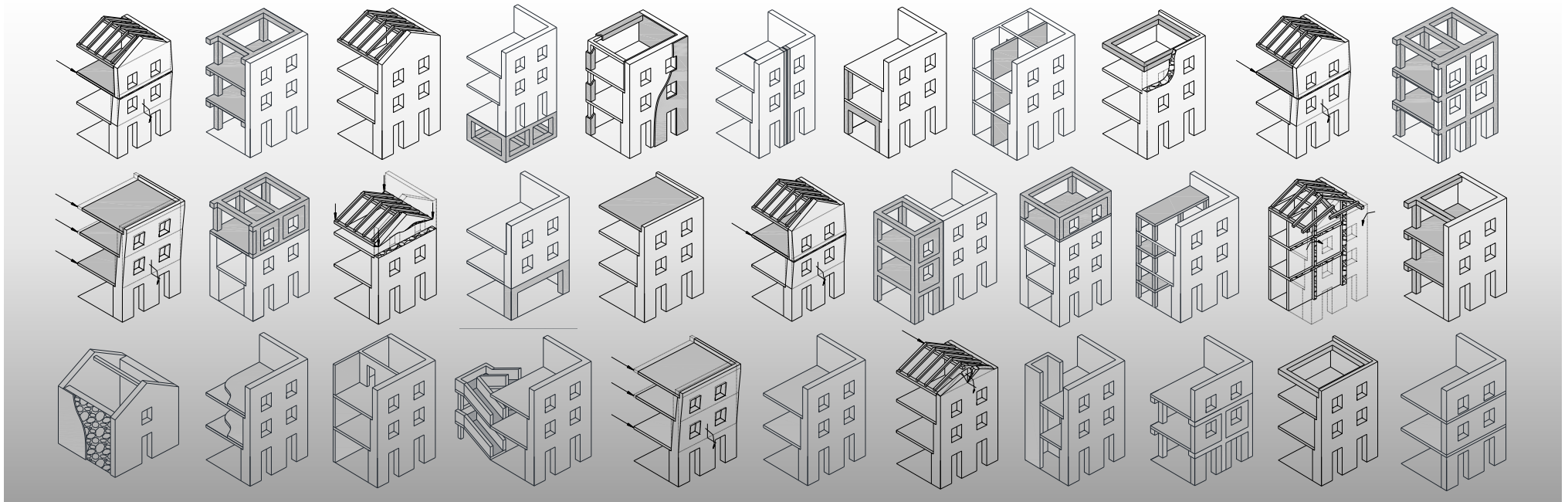


MITIGATING EARTHQUAKE VULNERABILITY OF MIXED URM-RC BUILDINGS AT THE URBAN SCALE

Numerical analysis of representative intervened URM-RC buildings

Gonçalo Correia Lopes (2nd year, U. Aveiro)

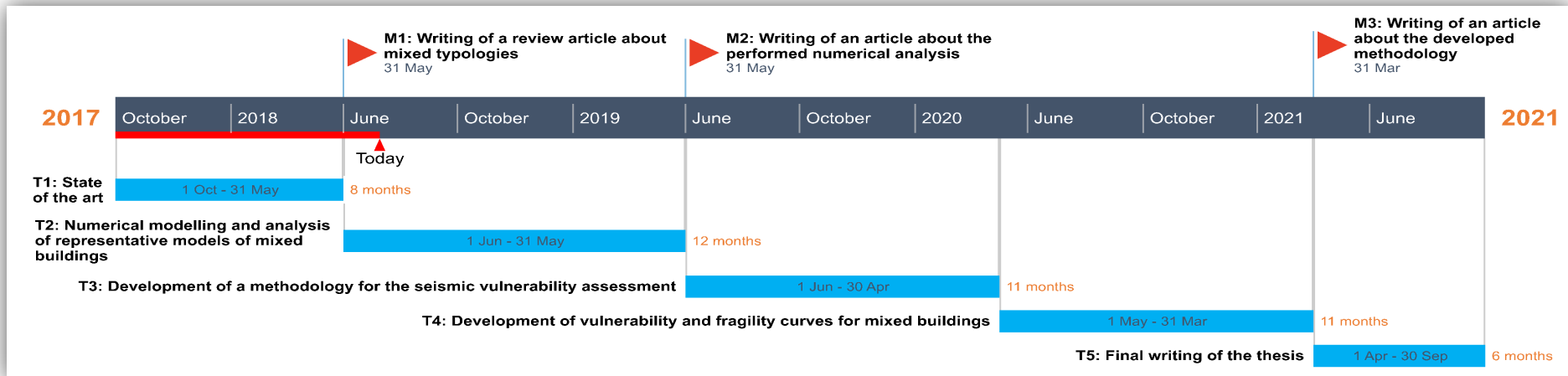
Supervision: Romeu Vicente (U. Aveiro), Miguel Azenha (U. Minho), Tiago Miguel Ferreira (U. Minho)



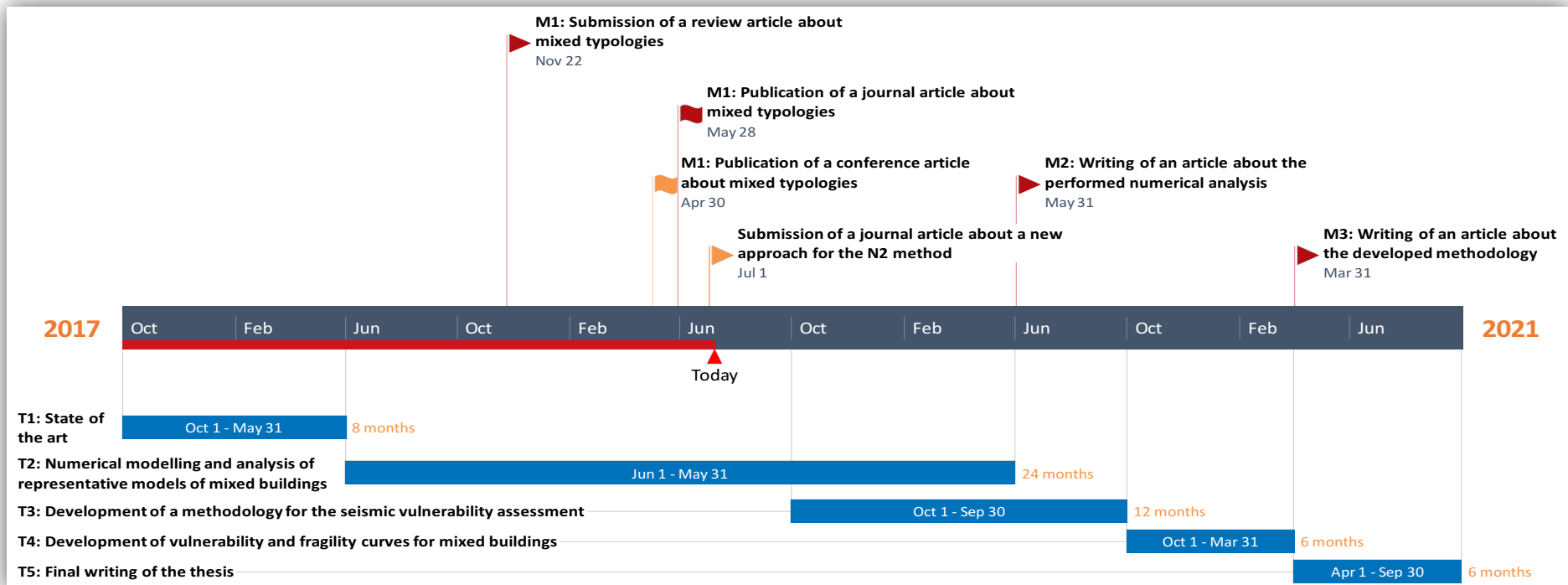
Presentation summary

- Thesis timeline and publications
- Part 1 – A BIM-based methodology for the seismic performance assessment of existing mixed URM-RC building typologies: a case study
- Part 2 – Ongoing tasks and upcoming tasks

Thesis timeline



Updated timeline



Thesis timeline and publications



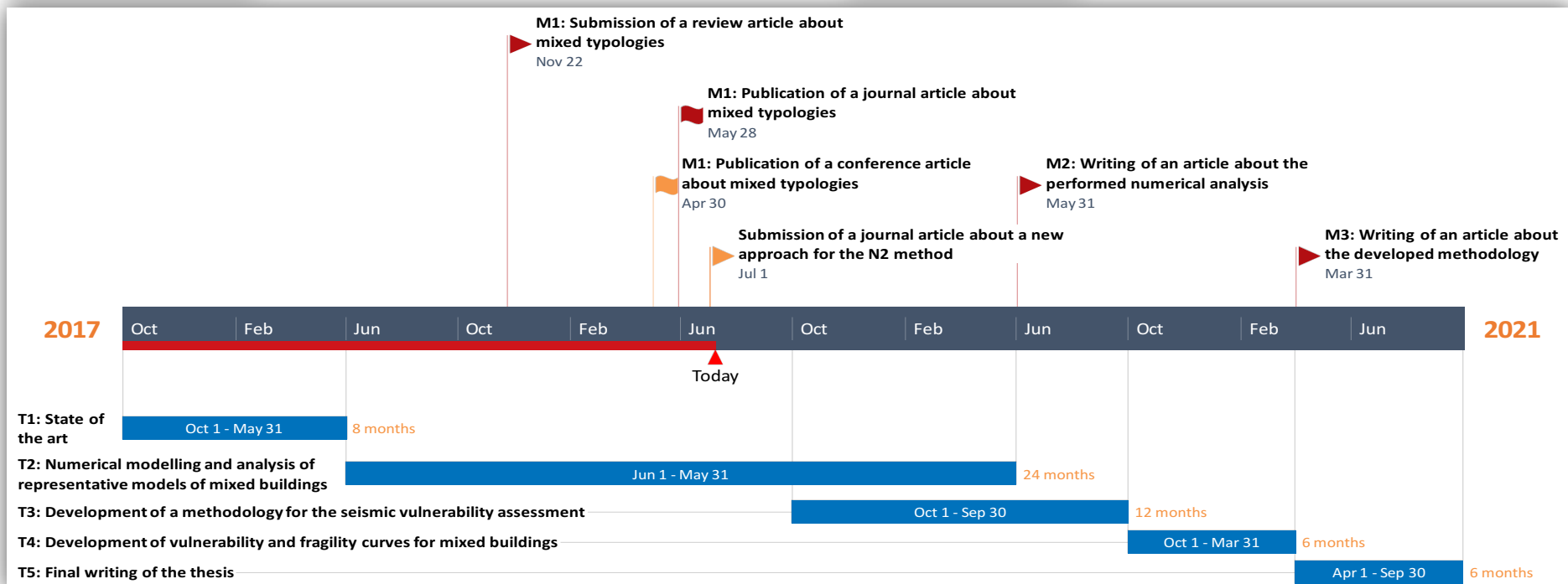
Presentation of a communication in a conference:

Lopes, G. C., Vicente, R., Ferreira, T. M., & Azenha, M. (2019). **Desafios e direções de investigação na identificação e caracterização de tipologias de edifícios de alvenaria intervencionados com recurso a betão armado**. *Sísmica 2019- 11º Congresso Nacional de Sismologia e Engenharia Sísmica*, Instituto Superior Técnico, Lisboa, Portugal.



Publication of a journal paper:

Lopes, G. C., Vicente, R., Ferreira, T. M., & Azenha, M. (2019). **Intervened URM buildings with RC elements: typological characterisation and associated challenges**. *Bulletin of Earthquake Engineering*, 1-33.

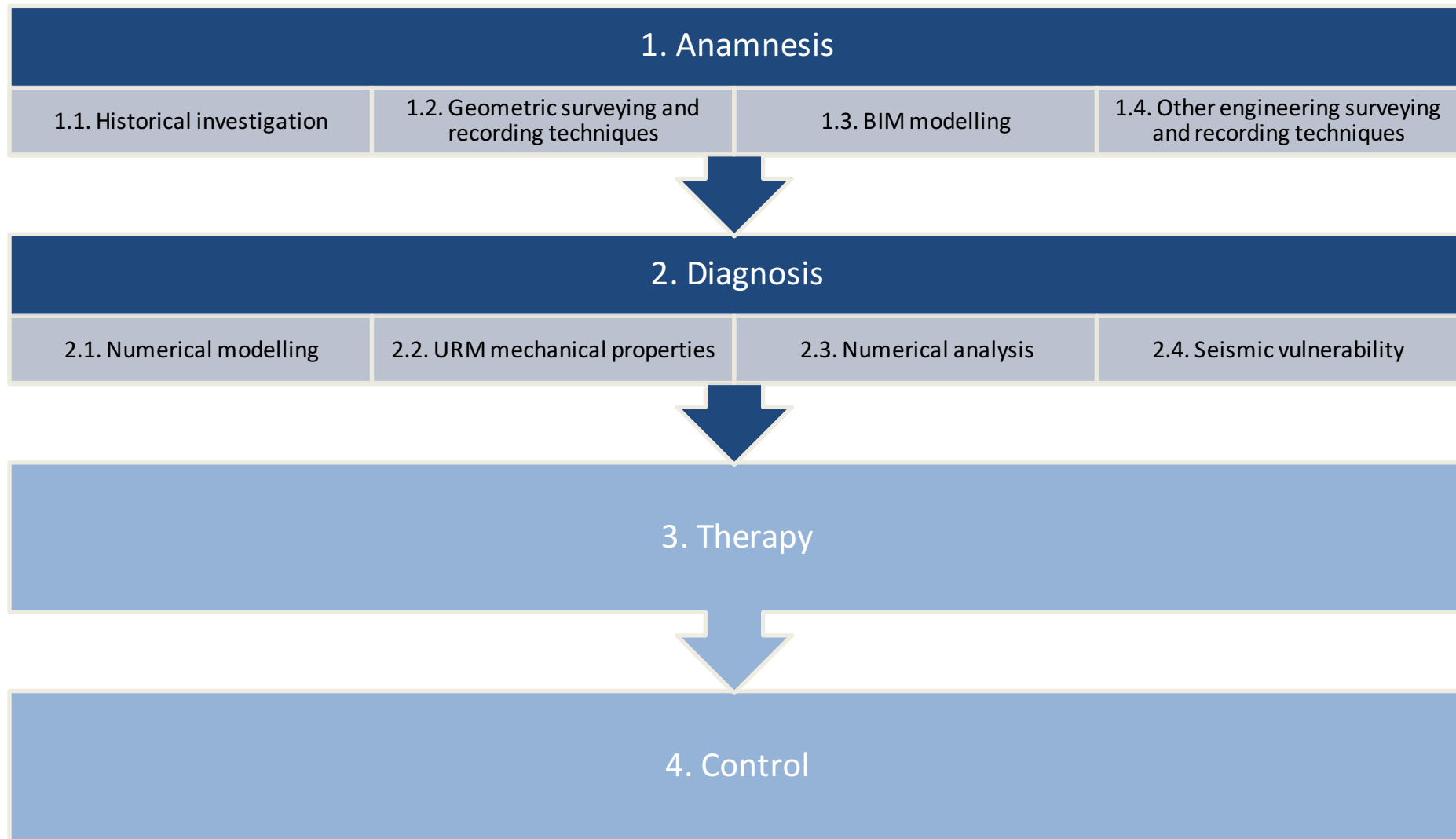


Part 1

A BIM-based methodology for the seismic performance assessment of existing mixed URM-RC building typologies

- Anamnesis
 - historical investigation
 - laser scanning
 - BIM modelling
- Diagnosis
 - numerical modelling
 - modal analysis
 - numerical analysis
 - seismic vulnerability assessment

BIM-based methodology



BIM-based methodology

1.1. Historical investigation



BIM-based methodology

1.2. Geometric surveying with 3D laser scanning



BIM-based methodology

1.2. Geometric surveying with 3D laser scanning



BIM-based methodology

1.3. BIM modelling



BIM-based methodology

1.3. BIM modelling



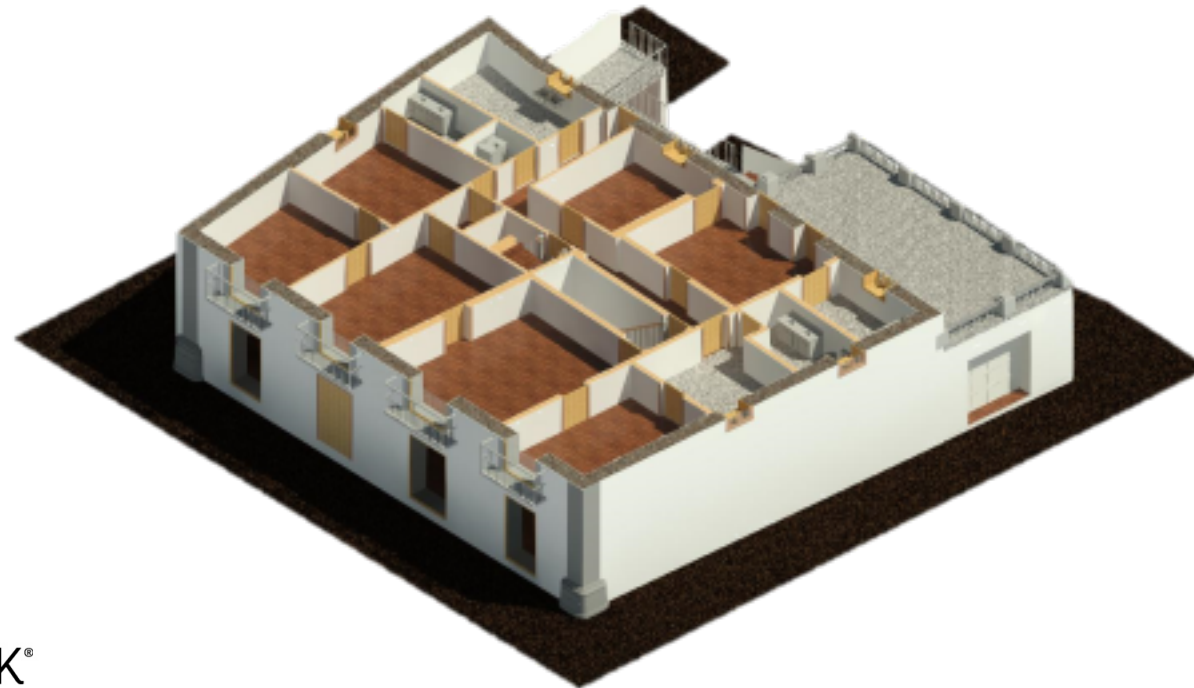
BIM-based methodology

1.3. BIM modelling



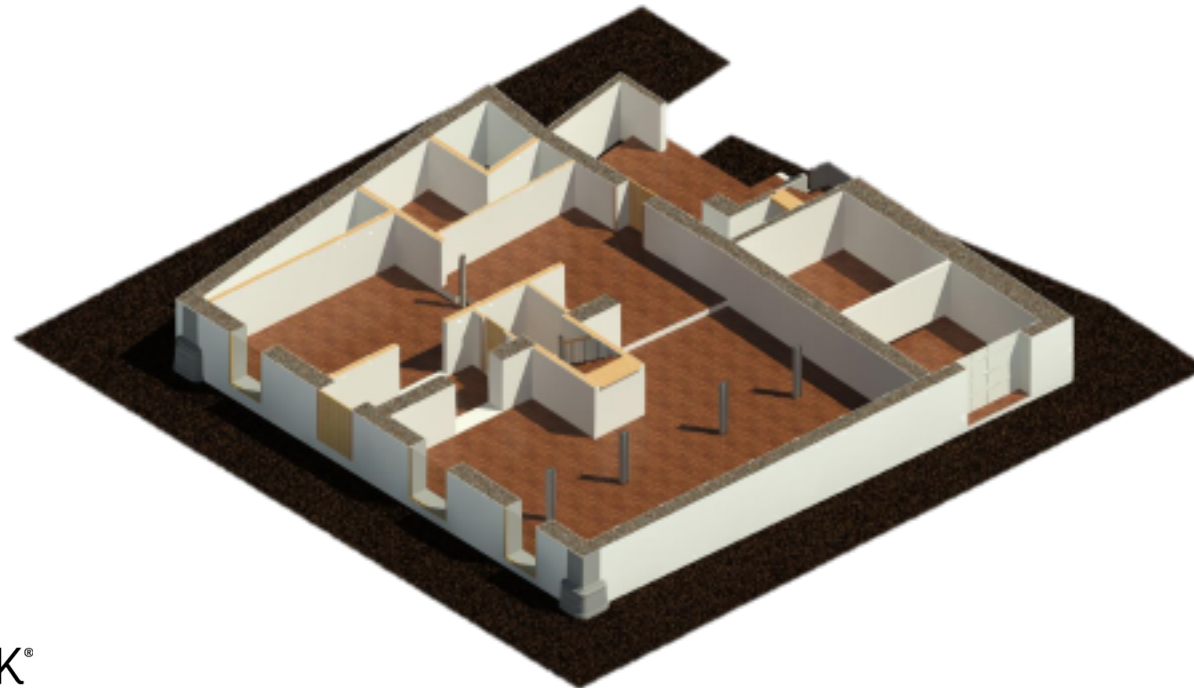
BIM-based methodology

1.3. BIM modelling



BIM-based methodology

1.3. BIM modelling



BIM-based methodology

1.3. BIM modelling



BIM-based methodology

1.3. BIM modelling



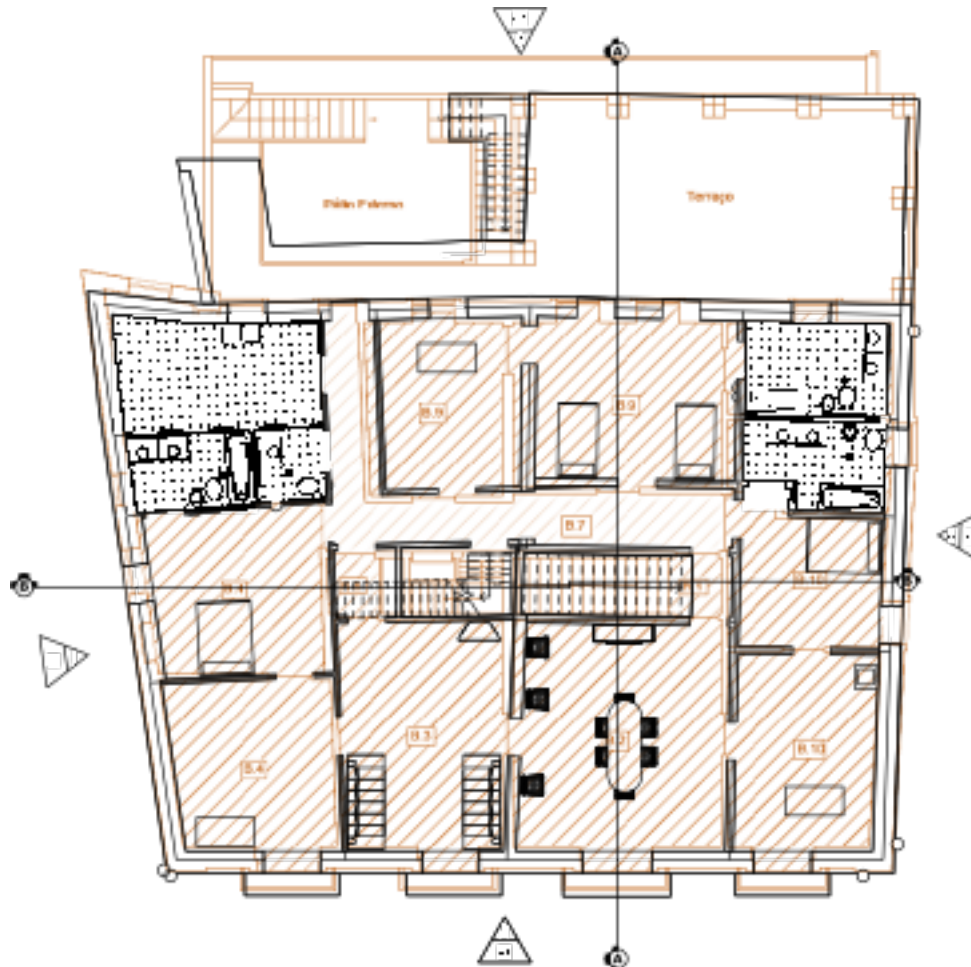
BIM-based methodology

1.3. BIM modelling



BIM-based methodology

1.3. BIM modelling



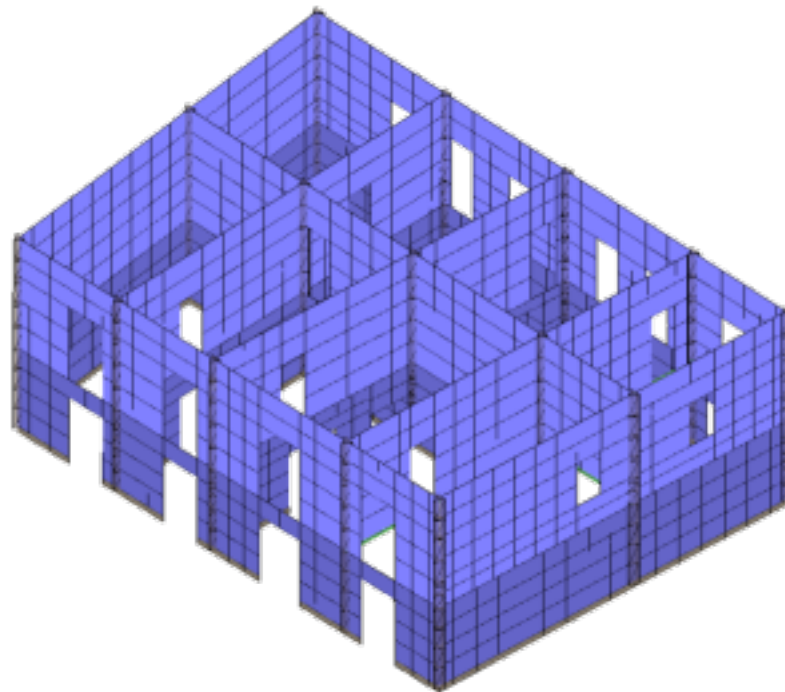
BIM-based methodology

2.1. Numerical modelling



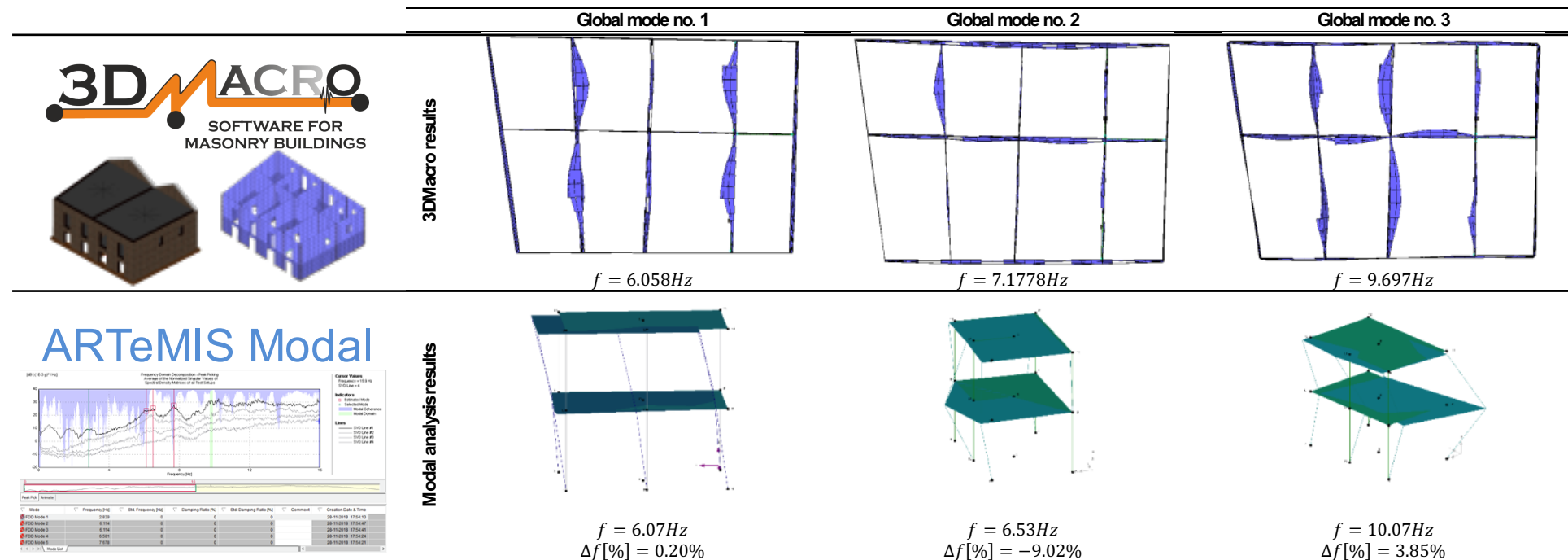
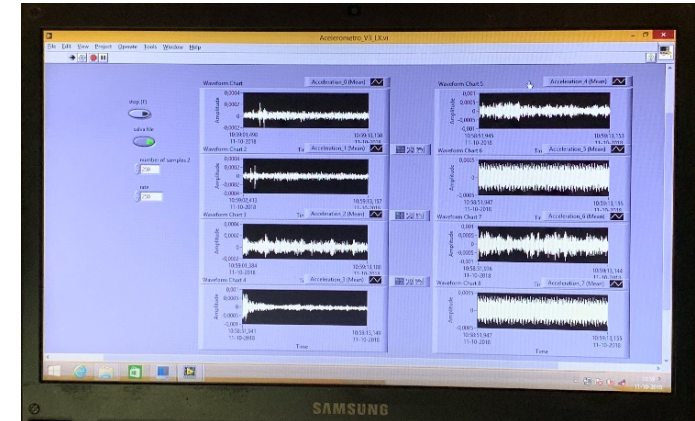
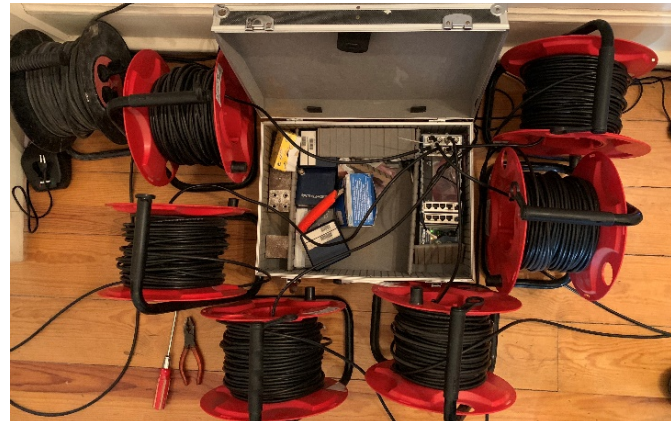
BIM-based methodology

2.1. Numerical modelling



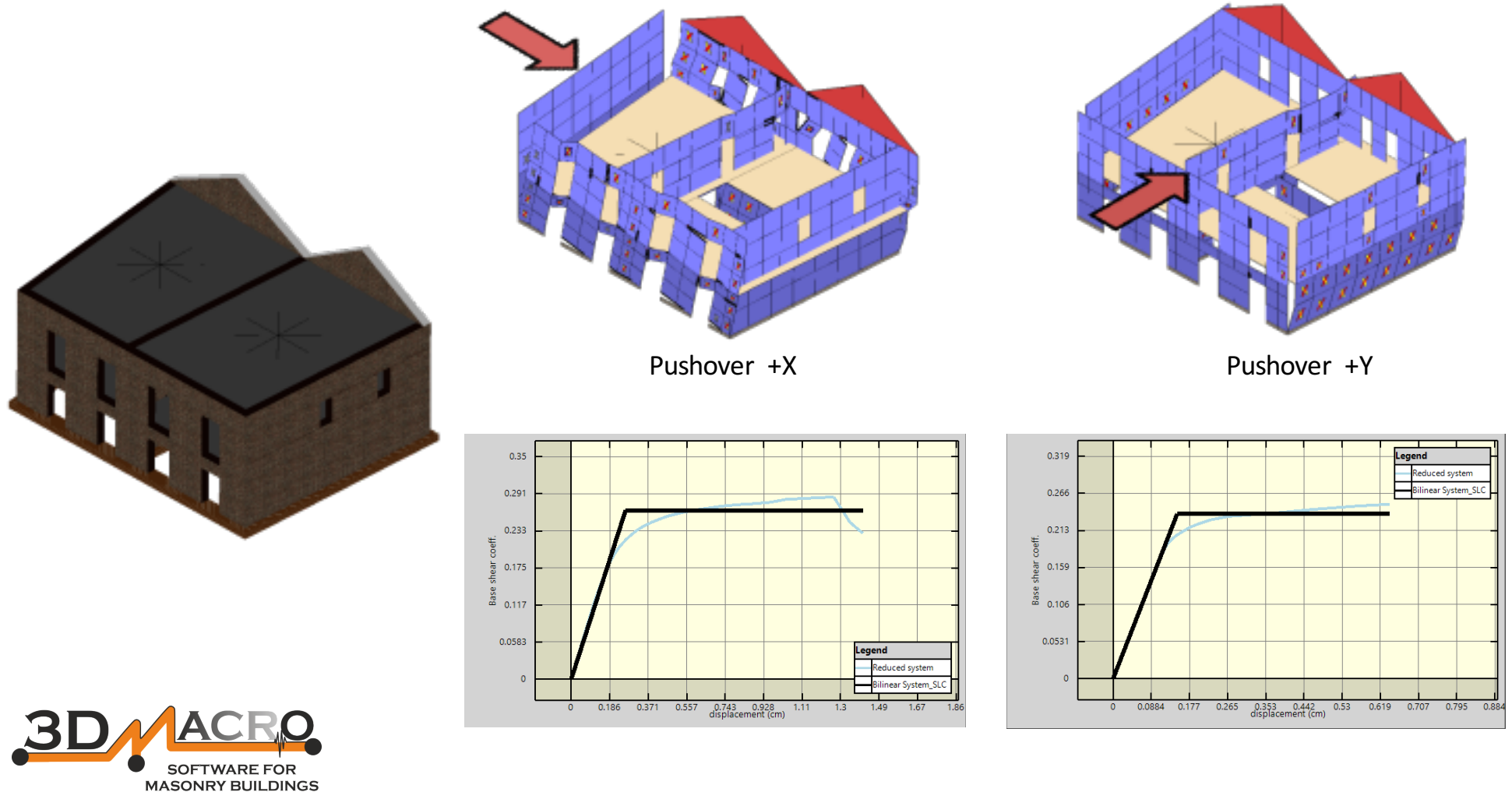
BIM-based methodology

2.2. Modal analysis: calibration of URM mechanical properties



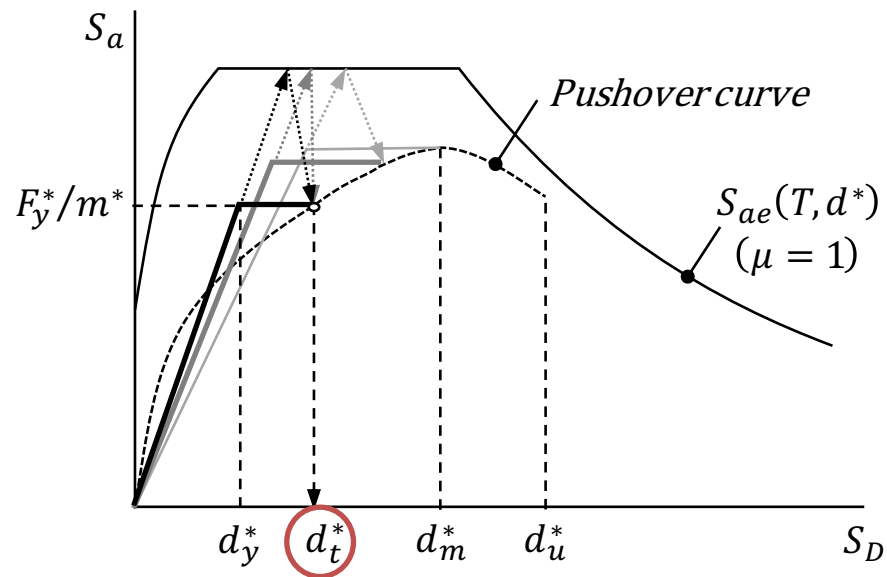
BIM-based methodology

2.3. Numerical analysis: non-linear static (pushover) analysis



The N2 method revisited

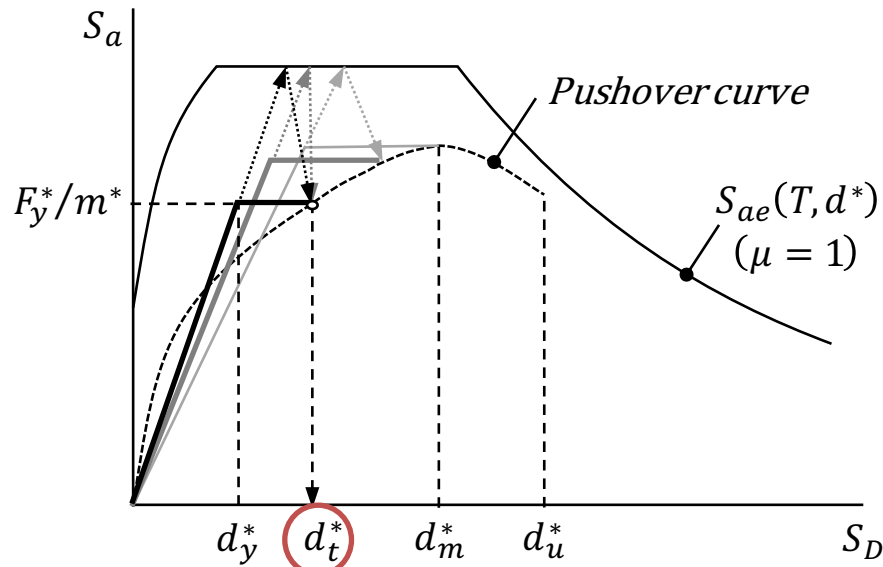
Proposal of a new displacement-based method to determine the target displacement (and for the seismic performance evaluation and vulnerability assessment of buildings)



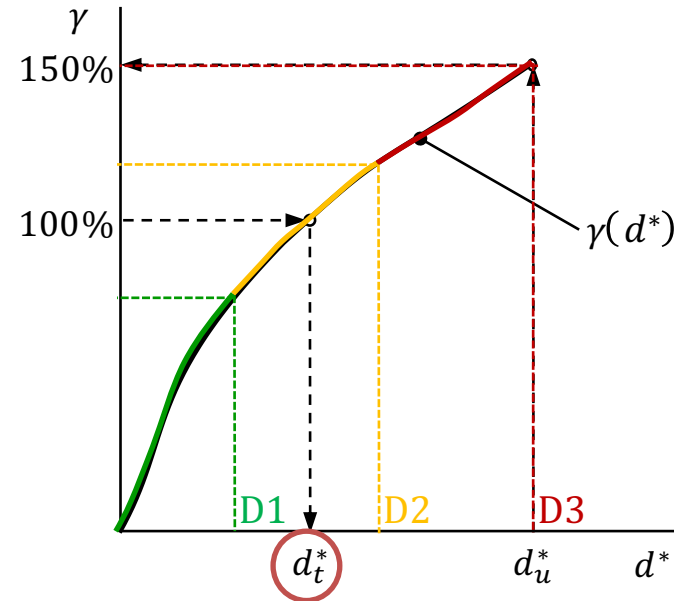
(a) EC8 iterative procedure

The N2 method revisited

Proposal of a new displacement-based method to determine the target displacement (and for the seismic performance evaluation and vulnerability assessment of buildings)



(a) EC8 iterative procedure



(b) Proposed method

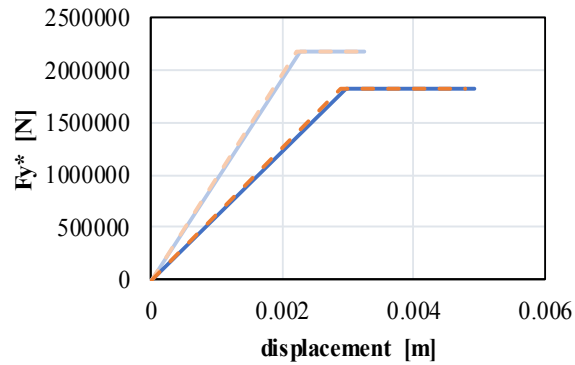
Scale factor for the initial seismic demand, γ

$$T^*(d^*) < T_c \quad \gamma(d^*) = \frac{S_a(d^*) \cdot T^*(d^*) \cdot T_c - S_a(d^*) \cdot (T^*(d^*))^2 + d^* \cdot 4\pi^2}{S_{ae}(d^*) \cdot T^*(d^*) \cdot T_c}$$

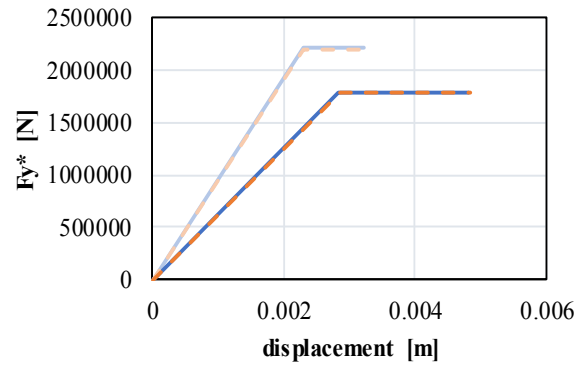
$$T^*(d^*) \geq T_c \quad \gamma(d^*) = \frac{d^* \cdot 4\pi^2}{S_{ae}(d^*) \cdot (T^*(d^*))^2}$$

BIM-based methodology

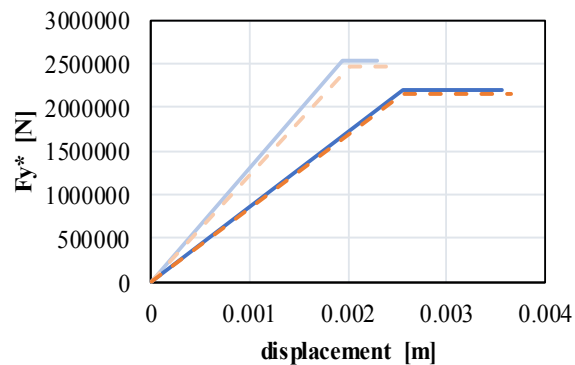
2.4. Seismic vulnerability



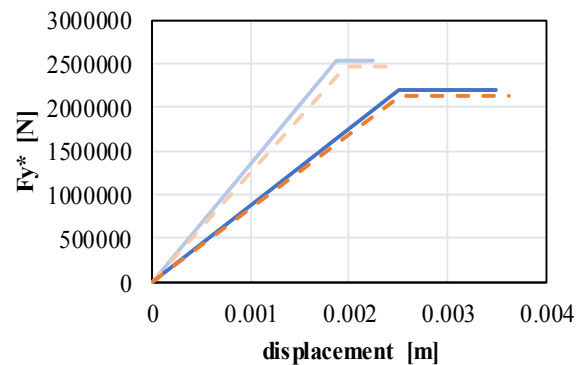
- 1 With RC Pushover+X Massa
- 5 With RC Pushover+X Acc
- - 9 Without RC Pushover+X Massa
- - 13 Without RC Pushover+X Acc



- 2 With RC Pushover-X Massa
- 6 With RC Pushover-X Acc
- - 10 Without RC Pushover-X Massa
- - 14 Without RC Pushover-X Acc



- 3 With RC Pushover+Y Massa
- 7 With RC Pushover+Y Acc
- - 11 Without RC Pushover+Y Massa
- - 15 Without RC Pushover+Y Acc

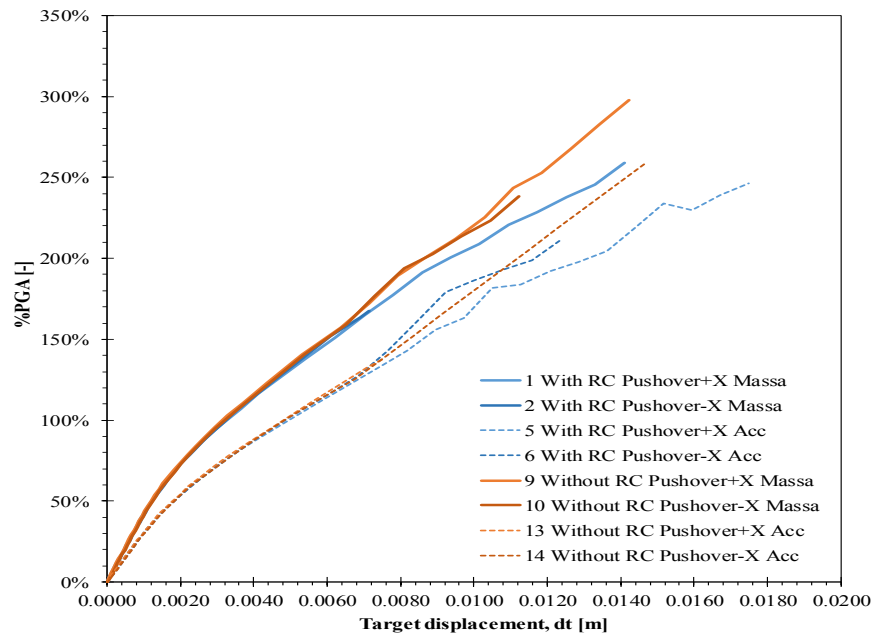
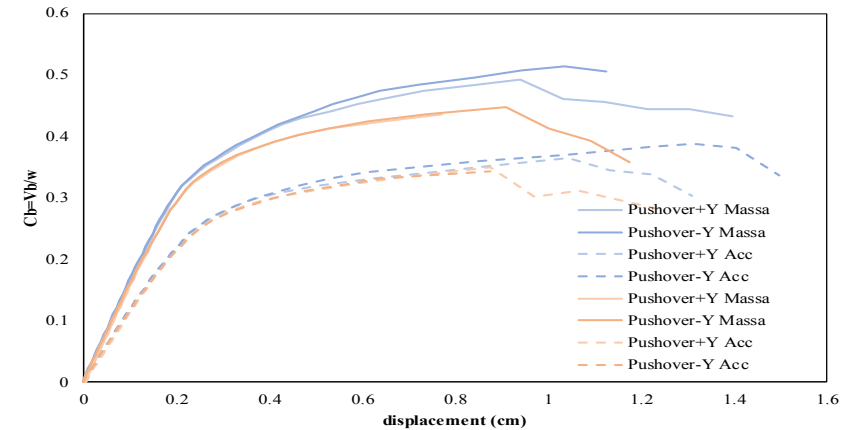
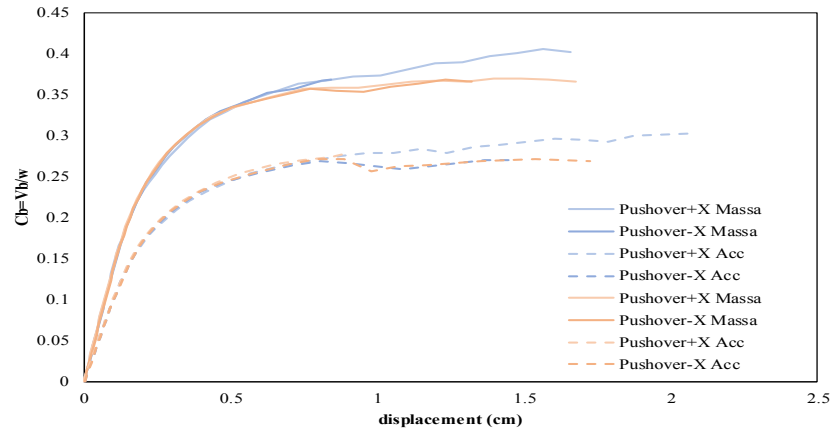


- 4 With RC Pushover-Y Massa
- 8 With RC Pushover-Y Acc
- - 12 Without RC Pushover-Y Massa
- - 16 Without RC Pushover-Y Acc

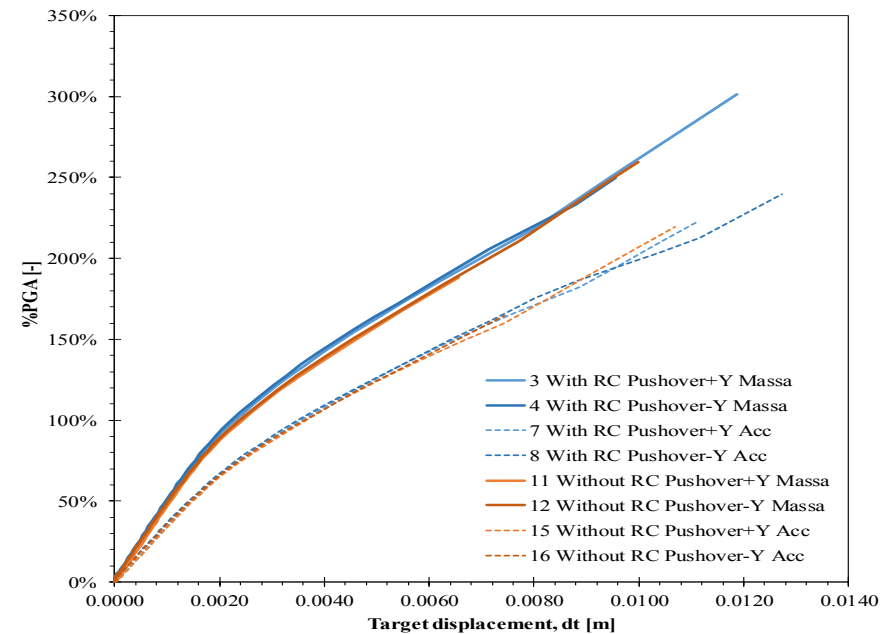
	Capacity	Stiffness	Ductility
Pushover+X Massa	0.043%	-2.457%	0.151%
Pushover+X Acc	0.051%	-3.185%	-0.160%
Pushover-X Massa	0.531%	0.607%	-0.069%
Pushover-X Acc	0.038%	0.982%	0.601%
Pushover+Y Massa	2.242%	6.041%	-2.434%
Pushover+Y Acc	2.460%	2.742%	-2.263%
Pushover-Y Massa	2.059%	6.487%	-2.125%
Pushover-Y Acc	3.046%	3.539%	-2.909%

BIM-based methodology

2.4. Seismic vulnerability



a) Force applied in +/-X direction



b) Force applied in +/-Y direction

Part 2

Ongoing tasks and upcoming tasks

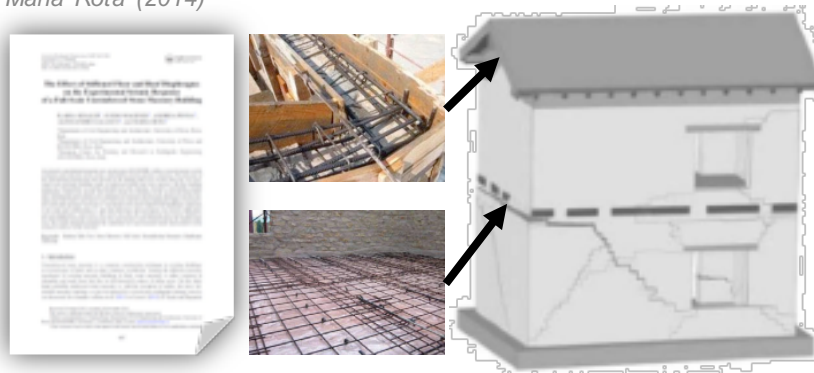
Numerical calibration and validation
Numerical analysis of representative intervened URM-RC buildings

Numerical analysis of representative intervened URM-RC buildings

Numerical calibration and validation

EUCENTRE experimental program

Ilaria Senaldi, Guido Magenes, Andrea Penna, Alessandro Galasco, Maria Rota (2014)



I. Senaldi et al.

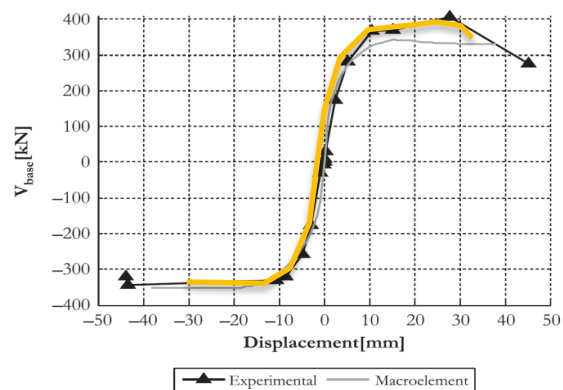
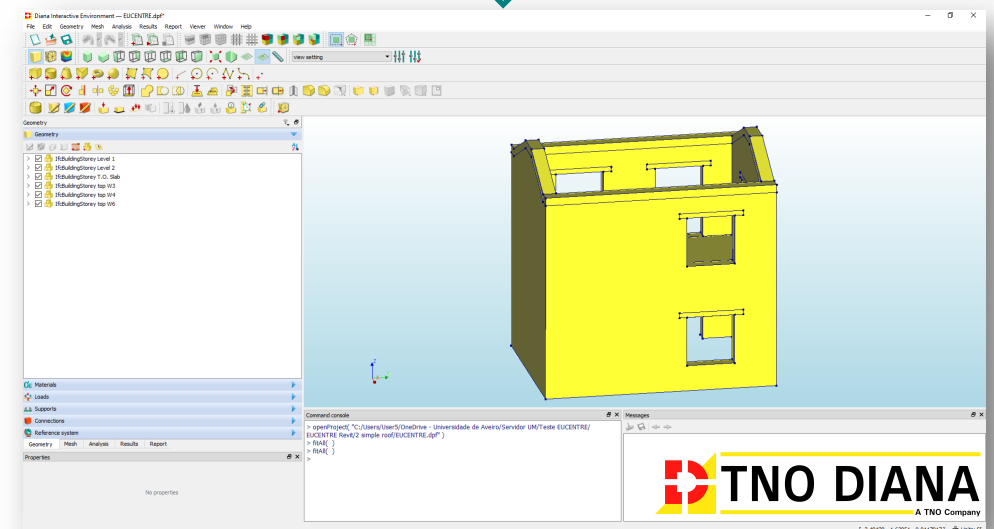
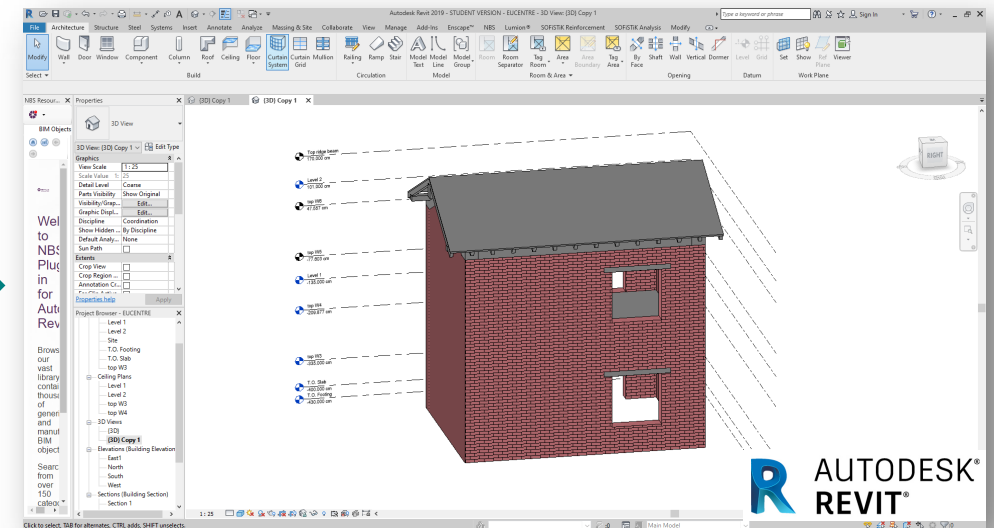
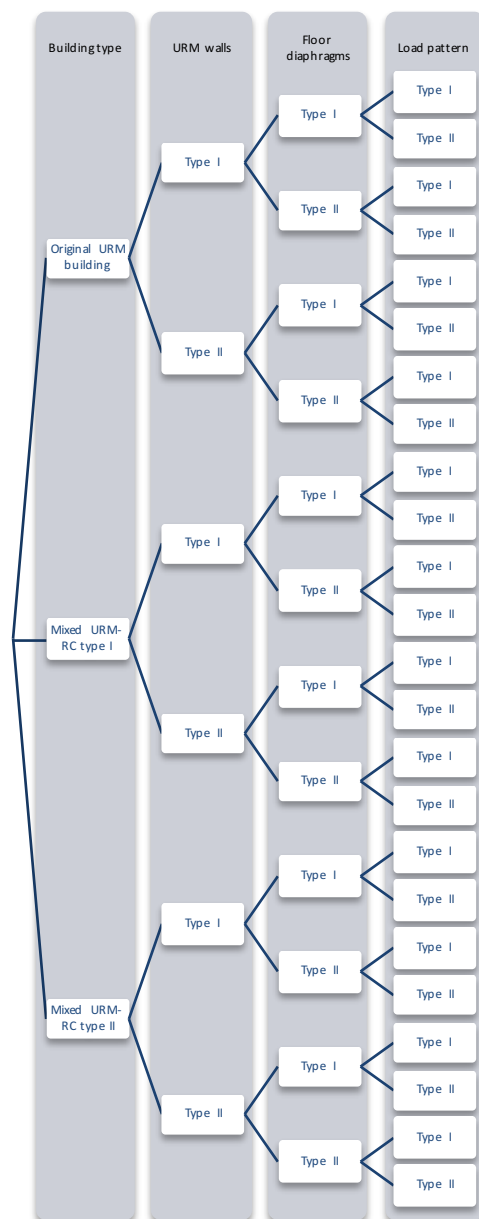


FIGURE 31 Comparison of numerical and experimental pushover curves.



Logic-tree with the definition of the possible building models



Selection of representative derived URM-RC buildings

Intervention nature/type	Selection of representative derived URM-RC buildings							
	A. Addition	Reinforced render or jacketing	Cooperating slabs (diaphragms)	New [shear] walls	Supplemental frames, beams or columns	Intermediate floors	Plan enlargement	Additional floors (raising)
	B. Insertion	Ring beams	Embedded frames	Seismic joints	Staircase	Cores	Underground structure	
C. Substitution	Roof structure	Roof slab	Floor slabs	Walls (in the original position)	Reengineered frames	Whole floor refurbishment	Built-in structure ('façadism')	

Variations (epistemic uncertainties):

- Building type (original and mixed URM-RC)
- Masonry quality
- Rigidity of floor diaphragms
- RC quality
- Load pattern

Thank you for your attention!

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email: gclopes@ua.pt

Thesis title: **Mitigating earthquake vulnerability of mixed URM-RC buildings at the urban scale**

Acknowledgements are due to the PhD grant PD/BD/135201/2017 provided by Foundation for Science and Technology (FCT), within the scope of the Doctoral Programme InfraRisk- (Analysis and Mitigation of Risks in Infrastructures) and to University of Aveiro, FCT/MEC for the financial support to the research Unit RISCO – Aveiro Research Centre of Risks and Sustainability in Construction – (FCT/UID/ECI/04450/2013)