



MeDEA

*Multidimensional seismic risk assessment
through explainable artificial intelligence*



Co-funded by the
European Union



e-CAMPUS
UNIVERSITÀ

MULTIDIMENSIONAL SEISMIC RISK ASSESSMENT COMBINING STRUCTURAL DAMAGES AND PSYCHOLOGICAL CONSEQUENCES USING EXPLAINABLE ARTIFICIAL INTELLIGENCE

Work Package 3 :

Identification of benchmark structures

Selection and calculation of the best EDPs to quantify the effect of seismic actions on structures

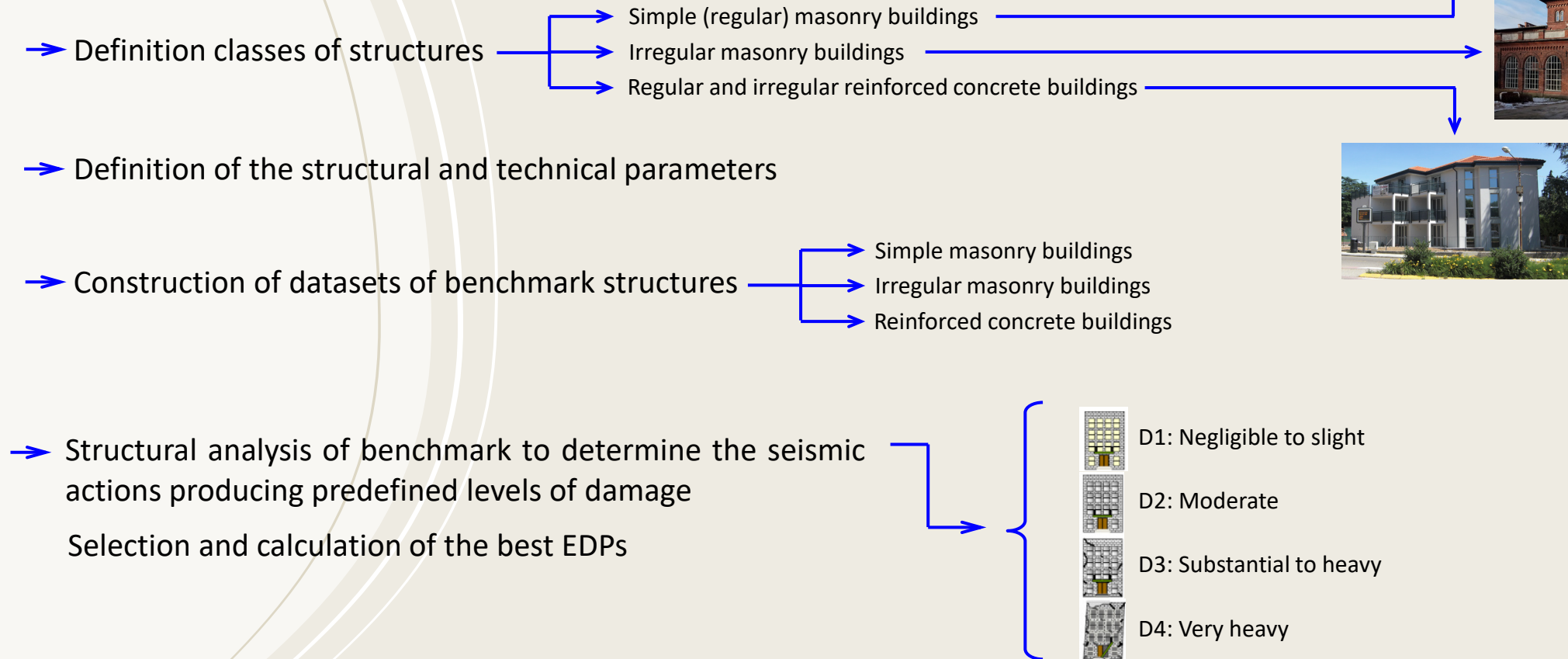
Fabrizio Comodini

Salvatore Verre e Riccardo Panico



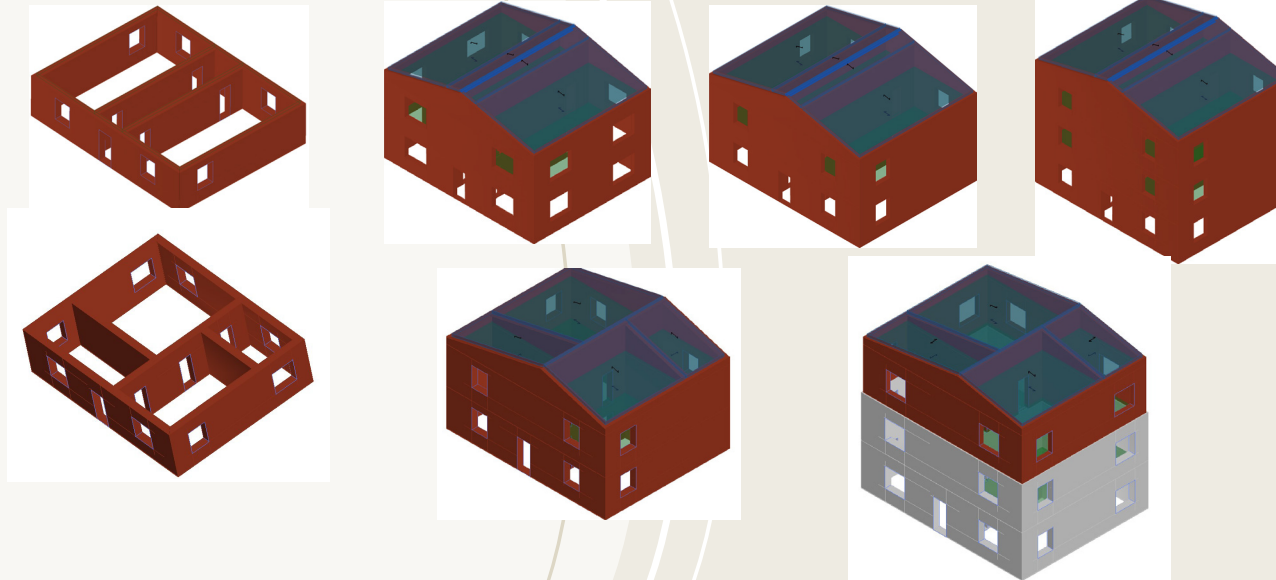
WP3: BENCHMARK STRUCTURES

● Structures

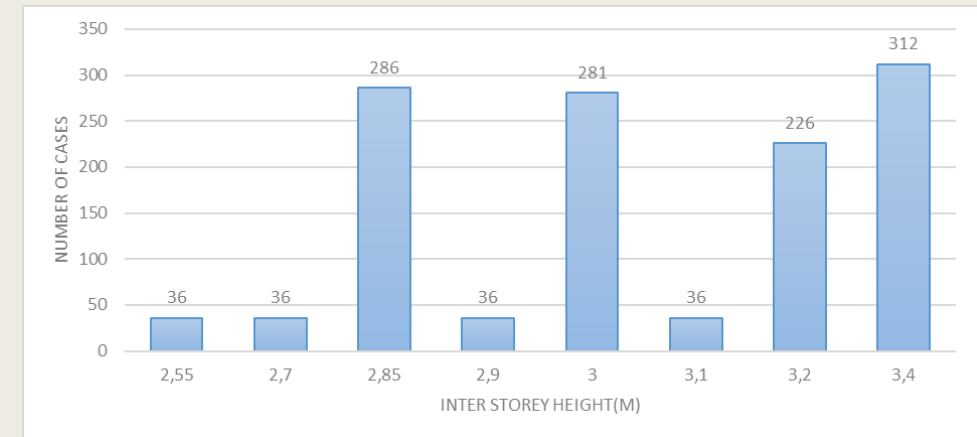
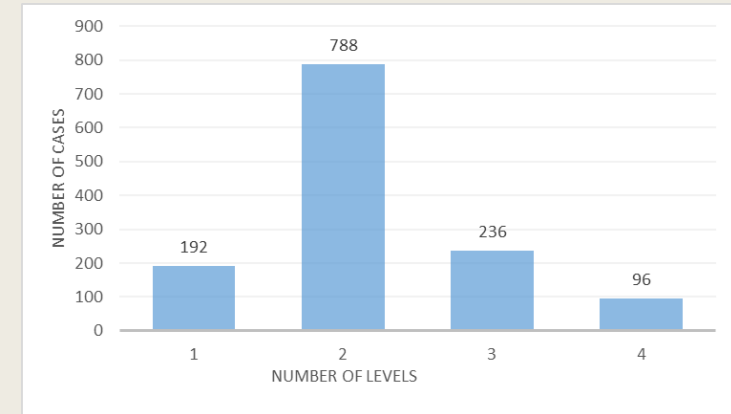


WP3: CLASS OF REGULAR MASONRY STRUCTURES - BENCHMARK ≈ 1500 cases

Some benchmarks of regular masonry buildings



N° 4 configurations of base schemes

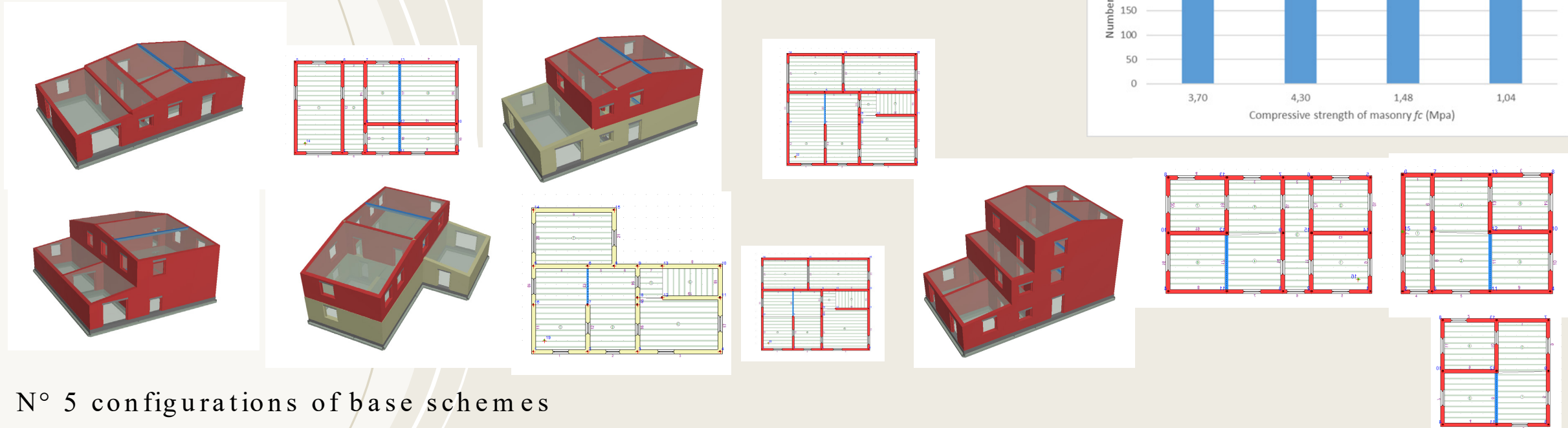


Range of variation of geometric and mechanical properties

	Elastic Modulus	Shear Modulus	Density	Average shear strength	Average compressive strength	Thickness of shear wall	Number of internal shear wall	Number of floors	Inter-storey height	Effective shear area	Seismic floor mass
	E_m (MPa)	G_m (MPa)	w_m (kN/m ³)	τ_m (MPa)	f_m (MPa)	t_m (m)	s_w (-)	n_f (-)	h_f (m)	$A_{\tau m}$ (m ²)	S_m (ton)
Range of variability	540-2850	180-950	13-22	0.02-0.07	1.04-4.30	0.30-0.45	1-2	1-4	2.55-3.40	12.78-25.02	36,90-110.35

WP3: CLASS OF IRREGULAR MASONRY STRUCTURES - BENCHMARK ≈ 1200 cases

Some benchmarks of irregular masonry buildings



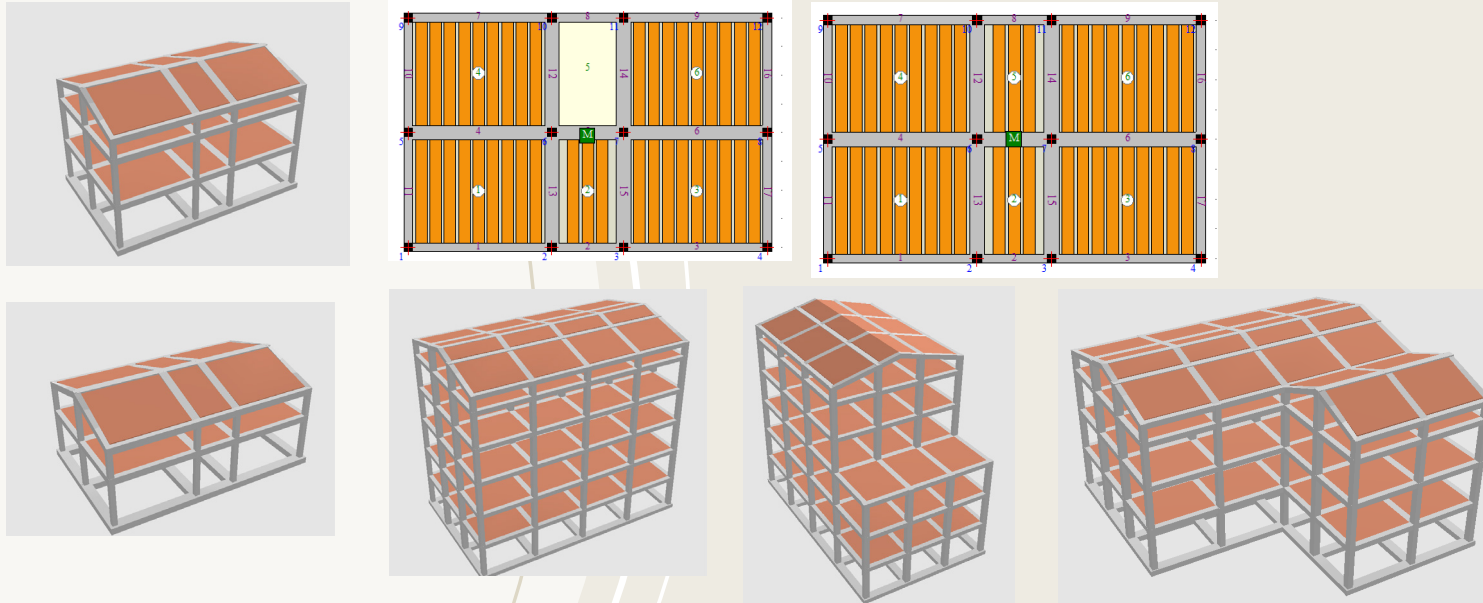
N° 5 configurations of base schemes

Range of variation of geometric and mechanical properties

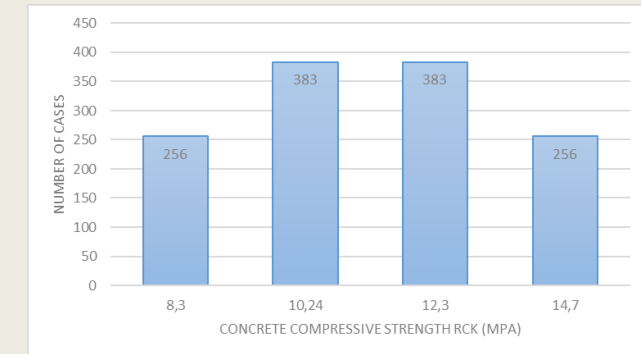
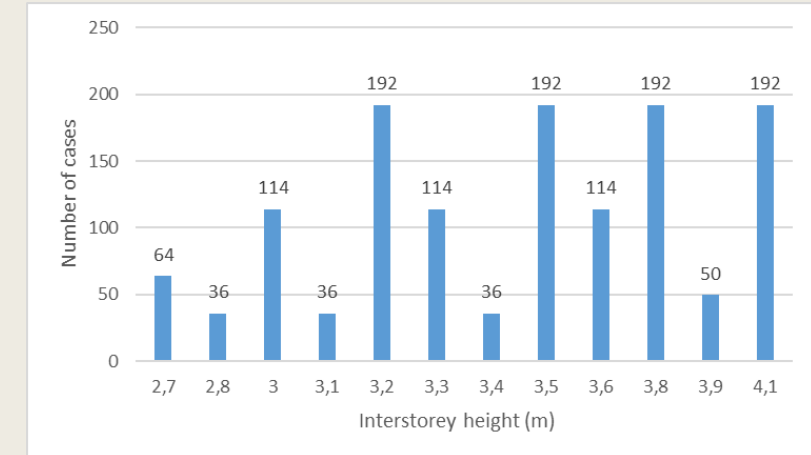
	Elastic Modulus	Shear Modulus	Density	Average shear strength	Average compressive strength	Thickness of shear wall	Number of internal shear wall	Number of floors	Inter storey height	Effective shear area	Seismic floor mass
	E_m (MPa)	G_m (MPa)	w_m (kN/m ³)	τ_m (MPa)	f_m (MPa)	t_m (m)	sw (-)	n_f (-)	h_f (m)	$A_{\tau m}$ (m ²)	S_m (ton)
Range of variability	540-2850	180-950	13-22	0.02-0.07	1.04-4.30	0.25-0.45	1-3	1-3	2.60-3.50	10,15 -25.02	80.48-474.00

WP3: CLASS OF REINFORCED CONCRETE STRUCTURES - BENCHMARK ≈ 1400 cases

Some benchmarks of reinforced concrete buildings



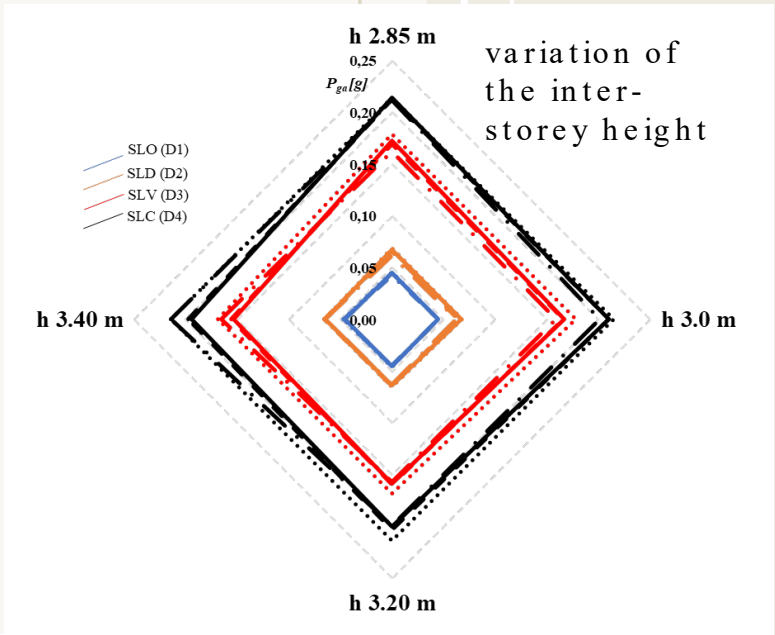
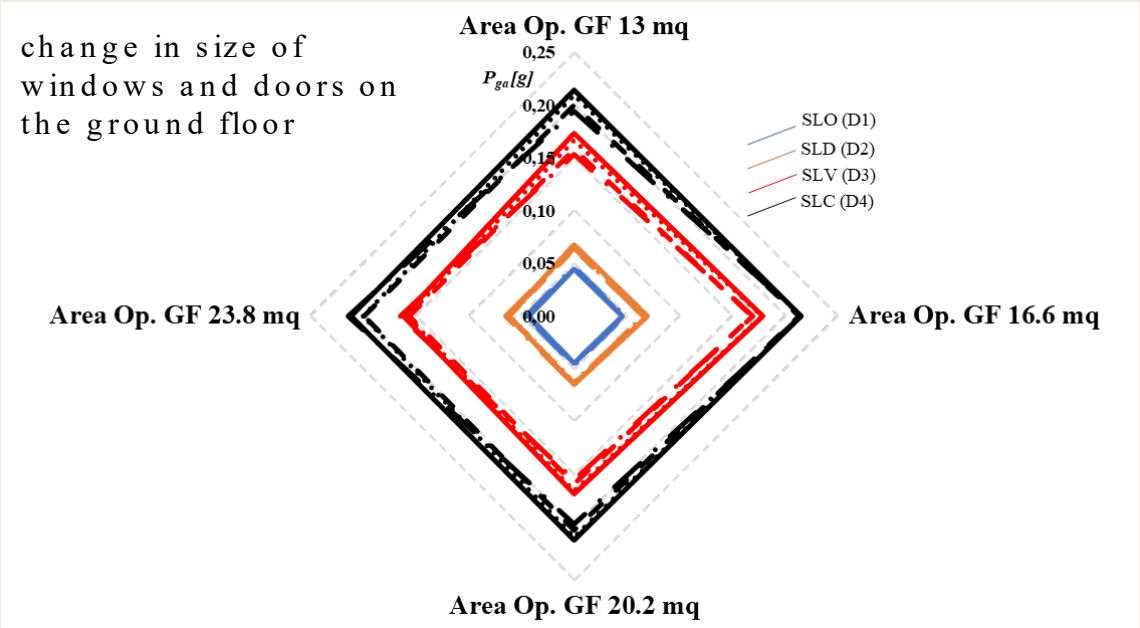
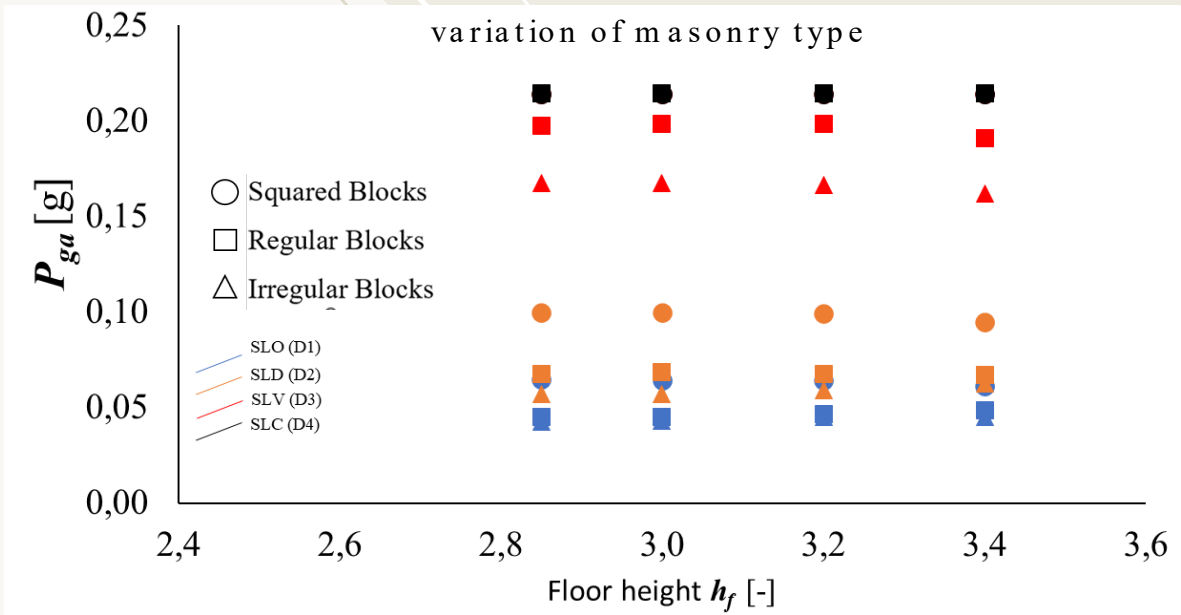
N° 5 configurations of base schemes



Range of variation of geometric and mechanical properties

	Elastic Modulus	Shear Modulus	Density	Average shear strength	Average compressive strength	Number of floors	Interstorey height	Seismic floor mass
	E_m (GPa)	G_m (GPa)	w_m (kN/m ³)	τ_m (MPa)	f_m (MPa)	n_f (-)	h_f (m)	S_m (ton)
Range of variability	25.4-31.5	10.7-13.1	24	1.64-2.56	8.30-14.17	1-6	2.60-3.50	37.27-1882.55

WP3: SENSITIVITY ANALYSIS OF TECHNICAL PARAMETERS

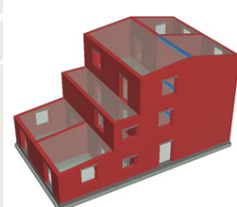
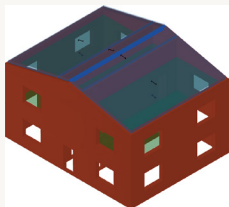


WP3: STRUCTURAL AND TECHNICAL PARAMETERS

MASONRY STRUCTURES PARAMETERS

ID	Description
F0	Number of levels
F1	Average floor height
F2	Sides ratio (x-length / y-length)
F3	Floor area
F4	Number of internal alignments of masonry wall in X-direction
F5	Number of internal alignments of masonry wall in Y-direction
F6	Area of the openings of the external masonry walls
F7	Area of the openings of the internal masonry walls
F8	Average thickness of external masonry shear wall
F9	Average thickness of internal masonry shear wall
F10	Average shear strength of masonry
F11	Average compressive strength of masonry
F12	Masonry gross density
F13	Elastic modulus
F14	Shear modulus
F15	Effective shear area
F16	Seismic floor mass
F17	Ratio seismic floor mass / Effective shear area
F18	Maximum eccentricity between center of mass and center of stiffness
F19	Maximum ratio between floor stiffnesses

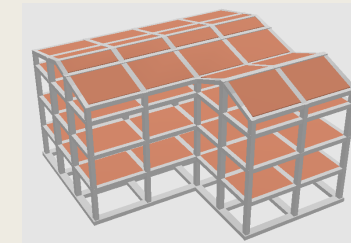
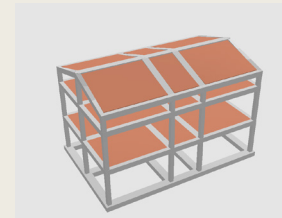
REGULAR AND IRREGULAR MASONRY STRUCTURES



REINFORCED CONCRETE STRUCTURES PARAMETERS

ID	Description
F0	Number of underground levels
F1	Number of floors
F2	Estimate building height
F3	Total length X-side
F4	Total length Y-side
F5	Seismic floor mass MAX / Seismic floor mass MIN
F6	Parameter between the max and the min (Ratio of Seismic floor mass / Concrete area)
F7	Average stress in the columns in the corner at the ground floor
F8	Average stress in the external column at the ground floor
F9	Average stress in the internal columns at the ground floor
F10	Ratio between maximum/minimum eccentricity
F11	Ratio between maximum/minimum stiffness X direction
F12	Ratio between maximum/minimum stiffness Y direction
F13	Period of the structure
F14	Shear force at the base

REINFORCED CONCRETE STRUCTURES



WP3: DATASETS OF BENCHMARK STRUCTURES

MASONRY STRUCTURES DATASET

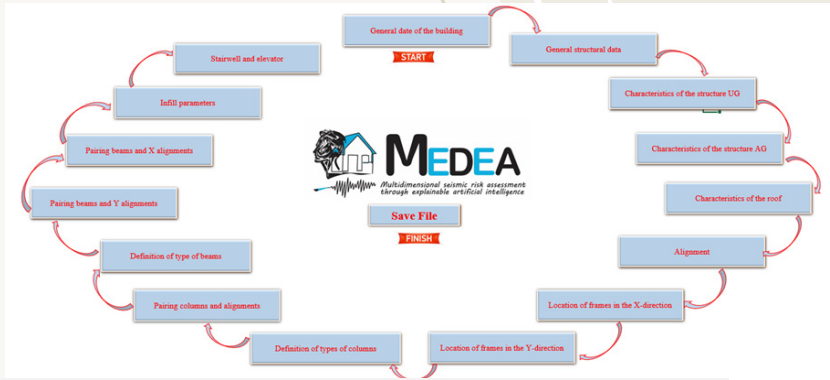
Analysis	Number	504 s
Analysis	Unit	Analysis 504
Number of Level	[-]	3.00
Average floor height	[m]	3.40
Sides ratio (x-length/ y-length)	[-]	1.28
Average floor area	[m ²]	120.28
Number of internal alignments of masonry wall in	[-]	0.00
Number of internal alignments of masonry wall in Y	[-]	2.00
Area of the openings of the external masonry walls	[m ²]	28.08
Area of the openings of the external masonry walls	[m ²]	21.60
Area of the openings of the external masonry walls	[m ²]	21.60
Area of the openings of the internal masonry walls	[m ²]	6.60
Area of the openings of the internal masonry walls	[m ²]	13.20
Area of the openings of the internal masonry walls	[m ²]	13.20
Average thickness of external masonry shear wall	[m]	0.30
Average thickness of external masonry shear wall	[m]	0.30
Average thickness of external masonry shear wall	[m]	0.30
Average thickness of internal masonry shear wall	[m]	0.30
Average thickness of internal masonry shear wall	[m]	0.30
Average thickness of internal masonry shear wall	[m]	0.30
Average shear strength of masonry (GF)	[MPa]	0.04
Average shear strength of masonry (EF 1)	[MPa]	0.04
Average shear strength of masonry (EF 2)	[MPa]	0.04
Average compressive strength of masonry (GF)	[MPa]	1.93
Average compressive strength of masonry (EF 1)	[MPa]	1.93
Average compressive strength of masonry (EF 2)	[MPa]	1.93
Masonry gross density (GF)	[kN/m ³]	18.00
Masonry gross density (EF 1)	[kN/m ³]	18.00
Masonry gross density (EF 2)	[kN/m ³]	18.00
Elastic Modulus (GF)	[MPa]	750.00
Elastic Modulus (EF 1)	[MPa]	750.00
Elastic Modulus (EF 2)	[MPa]	750.00
Shear Modulus (GF)	[MPa]	250.00
Shear Modulus (EF 1)	[MPa]	250.00
Shear Modulus (EF 2)	[MPa]	250.00
Average area of shear strength (GF)	[m ²]	9.48
Average area of shear strength (EF 1)	[m ²]	7.14
Average area of shear strength (EF 2)	[m ²]	7.14
Seismic floor mass (EF 1)	[ton]	74.79
Seismic floor mass (EF 2)	[ton]	74.79
Seismic floor mass – roofing plan (RP)	[ton]	110.35
Ratio of Seismic floor mass/ Average area of shear	[ton/m ²]	7.89
Ratio of Seismic floor mass/ Average area of shear	[ton/m ²]	10.48
Ratio of Seismic floor mass/ Average area of shear	[ton/m ²]	15.45

REINFORCED CONCRETE STRUCTURES DATASET

Building	[-]	A
Analysis	Unit	Modello 1-Analysis 1
Number of underground levels	[-]	0
Number of floor	[-]	3
Estimate building height	[m]	8,40
Total length X-side	[m]	12,50
Total length Y-side	[m]	6,50
Seismic floor mass MAX / Seismic floor mass MIN	[-]	1,03
Parameter between the max and the min (Ratio of Seismic floor mass/ Concrete area)	[ton/m ²]	1,03
Total vertical load per unit area	[kN/m ²]	68,81
Average stress (seismic combination) in the columns at the ground floor	[kN/m ²]	1583,27
Maximum eccentricity	[-]	0,00
Ratio between maximum/minimum stiffness X direction	[-]	3,47
Ratio between maximum/minimum stiffness Y direction	[-]	3,47
Period of the structure	[s]	0,43

WP3: DATASETS OF BENCHMARK STRUCTURES

APPLICATION FOR DATASET COMPILATION



General data of the building

Building identification		Type of the building	
Date of construction [Years]		Use class	
Building design code			
Type of concrete		Building regular in plan [-]	
Type of steel		Building regular in elevation [-]	
Category of use of the building			

General data of the building

S. No.	Building identification	Date of construction	Building design code	Type of concrete	Type of steel	Category of use of the building	Type of the building	Use class	Building regular in plan	Building regular in elevation
--------	-------------------------	----------------------	----------------------	------------------	---------------	---------------------------------	----------------------	-----------	--------------------------	-------------------------------

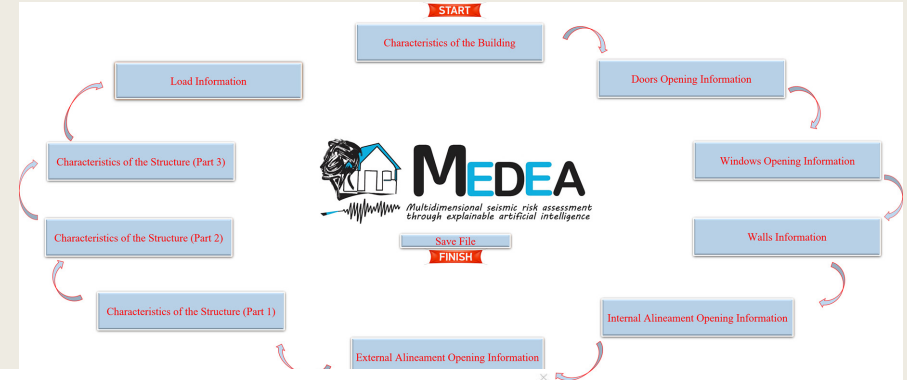
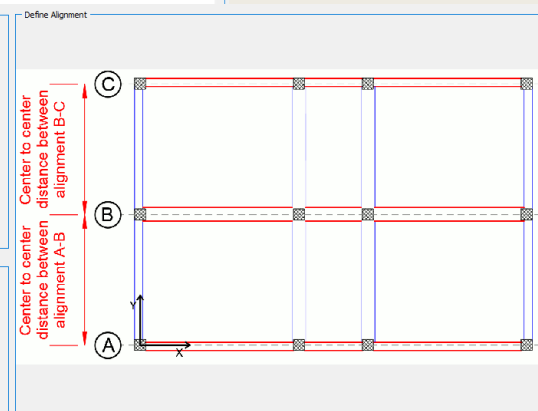
Alignment

Floor level [-]

Name of alignment

Center-to-center distances between alignments in the X direction

NOTE: At the beginning of each floor insert the "Alignment" that says "first" and length "zero"



Characteristics Structure Part 1

Floor level [-]

Average floor height [m]

Average roof height [m]

Total length X-side [m]

Total length Y-side [m]

Type of Masonry [-]

Number of alignments of internal masonry wall in Y-direction [-]

There are data concerning the mechanical properties of the materials [-]

Average compressive strength [MPa]

Average shear strength [MPa]

NOTE: If "yes" is selected in "There are data concerning the mechanical properties of the materials", the observer should enter the average value of compressive strength and shear strength. In case of "no" enter the symbol "-".

Opening Information Doors

Door type number [-]

b [m]

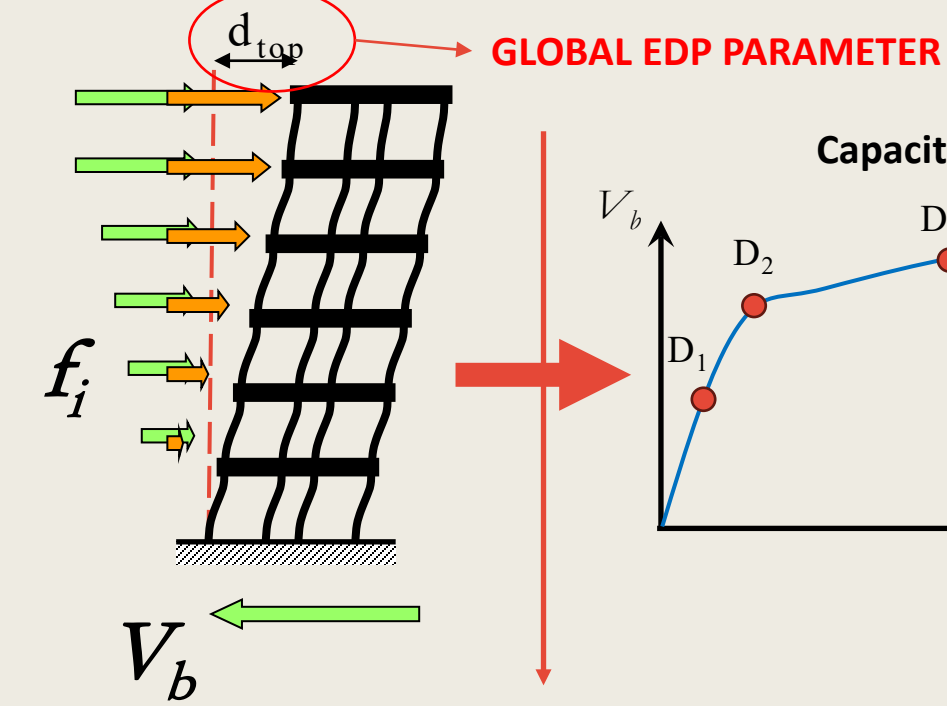
h [m]

Opening Information Doors

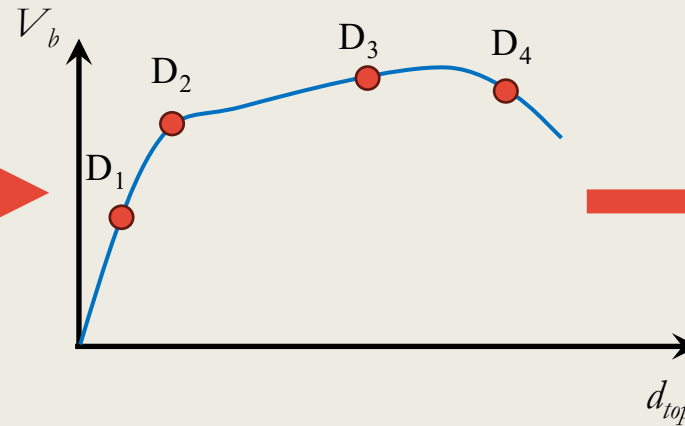
S. No.	Door type number [-]	b [m]	h [m]
--------	----------------------	-------	-------

The diagram shows a cross-section of a door with dimensions b [m] and h [m]. The diagram illustrates how the opening information process defines the dimensions of the door structure.

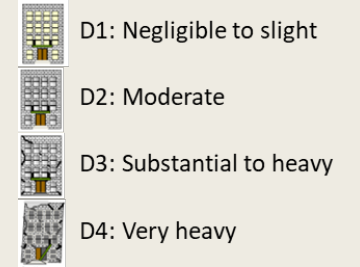
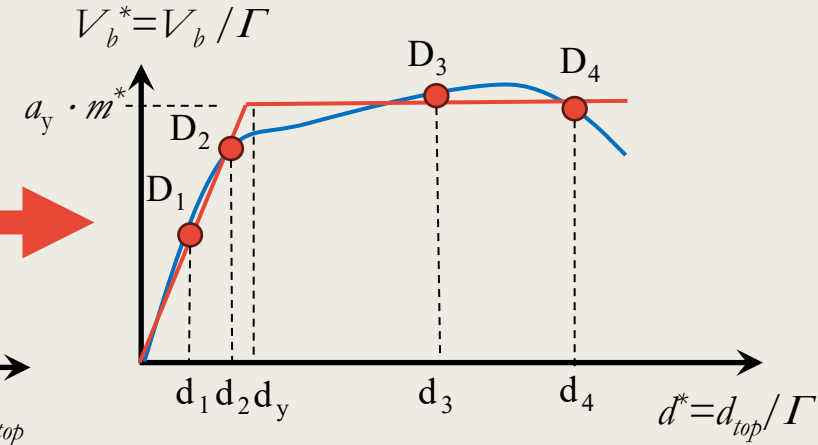
NON-LINEAR STATIC ANALYSIS



Capacity Curve



Capacity curve of the equivalent SDOF system



Damage levels and seismic capacity are identified by:

Displacement:

$d_1(D1) - d_2(D2) - d_3(D3) - d_4(D4)$

and

acceleration at the elastic limit of the equivalent bilinear curve

a_y

period of the SDOF equivalent system

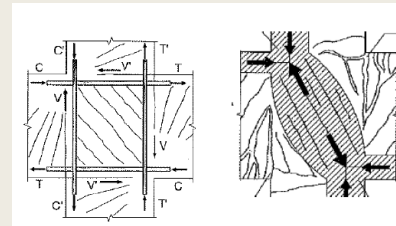
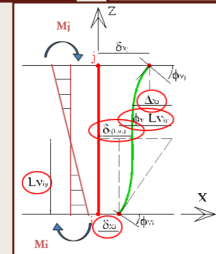
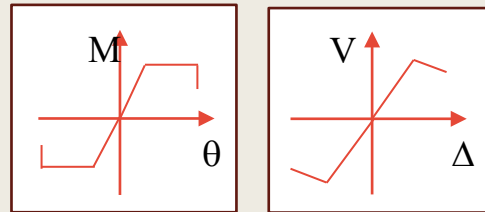
T^*

seismic mass of the SDOF equivalent system

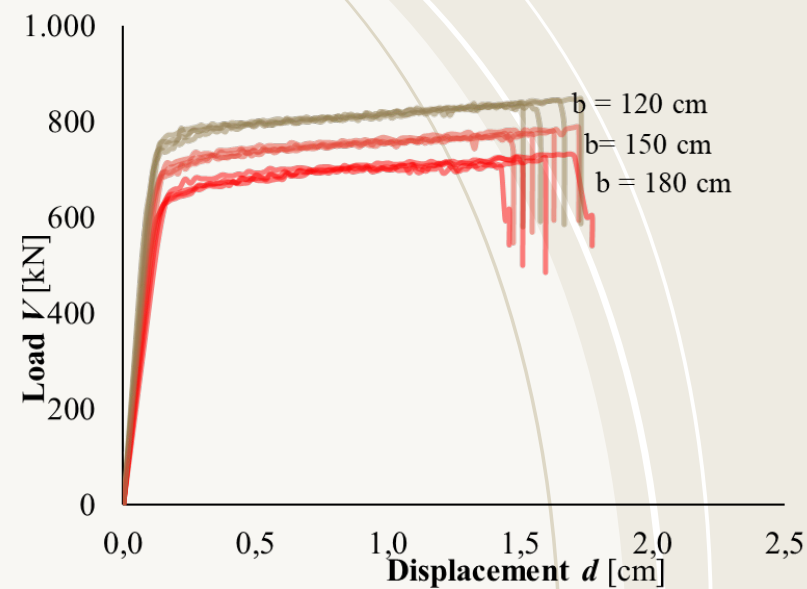
m^*

LOCAL EDP PARAMETERS FOR MASONRY AND REINFORCED CONCRETE STRUCTURES

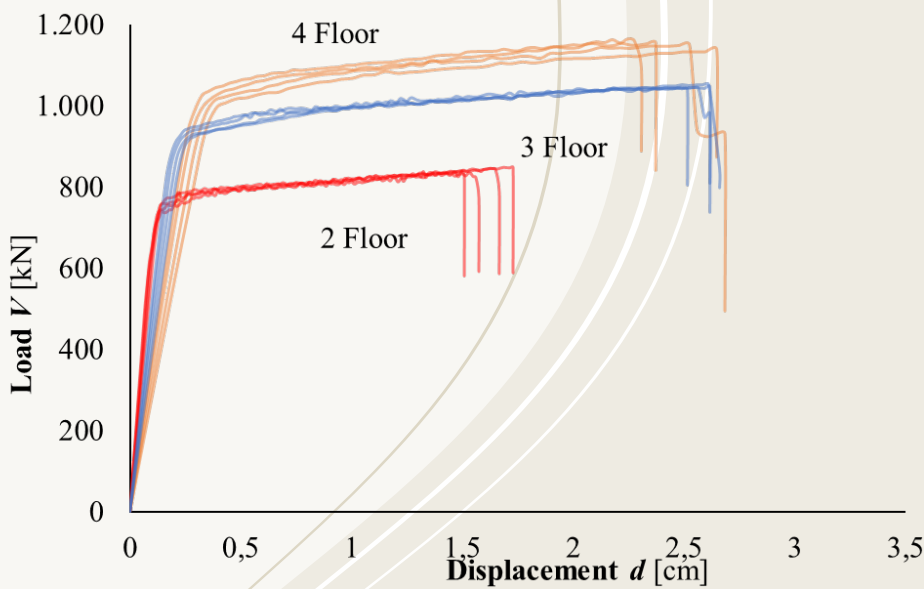
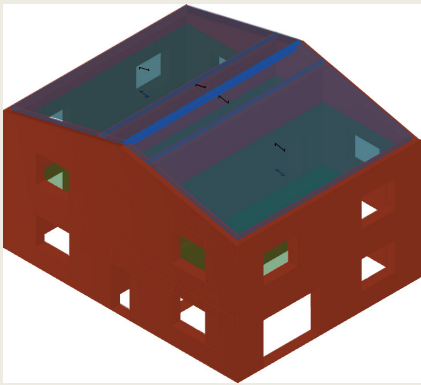
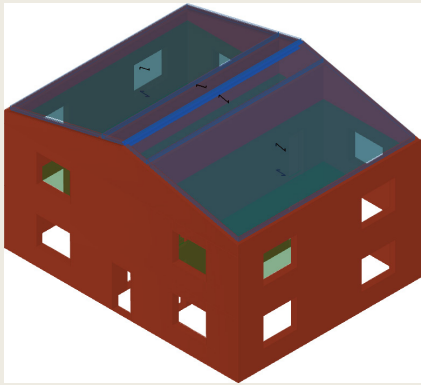
- Bending stresses
- Plastic hinge rotations
- Shear stresses
- Shear deformations
- Chord rotations
- Story drift
- Node collapse mechanism (only RC)



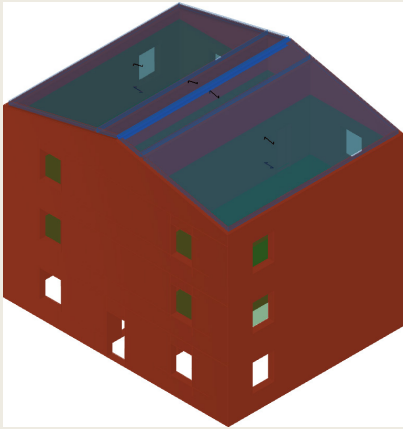
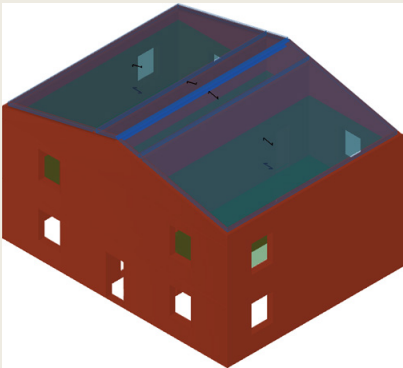
WP3: MASONRY BENCHMARK CASE ANALYSIS



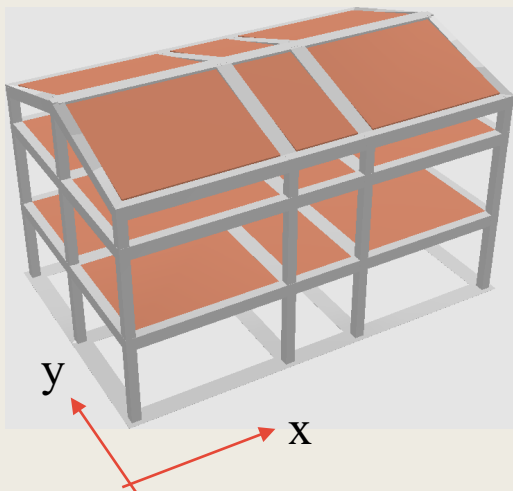
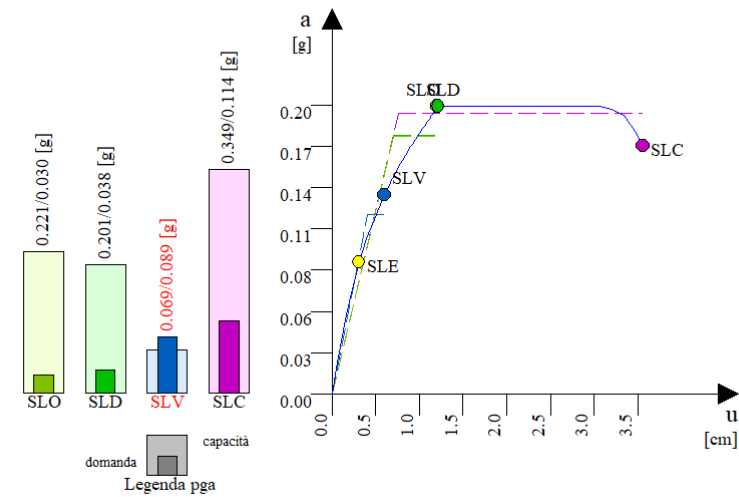
Variation of the shear strength area



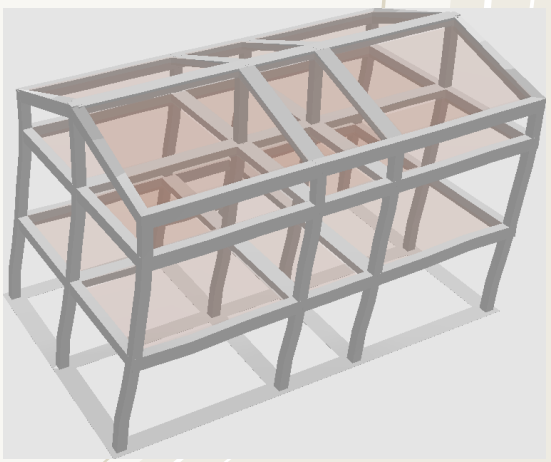
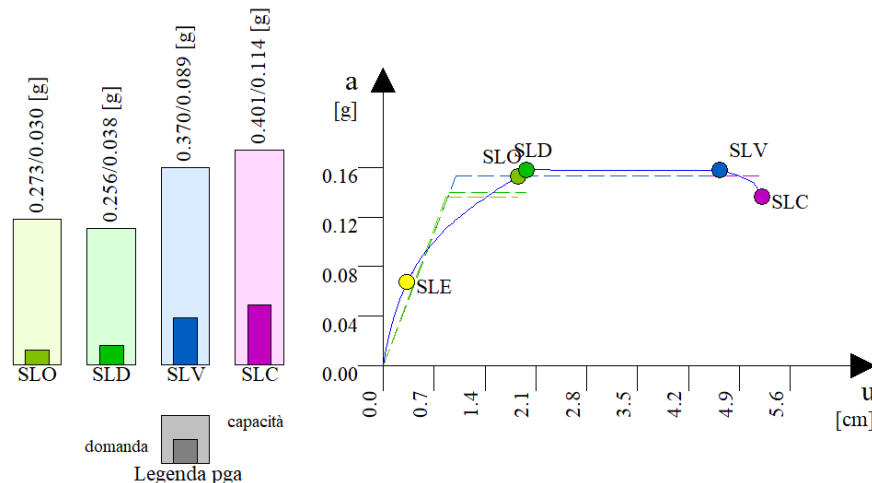
Variation of the number of storey



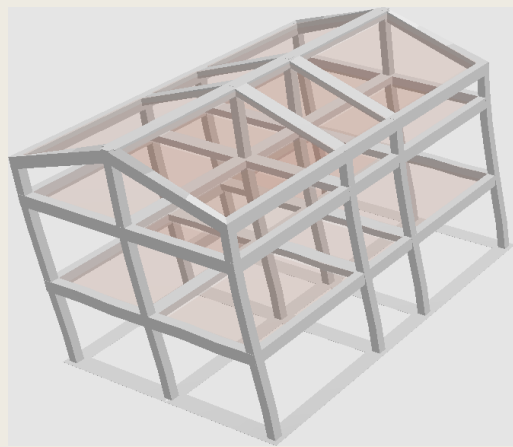
Curva analisi pushover in dir.0° d. costante ecc.0 [cm]



Curva analisi pushover in dir.90° d. costante ecc.0 [cm]



ag/g SLO (D1)	ag/g SLD (D2)	ag/g SLV (D3)	ag/g SLC (D4)
[g]	[g]	[g]	[g]
0,221	0,201	0,069	0,349
0,219	0,198	0,086	0,301
0,222	0,205	0,109	0,402
0,218	0,202	0,258	0,337



WP3: STRUCTURAL PARAMETERS DATASET FOR PREDEFINED LEVELS OF DAMAGE

Analysis	m*	T*	ay*	d*max (D1)	d*max (D2)	d*max (D3)	d*max (D4)
Unit	[ton]	[s]	[1/g]	[m]	[m]	[m]	[m]
Modello 1-Analysis 1	232,03	0,38	0,31	0,015	0,015	0,015	0,035
Modello 1-Analysis 2	224,49	0,38	0,31	0,015	0,015	0,014	0,041
Modello 1-Analysis 3	216,95	0,38	0,29	0,015	0,015	0,014	0,044
Modello 1-Analysis 4	209,42	0,38	0,27	0,013	0,013	0,031	0,047
Modello 1-Analysis 5	244,87	0,40	0,30	0,016	0,016	0,016	0,029
Modello 1-Analysis 6	236,87	0,39	0,31	0,015	0,016	0,015	0,037
Modello 1-Analysis 7	228,87	0,39	0,30	0,015	0,015	0,015	0,039
Modello 1-Analysis 8	220,87	0,38	0,29	0,015	0,015	0,015	0,046
Modello 1-Analysis 9	257,71	0,40	0,30	0,016	0,016	0,015	0,018
Modello 1-Analysis 10	249,25	0,40	0,32	0,016	0,016	0,016	0,033
Modello 1-Analysis 11	240,79	0,39	0,29	0,016	0,016	0,016	0,034
Modello 1-Analysis 12	232,34	0,39	0,30	0,015	0,015	0,016	0,040
Modello 1-Analysis 13	270,55	0,41	0,27	0,016	0,016	0,010	0,026
Modello 1-Analysis 14	261,64	0,41	0,17	0,018	0,016	0,015	0,019
Modello 1-Analysis 15	252,72	0,40	0,30	0,017	0,017	0,016	0,029
Modello 1-Analysis 16	243,80	0,39	0,30	0,015	0,015	0,015	0,036
Modello 1-Analysis 17	233,13	0,44	0,32	0,019	0,020	0,019	0,043
Modello 1-Analysis 18	225,59	0,43	0,30	0,018	0,019	0,020	0,043
Modello 1-Analysis 19	218,06	0,44	0,28	0,018	0,019	0,034	0,049
Modello 1-Analysis 20	210,52	0,43	0,28	0,017	0,017	0,035	0,050
Modello 1-Analysis 21	245,97	0,43	0,32	0,021	0,021	0,011	0,040
Modello 1-Analysis 22	237,97	0,44	0,31	0,018	0,019	0,018	0,043
Modello 1-Analysis 23	229,98	0,44	0,30	0,018	0,019	0,022	0,044
Modello 1-Analysis 24	221,98	0,40	0,28	0,018	0,019	0,035	0,051
Modello 1-Analysis 25	258,81	0,43	0,30	0,020	0,021	0,010	0,025
Modello 1-Analysis 26	250,35	0,44	0,30	0,019	0,020	0,016	0,026
Modello 1-Analysis 27	241,90	0,44	0,31	0,018	0,018	0,018	0,038
Modello 1-Analysis 28	233,44	0,44	0,30	0,019	0,019	0,031	0,025
Modello 1-Analysis 29	271,66	0,44	0,34	0,019	0,019	0,010	0,041
Modello 1-Analysis 30	262,74	0,43	0,30	0,019	0,021	0,011	0,027
Modello 1-Analysis 31	253,82	0,44	0,29	0,018	0,018	0,015	0,023
Modello 1-Analysis 32	244,91	0,45	0,29	0,018	0,019	0,020	0,040
Modello 1-Analysis 33	232,24	0,46	0,31	0,021	0,022	0,012	0,049
Modello 1-Analysis 34	226,70	0,48	0,30	0,021	0,022	0,026	0,054
Modello 1-Analysis 35	219,16	0,49	0,29	0,022	0,023	0,034	0,049



MeDEA
*Multidimensional seismic risk assessment
through explainable artificial intelligence*

Thanks for your attention

MULTIDIMENSIONAL SEISMIC RISK ASSESSMENT COMBINING STRUCTURAL DAMAGES AND
PSYCHOLOGICAL CONSEQUENCES USING EXPLAINABLE ARTIFICIAL INTELLIGENCE