Progetto DPC-ReLUIS 2022-2024 WP3-Task 1

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

Seismic risk of buildings considering the drafts of the upcoming PrEC8

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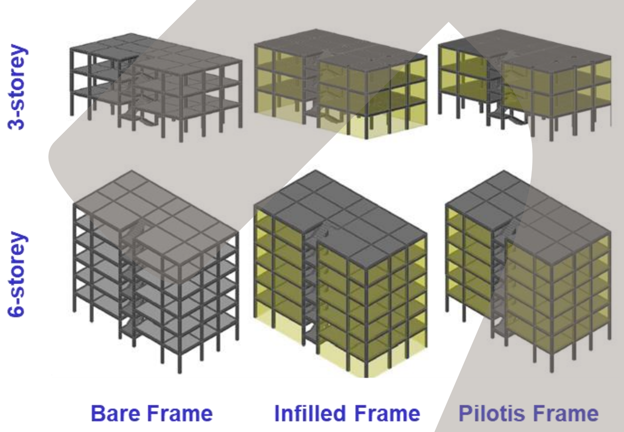
REINFORCED CONCRETE MRF BUILDINGS

Case-study buildings



Analysis and application of new EC provisions

1. Bond failure preventing check (§10.11.2)

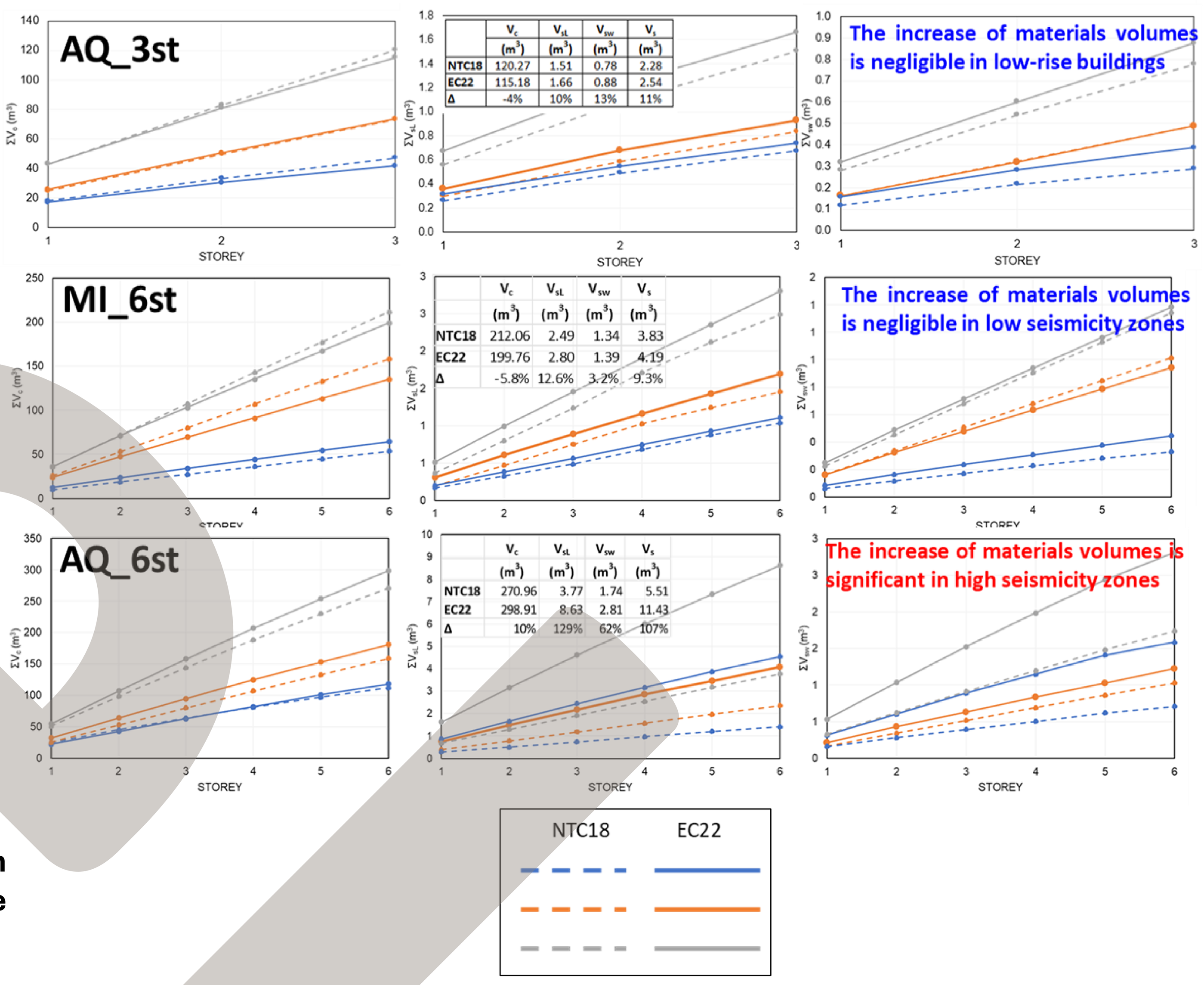
2. Magnification (and de-magnification) of axial force in columns (§10.6.2)

3. Stricter (nearly unsatisfiable) regularity criteria (§4.4.4.2)

4. Reduction of behaviour factors

These competing factors yield to a significant increase of the design seismic demand and in general, of longitudinal and transverse (due to capacity design rules) reinforcement

New EC provisions make reinforcement amount increase in mid- and high-rise buildings in high-seismicity zones (even by +100% with rspect to NTC)

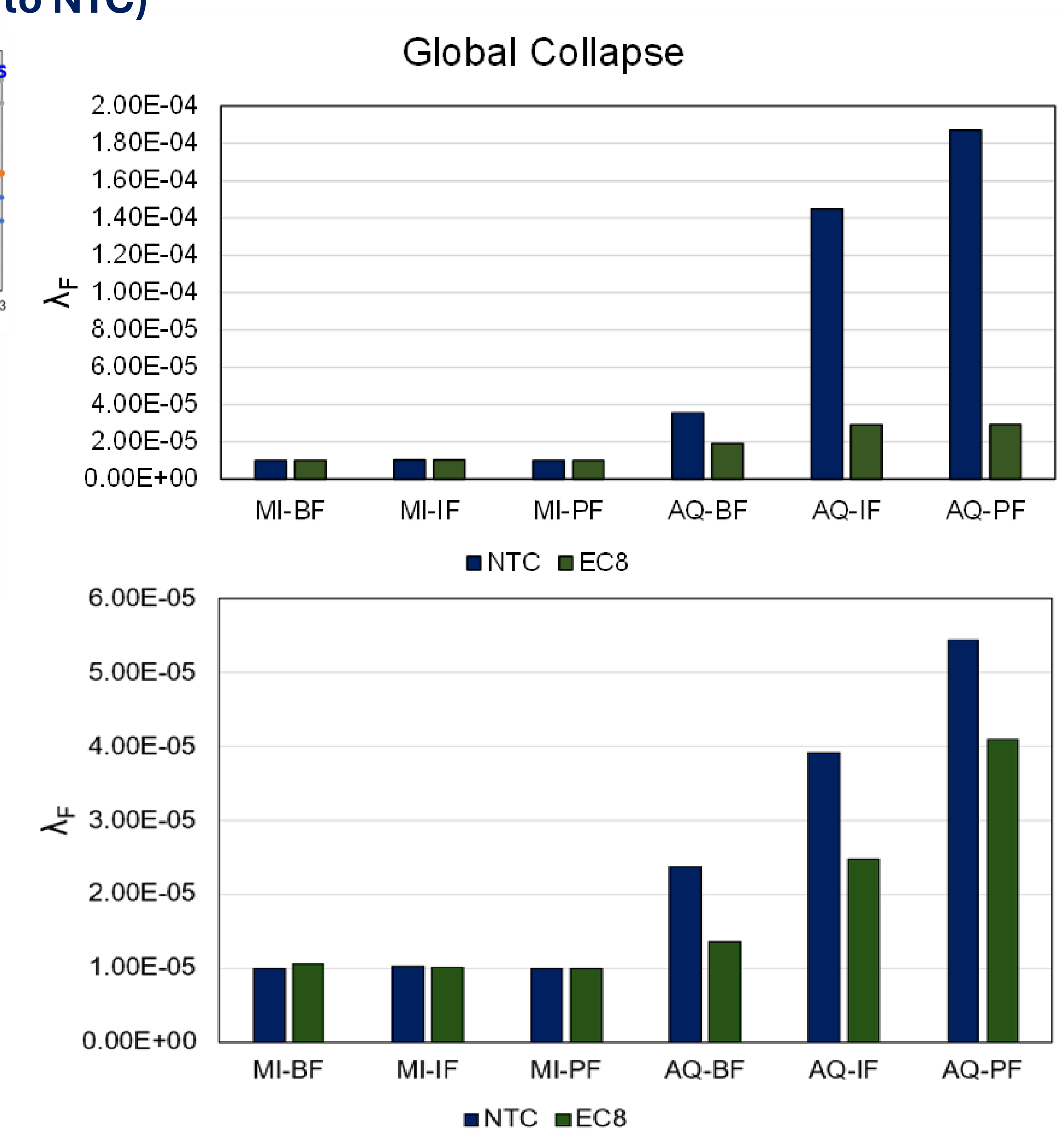


	V_c (m^3)	V_{sL} (m^3)	V_{sw} (m^3)	V_s (m^3)
NTC18	120.27	1.51	0.78	2.28
EC22	115.18	1.66	0.88	2.54
Δ	-4%	10%	13%	11%

	V_c (m^3)	V_{sL} (m^3)	V_{sw} (m^3)	V_s (m^3)
NTC18	212.06	2.49	1.34	3.83
EC22	199.76	2.80	1.39	4.19
Δ	-5.8%	12.6%	3.2%	9.3%

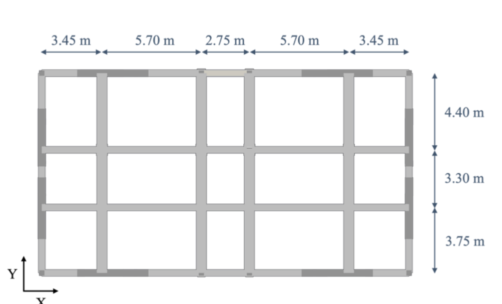
	V_c (m^3)	V_{sL} (m^3)	V_{sw} (m^3)	V_s (m^3)
NTC18	270.96	3.77	1.74	5.51
EC22	298.91	8.63	2.81	11.43
Δ	10%	129%	62%	107%

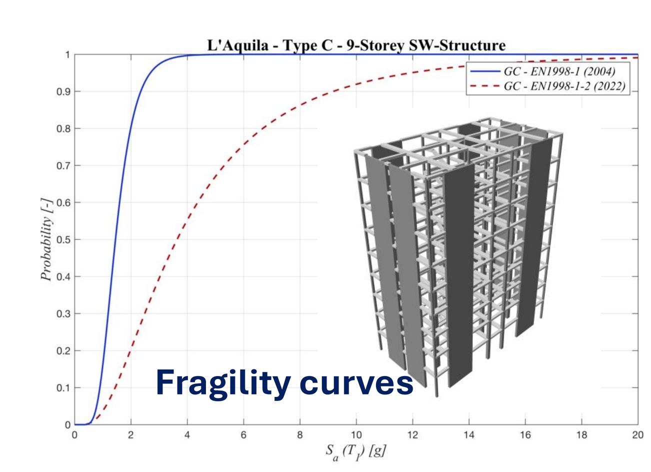
Significant reduction of failure rates



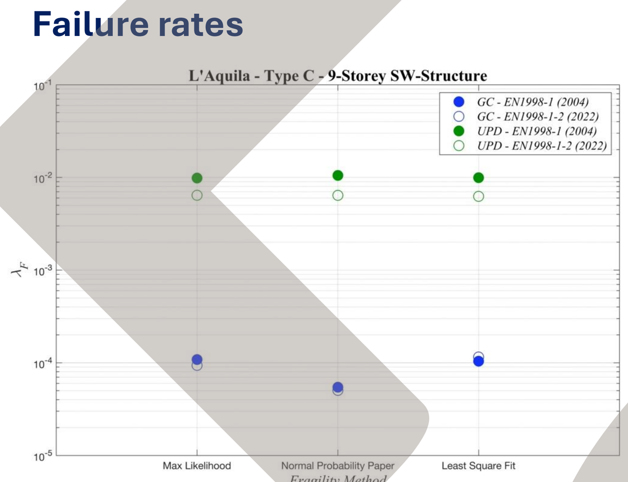
REINFORCED CONCRETE BUILDINGS

9-storey residential RC building





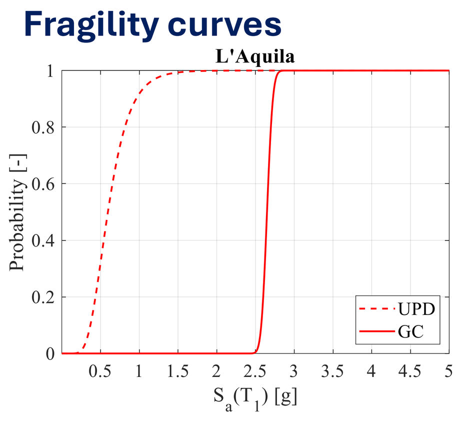
Failure rates



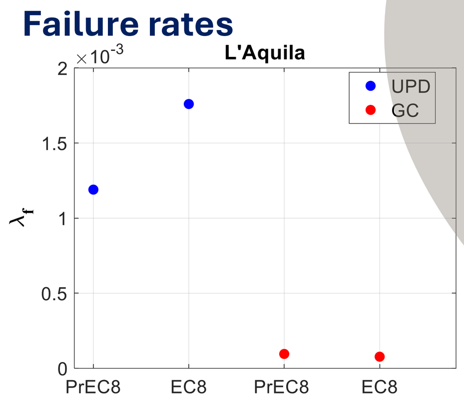
Primary walls, designed according to the PrEC8 require slightly larger cross-sections for the main elements (+2.3% more concrete) and significantly more longitudinal reinforcement (+74.8%) due to increased bending moments.

Precast industrial building

Fragility curves



Failure rates



Columns designed according to PrEN1998 (2022) saw a significant reduction in cross-sectional dimensions compared to EN1998 (2004). For the reference building, this led to a decrease in material usage of approximately 22.1% for concrete and 25.6% for steel reinforcement.

Comparison PrEC8 and EC8

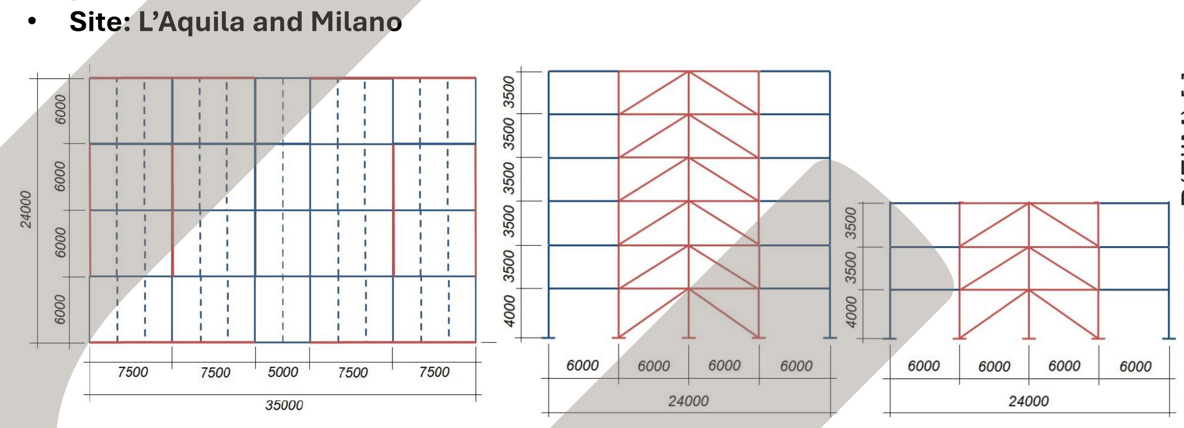
The failure rates determined considering the two versions of the standards are relatively similar (and low) for both UPD and GC. The difference between the standards is more pronounced for UPD.

STEEL BUILDINGS

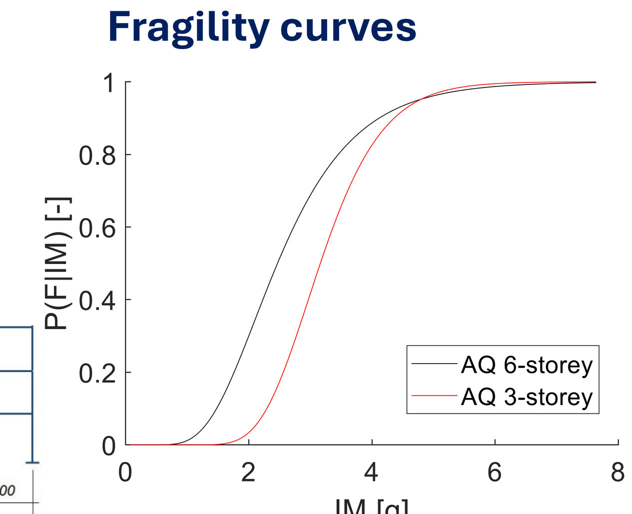
Remark: local collapse criterion adopted (first brace fracture) → → failure rates shall be interpreted as upper bounds

Case-studies

- **3- and 6-storey buildings with concentric braced frames (CBFs)**
- **plan size, 35 m X 24 m**
- **Site: L'Aquila and Milano**

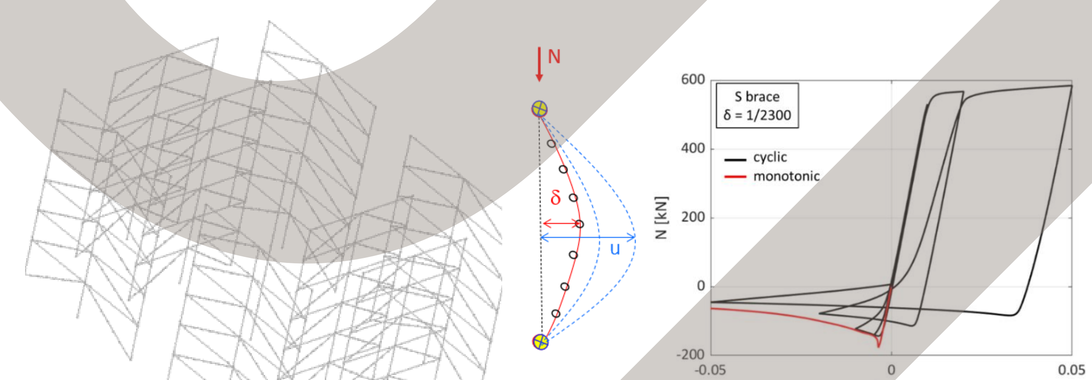


Fragility curves



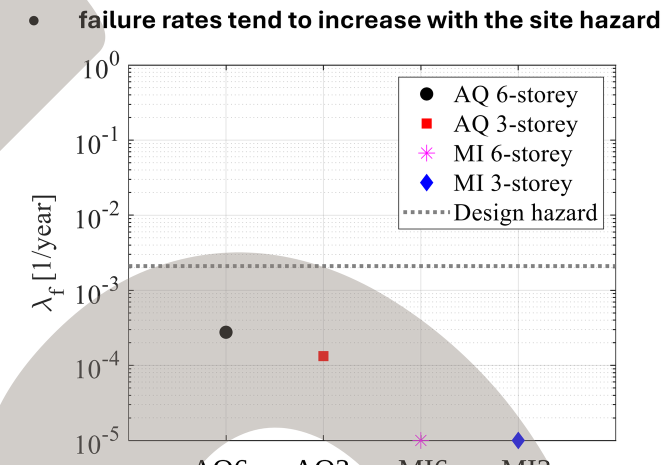
Modelling strategies

- **Distributed plasticity while lumped plasticity where necessary**
- **Geometric nonlinearities and explicit compression buckling simulation**



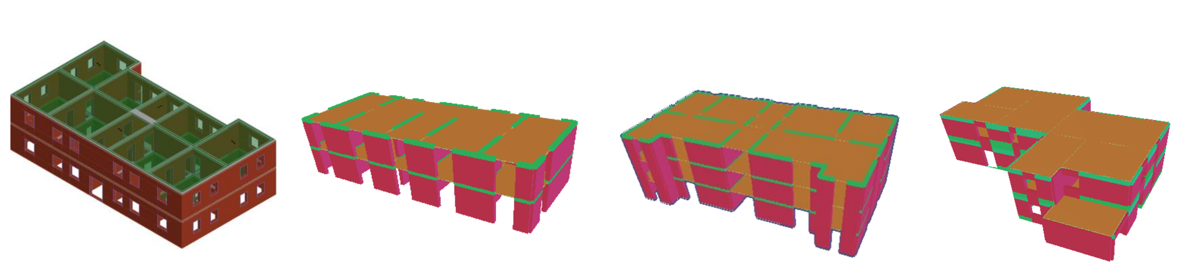
Annual failure rates

- **all failure rates notably lower than the design MAF**
- **highest failure rates for the buildings in L'Aquila**
- **failure rates tend to increase with the site hazard**



MASONRY BUILDINGS

Case-studies



Buildings C 2/3 storeys | **Building E2 2/3 storeys** | **Building E8 2/3 storeys** | **Building G5 2 storeys**

Analysis and application of new EC8 provisions

Design using simple masonry buildings' rules

In the most recent draft of EC8 1-2, the table with required minimum areas of masonry was removed by referring to National Annexes (not yet available)

In this work, 2 approaches were followed to define minimum areas:

(1st possibility): table 7.8.II in NTC 2018;

(2nd possibility): table in prEC8 1-2 (07/2022)

Design using linear static analysis

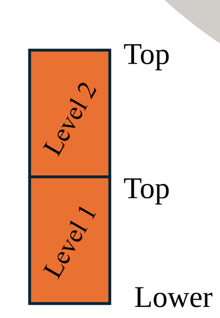
Design using nonlinear static analysis

New EC8 features

- Lower number of analyses (with respect to NTC 2018) required in case of linear and nonlinear analyses.
- The force distribution is obtained starting from the deformed shape corresponding to the application of horizontal forces equal to gravity loads.
- The same deformed shape is used to estimate the fundamental period (differently from Italian code and current EC8, which provide a simplified formula for the period).

Linear Analyses

	Top section of piers				Bottom section of piers			
	+100%Fx -30%Fy	100%Fx +30%Fy	+100%Fy -30%Fx	-100%Fy +30%Fx	100%Fx-30%Fy	-100%Fx +30%Fy	100%Fy-30%Fx	-100%Fy +30%Fx
Verified cases	100%	100%	100%	100%	100%	100%	100%	100%
N_{Rd}/N_{Ed} min	7.98	8.05	8.40	8.67	7.64	7.70	8.01	8.25
Verified cases	88%	88%	92%	91%	96%	97%	96%	97%
M_{Rd}/M_{Ed} min	0.31	0.31	0.33	0.31	0.51	0.50	0.54	0.50
Verified cases	88%	88%	92%	91%	96%	97%	96%	97%
V_{Rd}/V_{Ed} min	0.34	0.33	0.36	0.33	0.48	0.46	0.51	0.46



γ_{RD} (=1.75)

Buildings C		Simple masonry buildings			LSA		NLSA	
	CONFI G.	EC (1*)	EC (2*)	NTC 2018	EC	NTC 2018	EC	NTC 2018
2 storeys	Mi A	C1	C1	C1	C7	C4	C1	C1
	Mi C	C1	C1	C1	C7**	C7	C1	C1
	Aq A	C5	NO	C5	NO	NO	C3	C1
3 storeys	Mi A	C2	C1	C2	NO	C6	C1	C2
	Mi C	C2	C1	C2	NO	C6	C1	C2
	Aq A	C6	NO	C6	NO	NO	C3	C3

Designable? YES/NO

	Aq A	Mi C	Mi A
E2-3S clay	NO	YES	YES
E2-3S concr.	NO	YES	YES
E2-2S clay	YES	YES	YES
E2-2S concr.	NO	YES	YES
E8-3S clay	NO	YES	YES
E8-3S concr.	NO	YES	YES
G5-2S clay	YES	YES	YES

Failure rates

Buildings C

Failure Rate λ	Milano A		Milano C		Aquila A	
	C1	C7	C1	C7	C3	C5
UPD	0.0181	0.0027	0.0202	0.0001	0.0125	0.0112
GC	1.E-5	1.E-5	1.E-5	1.E-5	0.0003	0.0003

Failure Rate λ	Milano A		Milano C		Aquila A	
	C1	C2	C1	C2	C3	C6
UPD	0.0320	0.0182	0.0353	0.0331	0.0177	0.0169
GC	1.E-5	1.E-5	1.E-5	1.E-5	0.0010	0.0010

Buildings E and G

Failure Rate λ	Milano A		Milano C		Aquila A	
	E2-2S clay	E2-2S concr.	E2-2S clay	E2-2S concr.	E2-2S clay	E2-2S concr.
UPD	1.0E-5	1.0E-5	1.0E-5	1.0E-5	1.2E-3	-
GC	1.0E-5	1.0E-5	1.0E-5	1.0E-5	3.7E-4	-

Failure Rate λ	Milano A		Milano C		Aquila A	
	E2-3S clay	E2-3S concr.	E2-3S clay	E2-3S concr.	E2-3S clay	E2-3S concr.
UPD	1.1E-5	2.2E-5	1.1E-5	2.8E-5	2.8E-5	-
GC	1.0E-5	1.0E-5	1.0E-5	1.0E-5	1.0E-5	-

Failure Rate λ	Milano A		Milano C	
	E8-3S clay	E8-3S concr.	E8-3S clay	E8-3S concr.
UPD	1.0E-5	1.3E-5	2.2E-5	1.3E-5
GC	1.0E-5	1.0E-5	1.0E-5	1.0E-5

Failure Rate λ	Milano A	Milano C	Aquila A
	G5-2S	G5-2S	G5-2S
UPD	1.0E-5	1.0E-5	2.4E-4
GC	1.0E-5	1.0E-5	1.0E-4