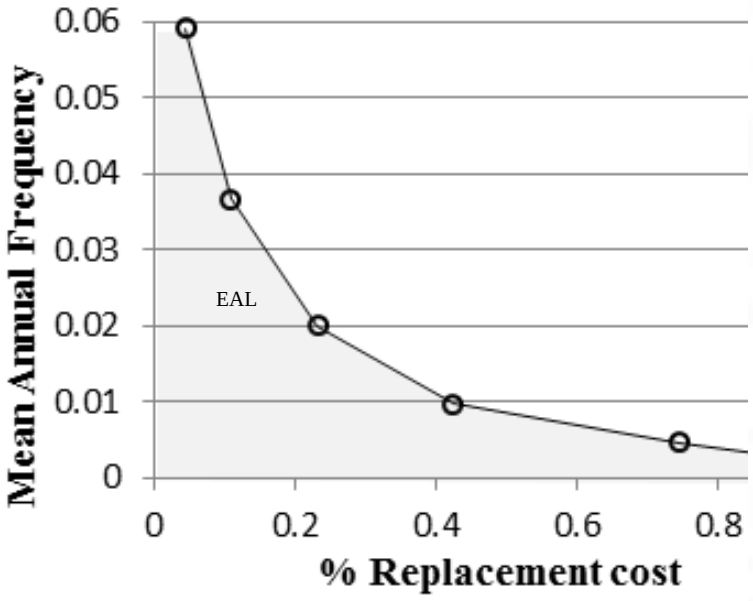
NZSEE Seismic Assessment Guidelines, 2017

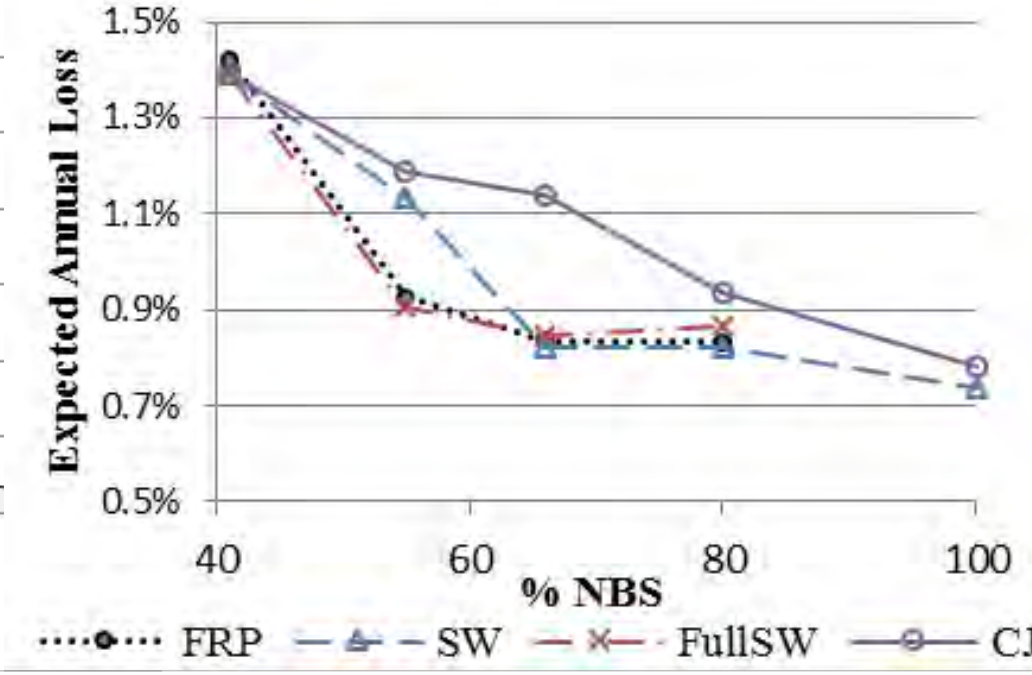




Ligabue, Pampanin, Savoia, 2015

Expected Annual Losses vs. %NBS



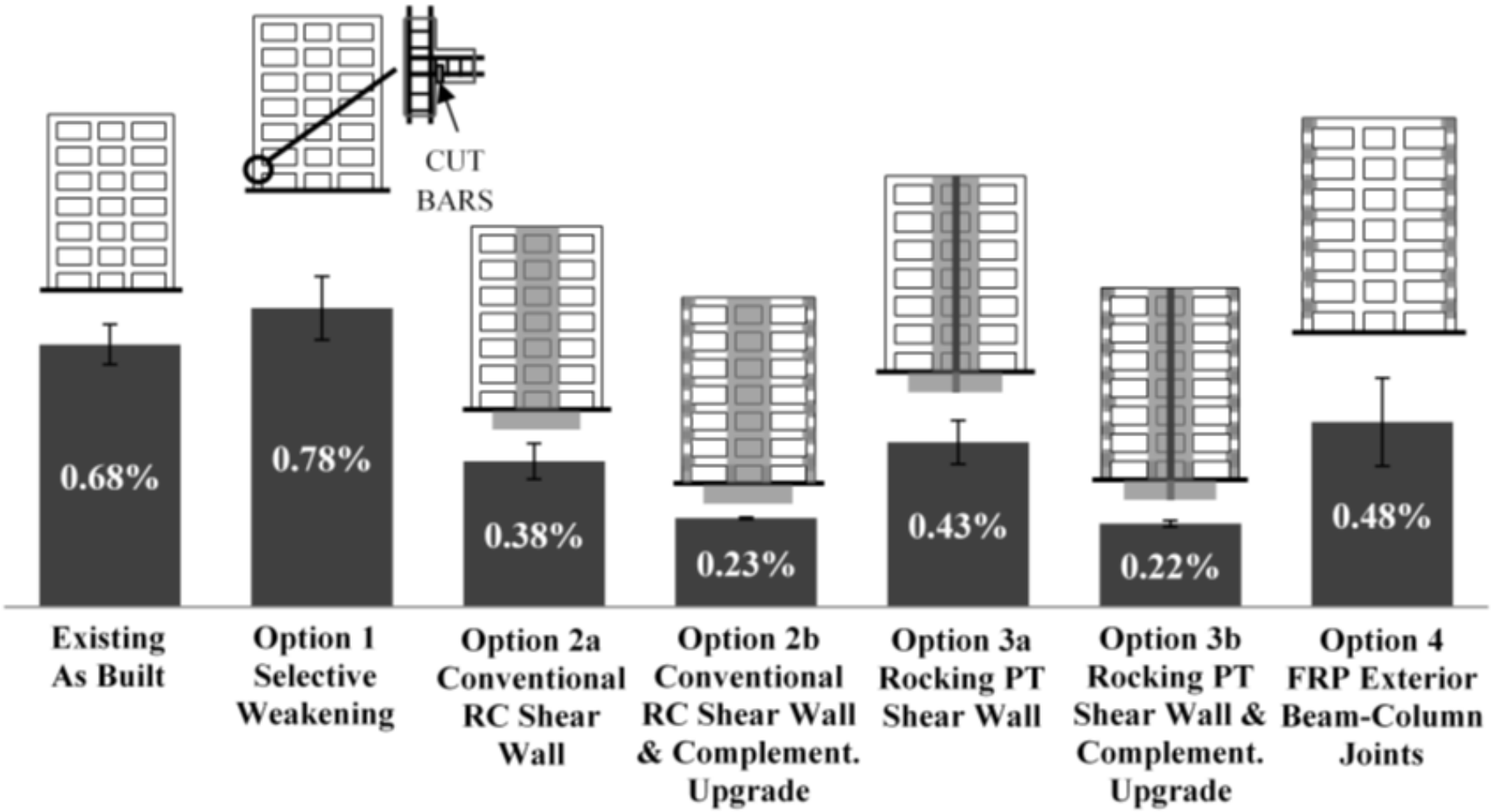


Ligabue, Pampanin, Savoia, 2015

Effects (Economical Losses) of Different Retrofit Strategies

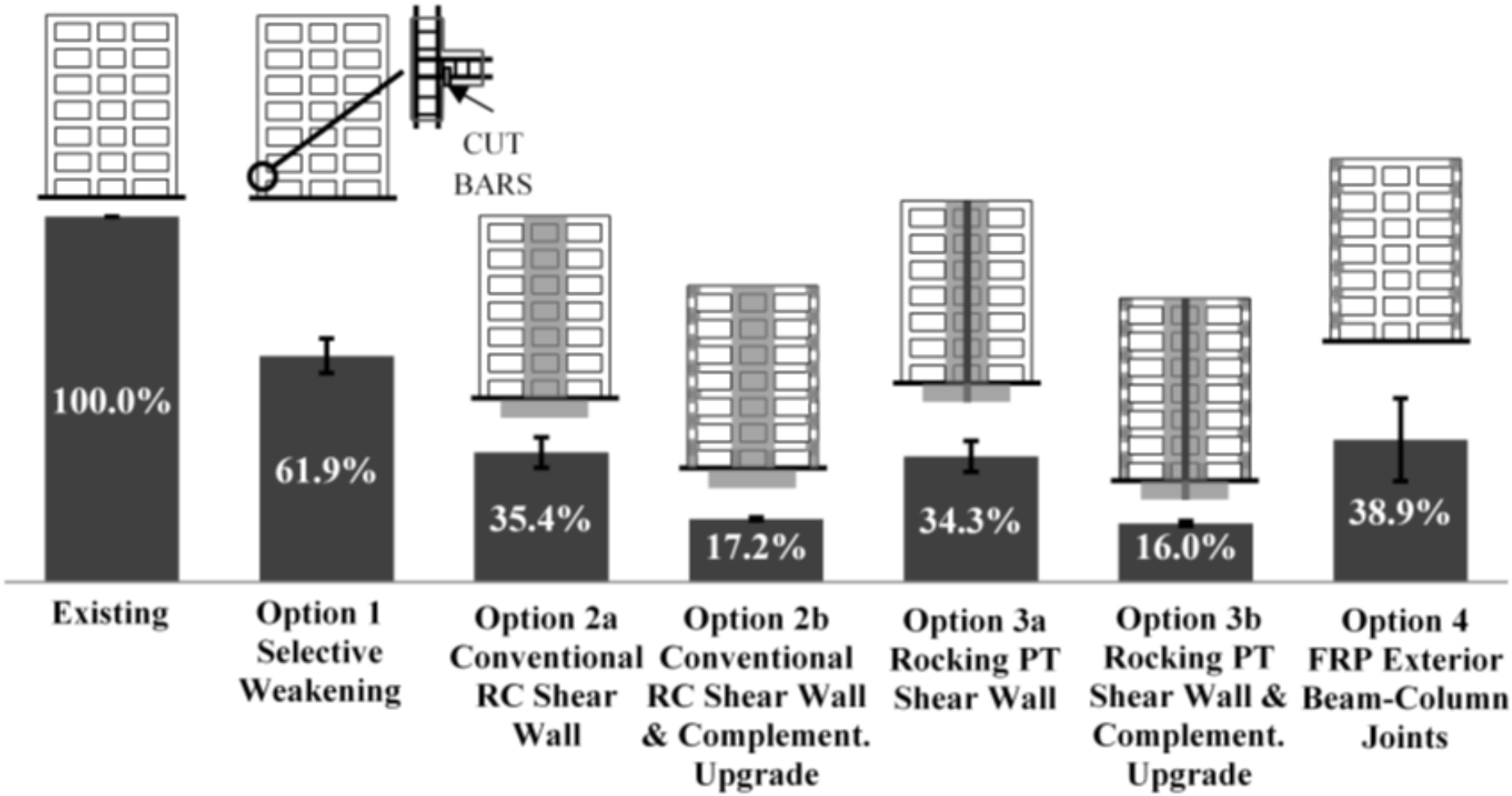
Comparison of alternative retrofit solutions

Expected annual loss (EAL) as a percentage of the building replacement cost (Beetham, 2013)



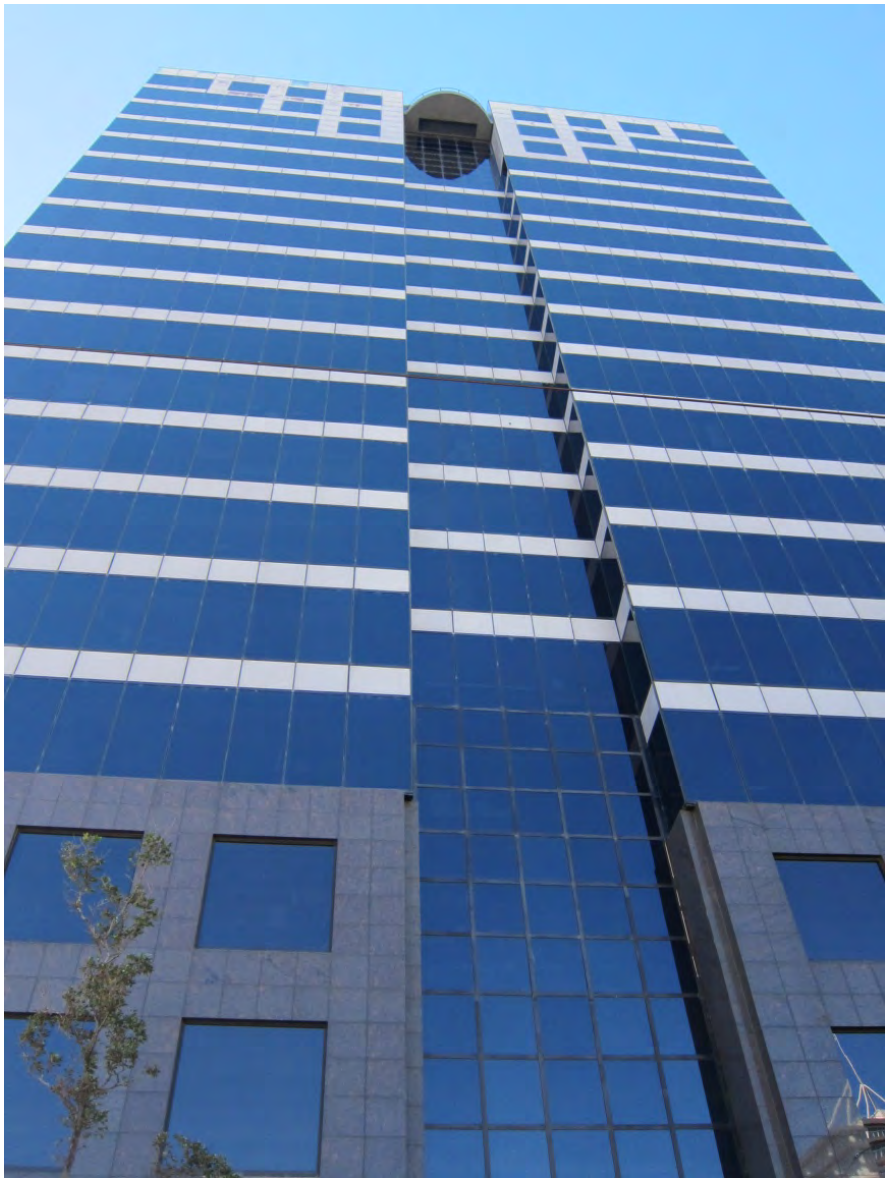
Comparison of alternative retrofit solutions

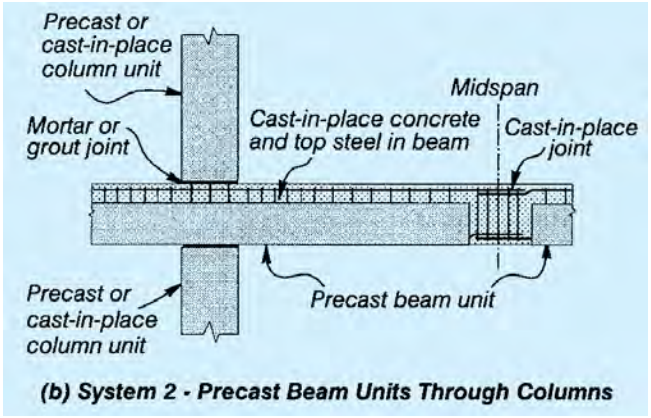
Probable maximum loss (PML) – under a Design Level earthquake (500 years return period or 10% probability of exceedance in 50 years) (Beetham, 2013)



Damaged Buildings

(PwC-PricewaterhouseCooper - 22 storeys)





(b) System 2 - Precast Beam Units Through Columns

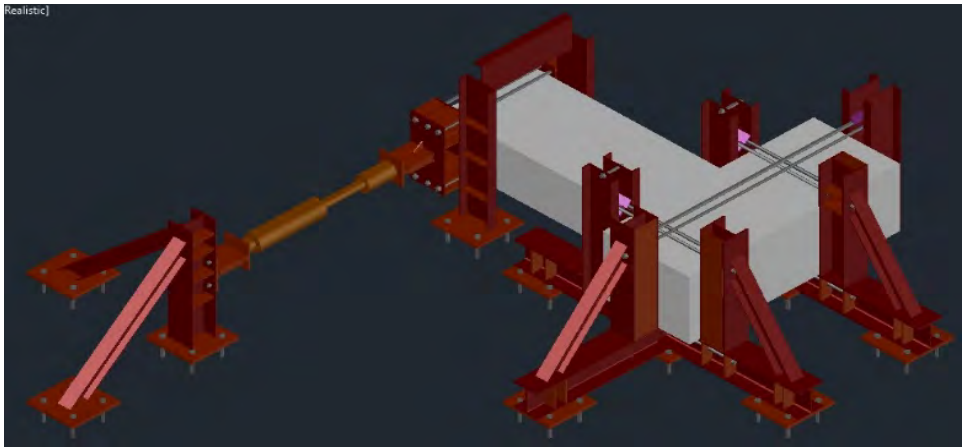
Severe Damage Repairable?

Plastic Hinges in beams
(Sacrificial Fuses)

Demolished

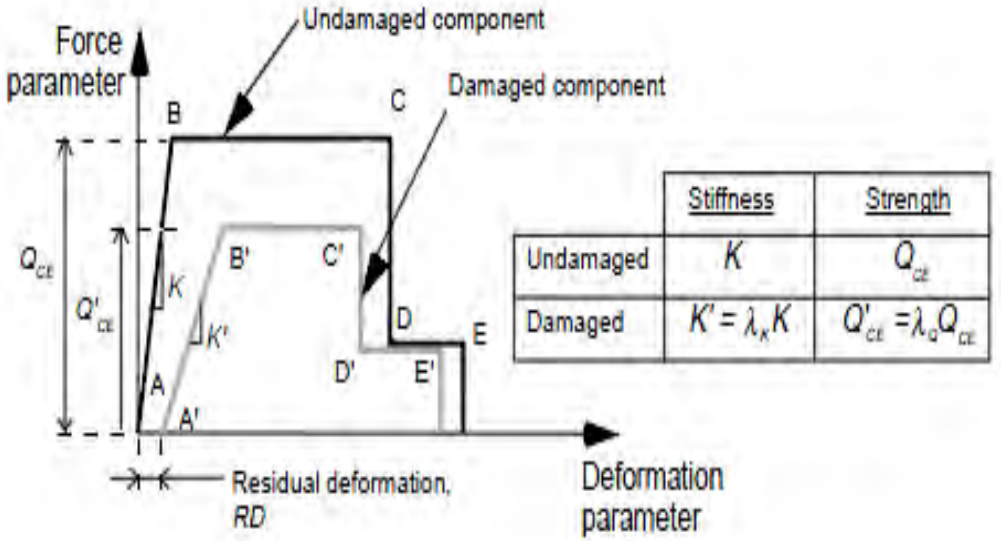
Residual Capacity and Repairability?

Cuevas and Pampanin (2011-2017)

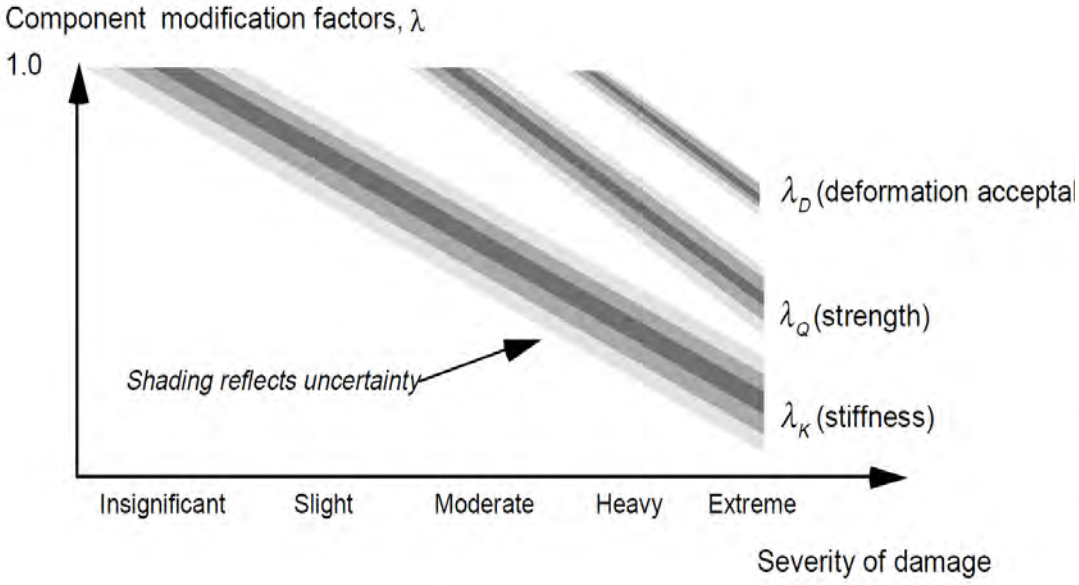


Reduced Capacity Curves

(FEMA 306, Di Ludovico et al., Cuevas and Pampanin; Rossi, Del Vecchio, Pampanin)

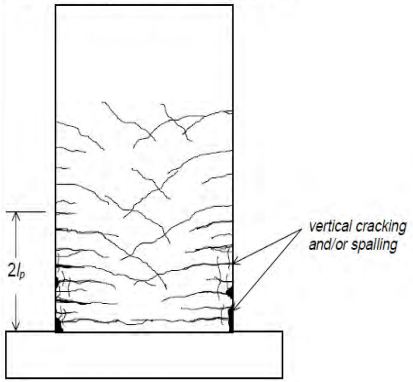


	Stiffness	Strength
Undamaged	K	Q_{CE}
Damaged	$K' = \lambda_K K$	$Q'_{CE} = \lambda_Q Q_{CE}$

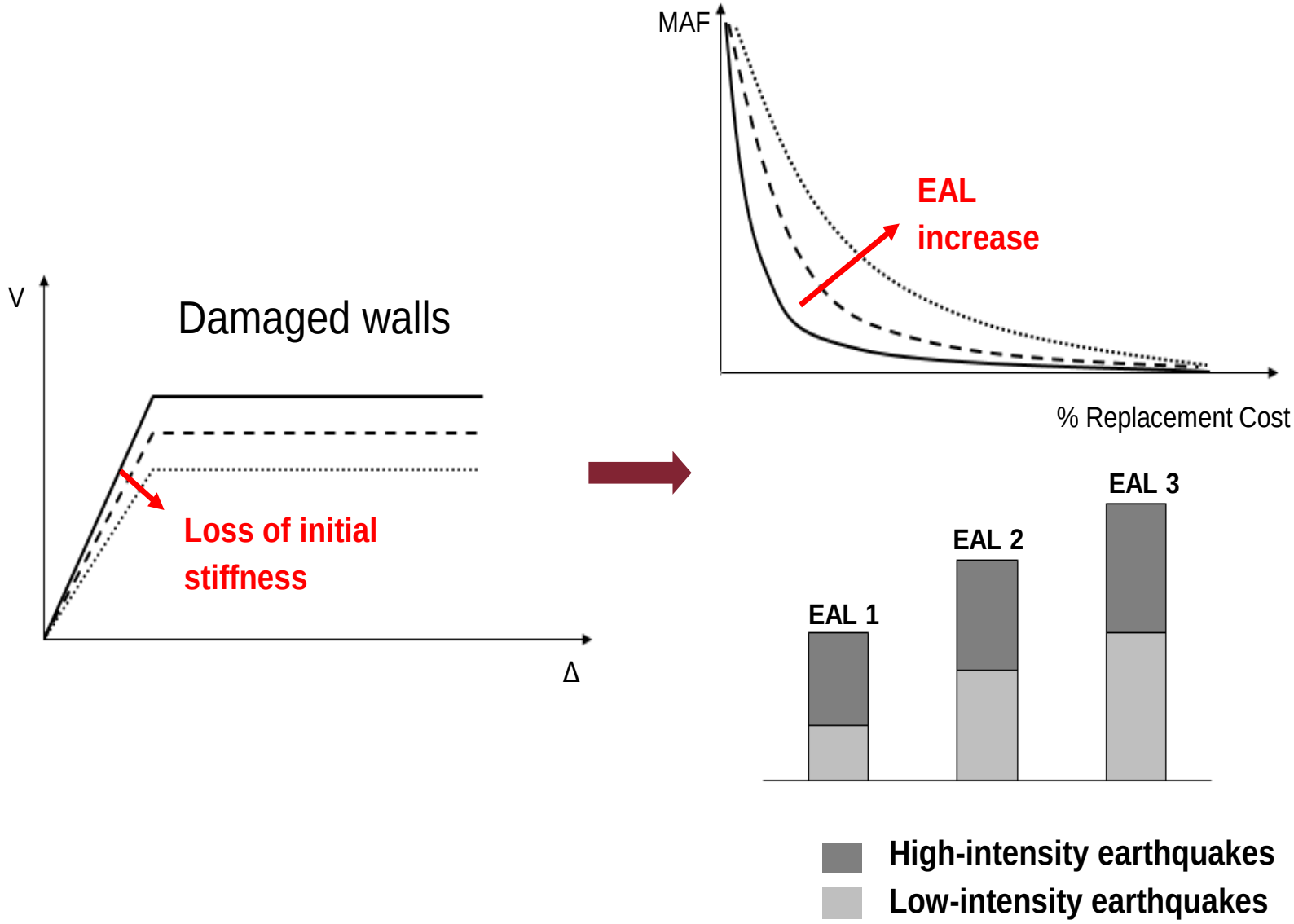


COMPONENT DAMAGE CLASSIFICATION GUIDE
continued

RC1A

Severity	Description of Damage	Performance Restoration Measures
Slight $\lambda_K = 0.6$ $\lambda_Q = 1.0$ $\lambda_D = 1.0$	*Criteria:* • Crack widths do not exceed 1/4 in., and • No shear cracks exceed 1/8 in., and • No significant spalling or vertical cracking, and • No buckled or fractured reinforcement, and • No significant residual displacement. *Typical Appearance:* Similar to insignificant damage, except wider flexural cracks and typically more extensive cracking.	• Inject cracks $\lambda_K^* = 0.9$ $\lambda_Q^* = 1.0$ $\lambda_D^* = 1.0$
Moderate $\lambda_K = 0.5$ $\lambda_Q = 0.8$ $\lambda_D = 0.9$	*Criteria:* • Spalling or vertical cracking (or incipient spalling as identified by sounding) occurs at toe regions in plastic hinge zone, typically limited to the cover concrete, and • No buckled or fractured reinforcement, and • No significant residual displacement. *Typical Appearance:* Crack widths typically do not exceed 1/4 in.  Note: l_p *is length of plastic hinge. See Section 5.3.3*	• Remove and patch spalled and loose concrete. Inject cracks. $\lambda_K^* = 0.8$ $\lambda_Q^* = 1.0$ $\lambda_D^* = 1.0$
Heavy	Not Used	
Extreme	*Criteria:* • Reinforcement has fractured. *Typical Indications* • Wide flexural cracking typically concentrated in a single crack. • Large residual displacement.	• Replacement or enhancement required.

Expected impact of damage (loss of stiffness and strength) in terms of performance and EAL

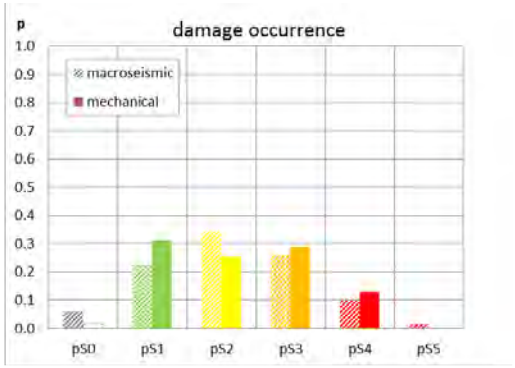


COMPARING & MERGING SEISMIC RISK RATING & REGULATORY APPROACHES

MAME2006

Cross-calibrated macroseismic-mechanical method
(Giovinazzi and Lagomarsino, 2005)

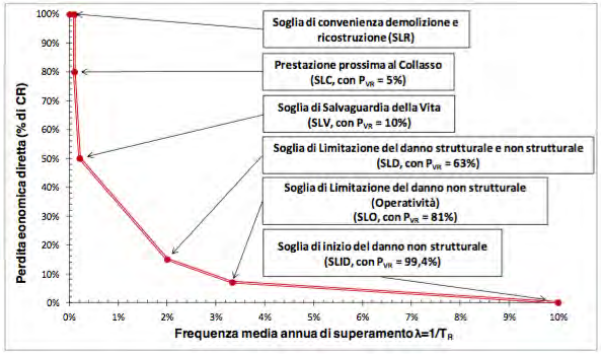
Type of Structure		Vulnerability Class A B C D E F
REINFORCED CONCRETE (RC)	frame without earthquake-resistant design (ERD)	
	frame with moderate level of ERD	
	frame with high level of ERD	
	walls without ERD	
	walls with moderate level of ERD	
	walls with high level of ERD	



ITA2017

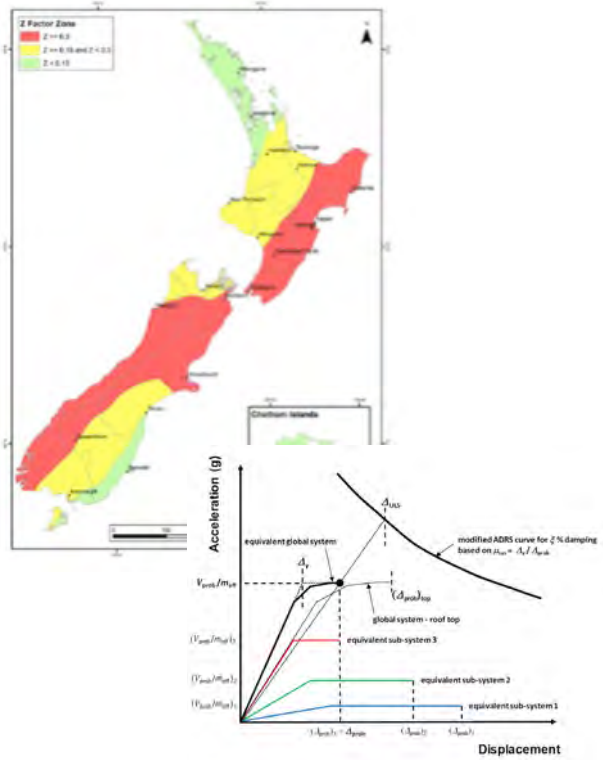
Italian Guidelines on Seismic Risk Classifications and Financial Incentives

$$\%IS-V = \frac{PGA_C(SLV)}{PGA_D(SLV)}$$



NZSEE2017

Seismic Assessment of Existing Buildings

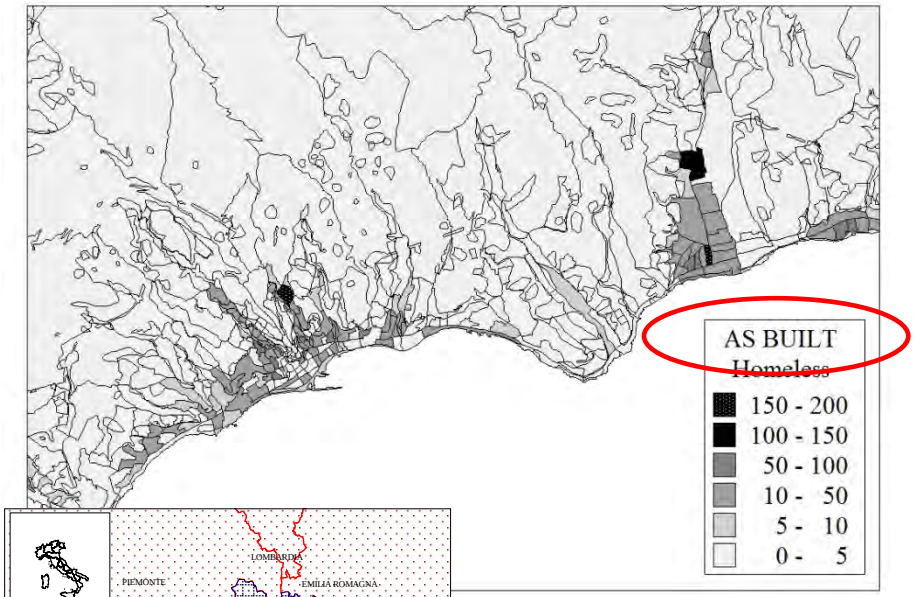


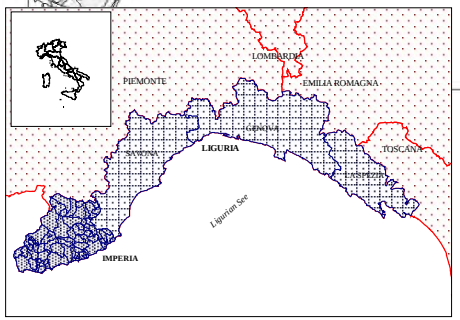
Giovinazzi, S., and Pampanin, S., (2017). Simplified Approaches for the Seismic Risk Rating of Reinforced Concrete Buildings and the Selection of Retrofit Strategies. Proceedings of the XVII ANIDIS Conference, Pistoia, Italy.

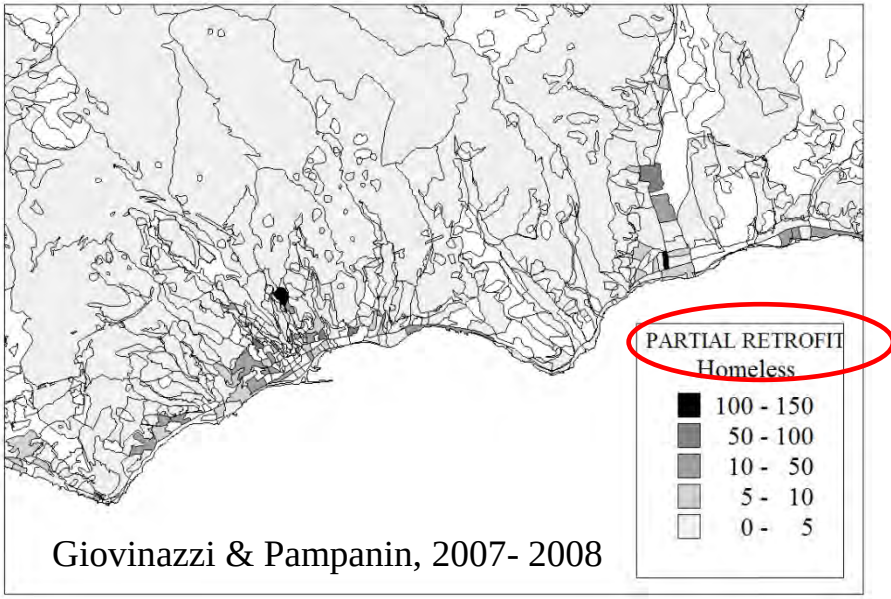
RAISING THE BAR:

Towards a National Plan for Seismic Risk Reduction and Rehabilitation of the Building Stock

- **Risk-based Prioritization**
- **Long term: 30 years**
- **Constant investement: 0.2-0.3% GDP/year**
- **…**







Giovinazzi & Pampanin, 2007- 2008

The bar has been set to very high level

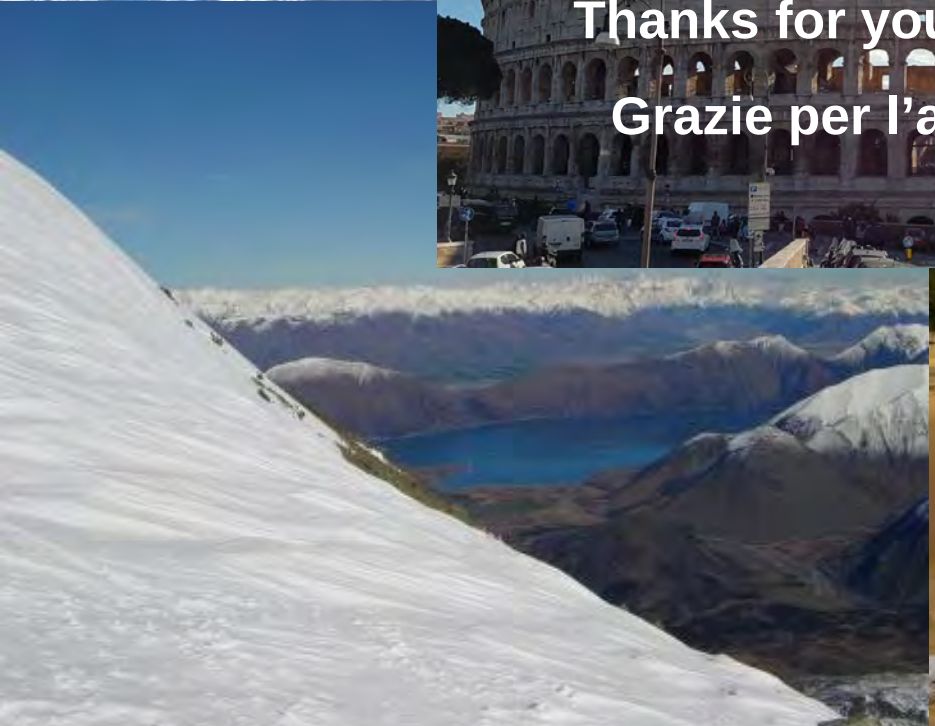
but the International Earthquake Engineering community is going to get there together!

International Collaborators/Teams:
EERI (US), AIJ/JAEE (Japan), EEFIT (UK), NCEER (Taiwan), European Universities

Kia Ora

Thanks for your attention

Grazie per l’attenzione



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