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Seismic vulnerability assessment of the residential URM buildings built during the XX century in Florence

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ABSTRACT

This work deals with the urban scale vulnerability assessment of the unreinforced masonry buildings with RC slabs built during the XX century in Florence. The public housing interventions, for their numerosity and the archive documentation of the design projects, have been chosen as representative of the coeval urban stock. A meaningful database with a large number of selected buildings was realized. Every construction has been firstly investigated adopting an empirical approach based on geometrical and mechanical parameters; houses have been divided into typological classes in function of geometrical and architectonical features. Then, a typology with a specific related case study has been selected and assessed by an analytical procedure. An equivalent frame modeling discretization has been adopted and the seismic performance has been evaluated by means of nonlinear static analyses. Both aleatory and epistemic uncertainties have been considered; then, their sensitivity has been studied. The aleatory uncertainties have been investigated adopting the star design with the central star approach, while the epistemic uncertainties have been modeled through a logic tree approach. Analytical fragility curves have been finally derived, considering both the dispersions in terms of capacity and seismic demand. The fragility curves pointed out the vulnerability of the case study and the related damage scenarios for different expected return periods. Specifically, they showed a high vulnerability of these buildings for the 475 and 975 years return period; for the Life Safety limit state (SLV), around 40% of probability to have DL4 and 40% to reach DL5 is expected. The results have been finally extended to the building class population through a simplified procedure calibrated on the analytical results. The results point out homogeneous outcomes, exhibiting a high vulnerability and a relevant brittle behavior in the plastic phase.

Keywords: urban scale approach, hybrid approach, URM buildings, nonlinear static analysis, EF discretization, residential buildings.

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LIST OF SYMBOLS

Symbol	*Definition*	*Unit*
$\Delta_{PLi,Xk}$	Variable that expresses the sensitivity to the aleatory uncertainties	
$\Delta_{PLi,Yj}$	Variable that expresses the sensitivity to the epistemic uncertainties	
T_1	Fundamental period	s
Δ_{LS4}	Interstory drift limit of the pan	
$\Lambda_{P,DLk}$	internal drift limit for the attainment of strength degradation	
τ_x	Masonry shear strength of the wall	
$A_{u,X}$	Spectral accelerations at the ultimate displacement	m/s^2
$D_{u,SPWS}$	Ultimate displacement for SPWS configurations	m
$D_{u,WPSS}$	Ultimate displacement for WPSS configurations	m
D_y	Displacement at the yielding point	m
$F_{el,max}$	Idealized maximum base shear	kN
F_y	Base shear at the yielding point	kN
H_f	Heaviside function	
$K_{i,x}$	Correction factors of the DVM	
M_u	Ultimate bending moment	
V_u	Ultimate shear	
$\bar{X}$	Mean value of performed tests	
k_r	Vertical regularity factor	
$p_{DSk}(im)$	Discrete probability considering the k-th LS considered.	
γ_i	Masonry specific weight at i-th level	kN/m^3
μ_D	Expected level of damage	
$a_{x,y,i}$	The ratio between the resistant masonry area in the considered direction over the gross area, for each *i*-th, level	
$d*$	Displacement of the equivalent SDOF system	m
E	Elastic Young's Modulus	MPa
E_d	Energy dissipated during the hysteretic cycle	
E_{s0}	Elastic energy produced towards the two senses of the cyclic analysis	
f_m	Compressive strength	MPa

f_t	Tensile strenght	*MPa*
f_{v0}	Shear strength according to the Mann and Muller criterion	*MPa*
$f_{x,y}$	Base shear at the ground floor	*kN*
f_{ym}	Characteristic yielding stress	*MPa*
g	Gravity acceleration	$9.81\ m/s^2$
G	Shear Modulus	*MPa*
H	Total height of the building	*m*
h_i	Interstory height of the i-th level	
H_p	Minimum value between the tensile resistance of the interposed element and $0.4\ f_h ht$	
k	Ratio between variance of performed tests prior distribution variance	
$k_{x,y,i}$	Spandrels contribution factor defined as the ratio between the total volume of the wall over the volume of the piers	
$m*$	Mass of the equivalent SDOF system	
$\mathrm{m_i}$	Mass of the i-th node of the model	
n	Number of tests of the Bayesian approach	
Nf	Number of floors of the building	
N_p	Number of piers	
q	Q factor behavior	
Q	Macroseismic ductility factor	
q_i	Seismic floor load considering the deal loads and a fraction of the live loads	daN/m^2
Rc	Cubic compressive strength	*MPa*
S_a	Spectral acceleation	m/s^2
S_d	Spectral displacement	*m*
$T*$	Equivalent period	*s*
$u_{i,j}$	Displacements of the nodes	
$V*$	Base shear of the MDOF system	*kN*
$\mathbf{Y}$	Vector that collects the values $log(IM_{LS,i})$, $i = 1,\ldots,M$	
$\mathbf{Z}$	Matrix of the normalized values	
$\boldsymbol{\alpha}_i$	Angular coefficient of the hyperplane of the normalized variables	
β_C	Dispersion in the seismic capacity	
β_D	Dispersion in the seismic demand	
Γ	Participation factor	
δ_{Ei}	Drift values	

ε_x	Coefficient ranging between 0 and 1 expressing the behavior of the structure	
$\zeta_{x,i}$	Fraction component in the considered direction	%
η	Damping correction factor	
μ’	Prior mean value	
ξ_{el}	Elastic viscous damping	%
ξ_{eq}	Equivalent viscous damping	%
ξ_{visc}	Hysteretic damping	%
σ_x	Average vertical compressive stress at the middle height of the first level	
τ_0	Shear strength according the Turnskek and Cacovic criterion	*MPa*
ϕ_i	Referred normalized displacement	
$\varphi_{i,j}$	Rotation of the nodes	
Φ	Standard cumulative distribution function	
N	Axial force	
b	Ratio of height and length of the panel	
l	Length of the element	*m*
t	Thickness of the element	*m*
θ	Drift at the building scale	
$\mu"$	Updated mean value	
μ'	Prior mean value	
$\sigma"$	Updated standard deviation	
σ'	Prior standard deviation	