

INVESTIGATIONS ON THE SEISMIC BEHAVIOUR OF URM BUILDINGS WITH TIMBER FLOORS: RESEARCH METHODOLOGY AND INTRODUCTORY RESULTS

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Outline

□ Introduction

- Overview
- Seismic behaviour of URM buildings
- Experimental tests
- Modelling and analysis

□ Research methodology

- Objectives, tasks and methods
- Features, boundaries and assumptions
- Timeline

□ Work in progress

Introduction

Overview

Seismic behaviour of URM buildings

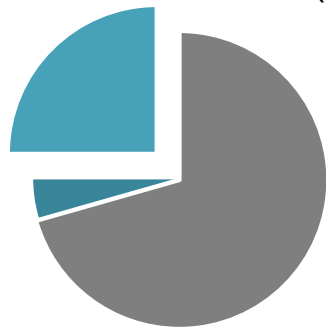
Experimental tests

Modelling and analysis

Introduction

- ❑ Significant portion of the existing built stock
- ❑ Vulnerable building typology

Fatalities attributed to earthquakes
(20th century)



75% – Failure of buildings

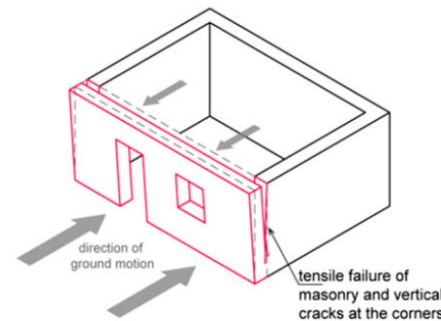
60% - Failure of URM buildings



Introduction

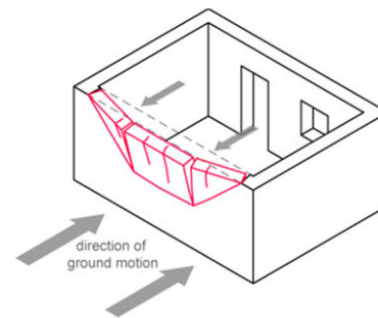
❑ Local out-of-plane mechanisms

- Overturning
- Flexure failure



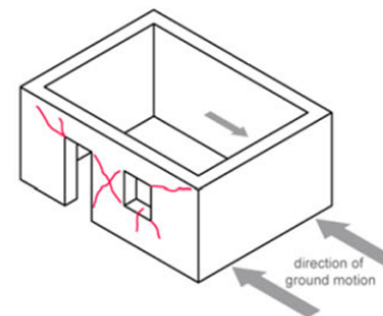
❑ Global mechanism

- Interaction between out-of-plane and in-plane walls



❑ Vulnerabilities

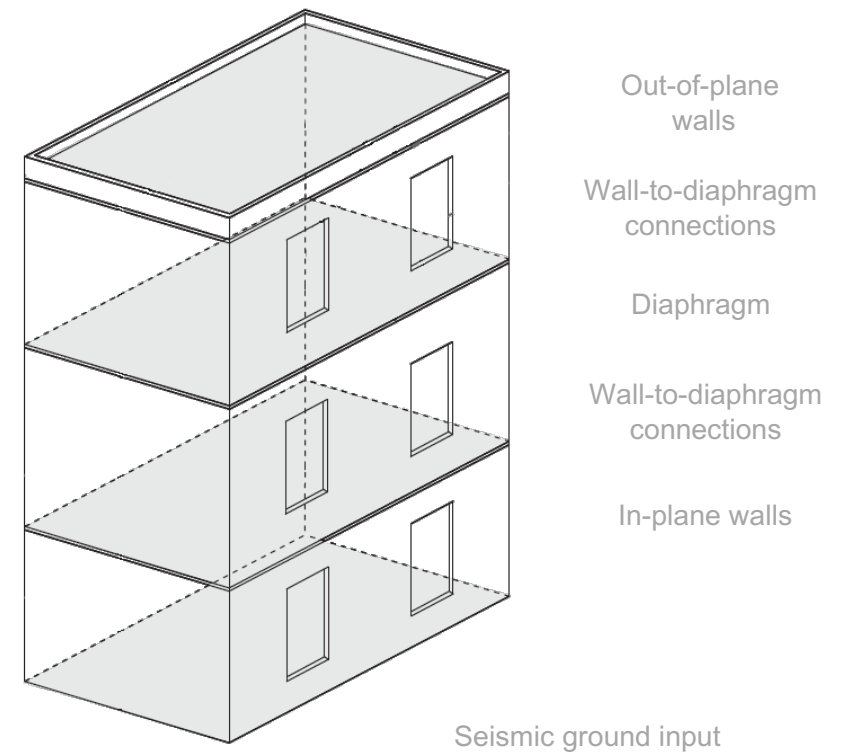
- Low material properties
- Unfavourable geometrical layout
- High mass
- Inappropriate diaphragm stiffness
- Poor connections



Ortega et al. (2018)

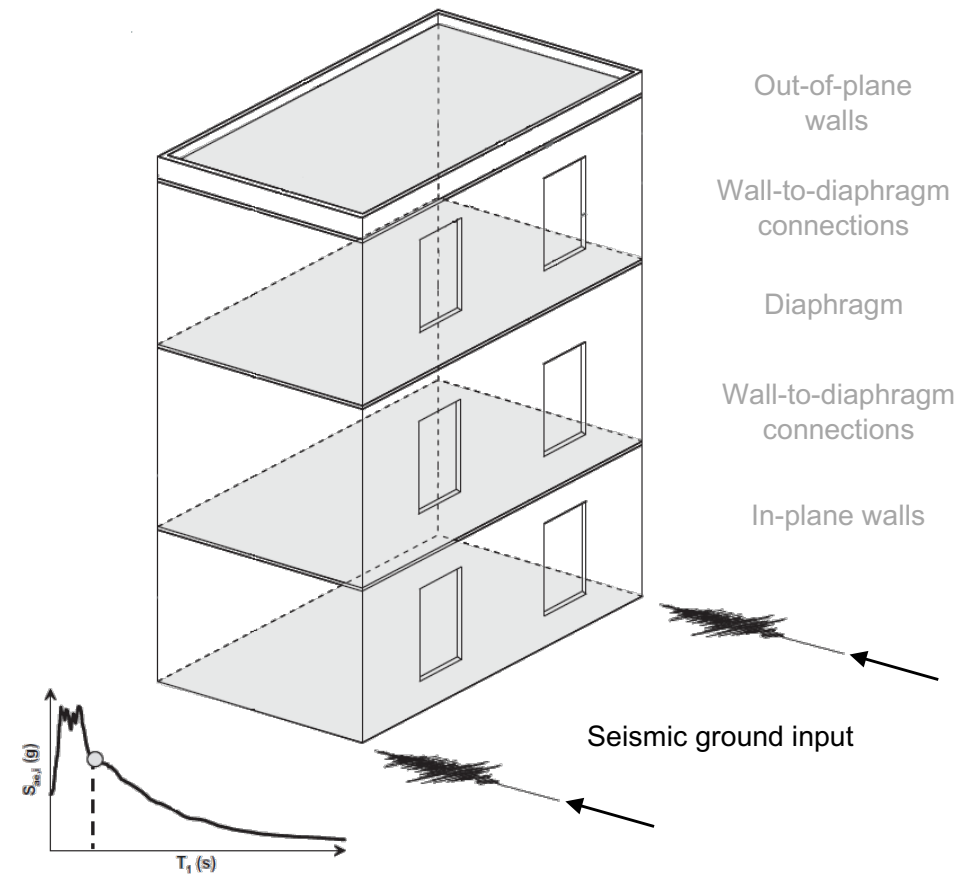
Seismic response of URM buildings

□ Dynamic response



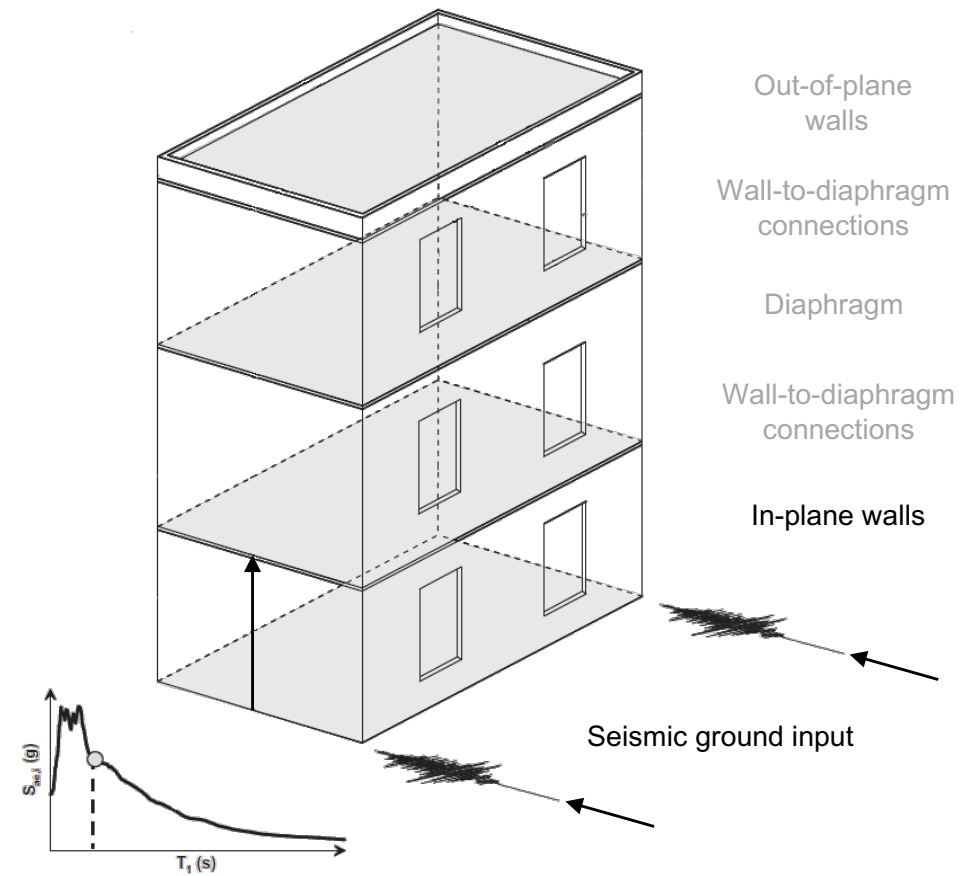
Seismic response of URM buildings

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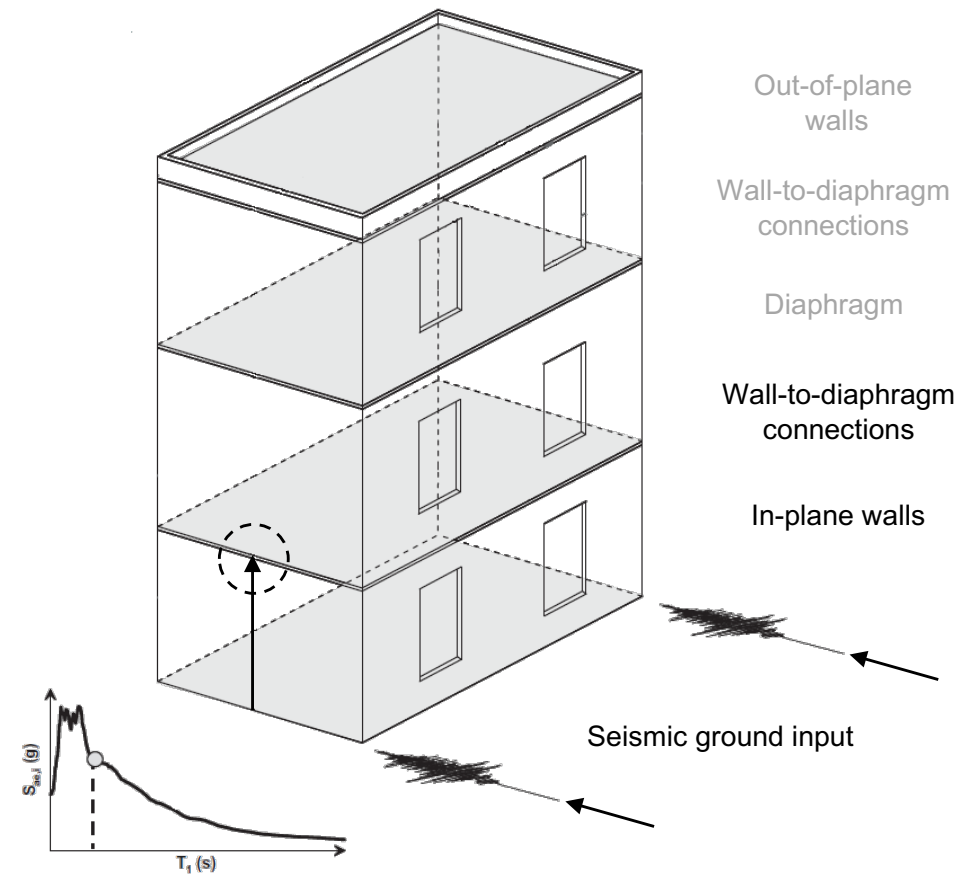
Seismic response of URM buildings

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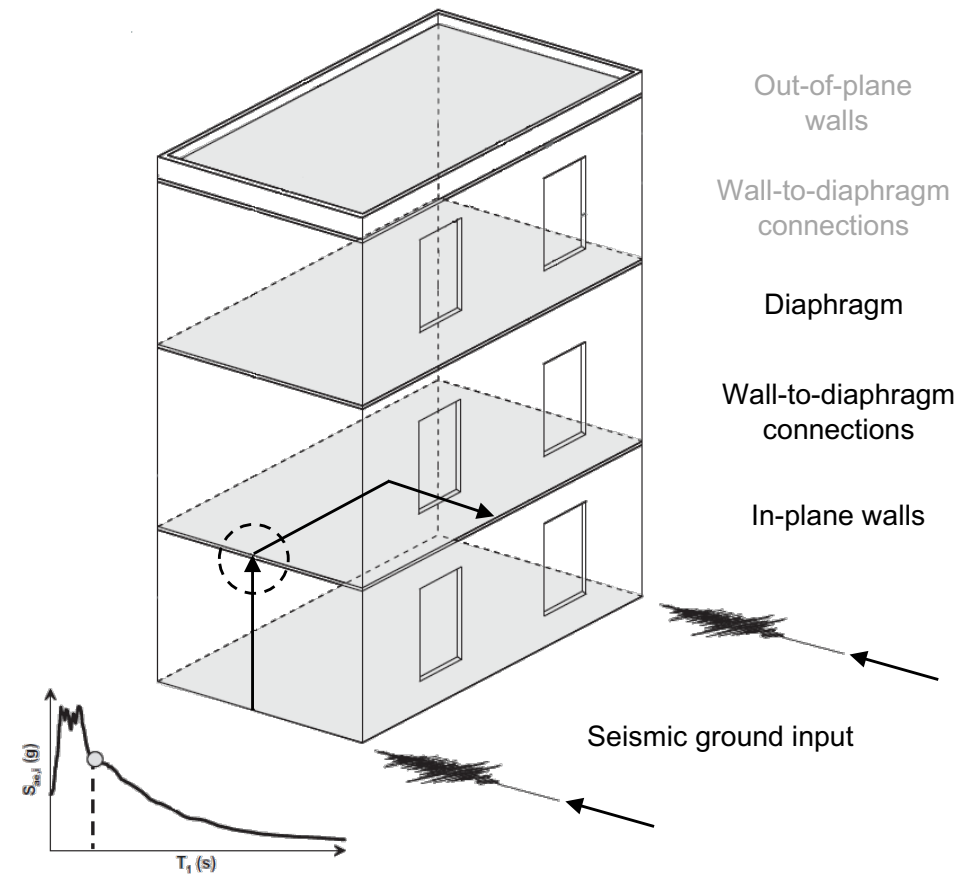
Seismic response of URM buildings

□ Dynamic response



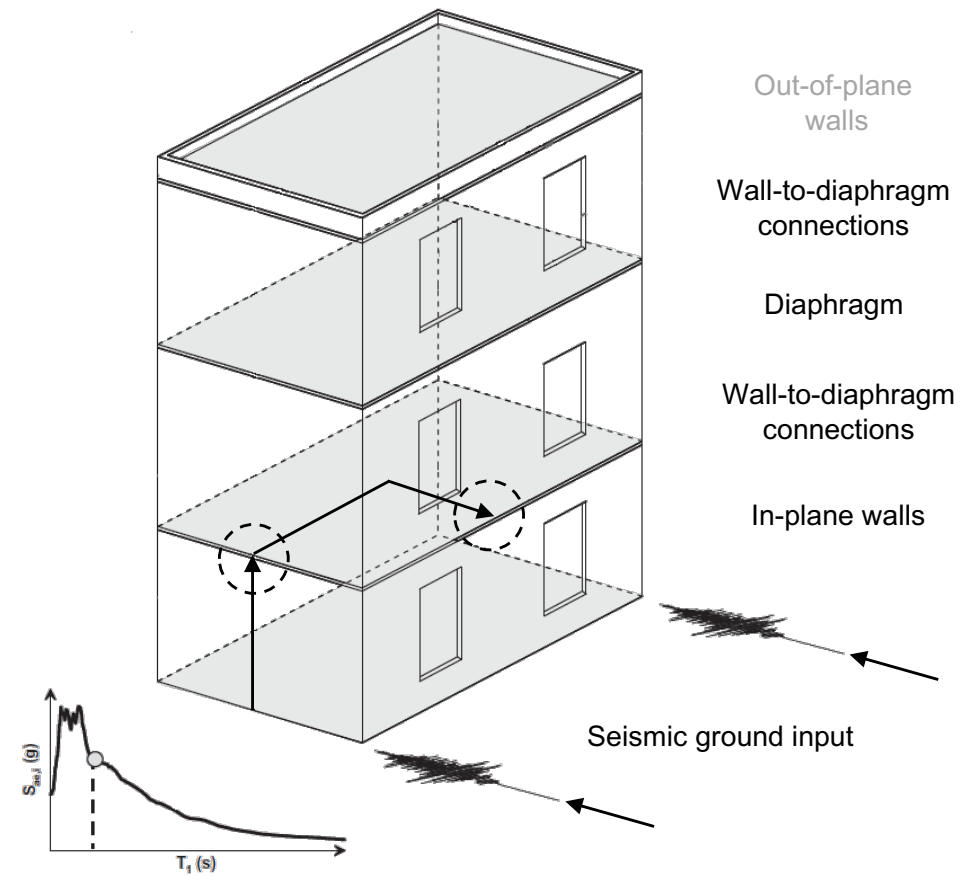
Seismic response of URM buildings

□ Dynamic response



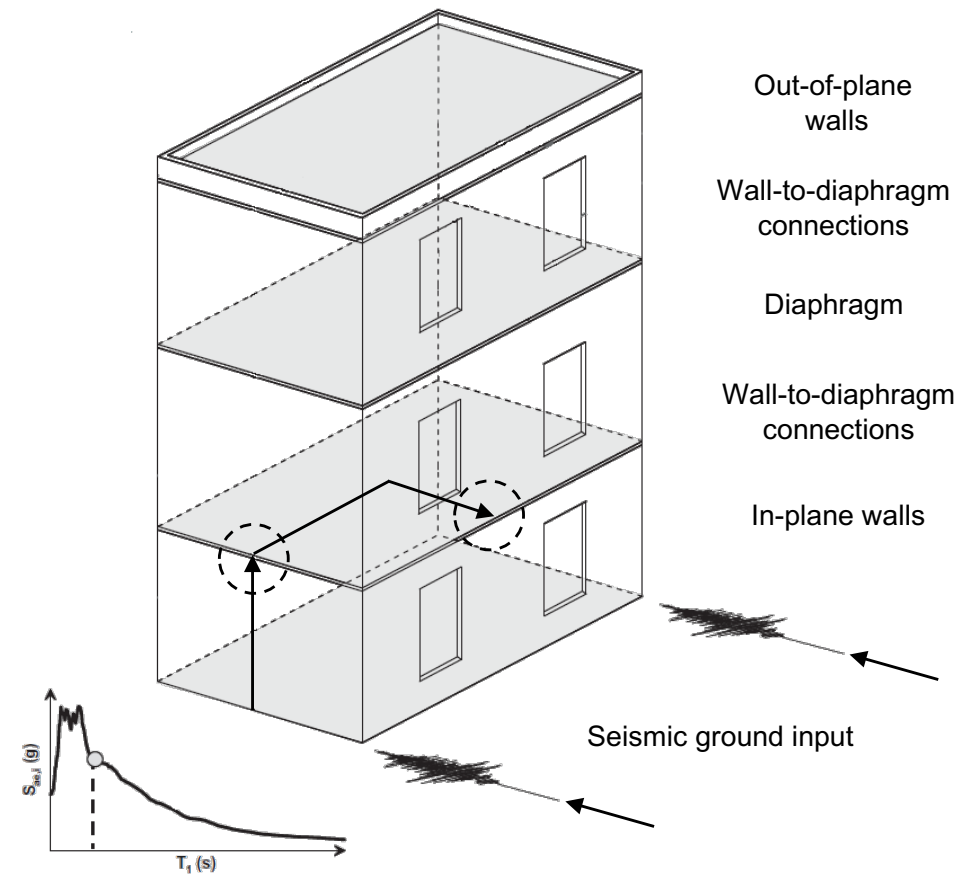
Seismic response of URM buildings

□ Dynamic response



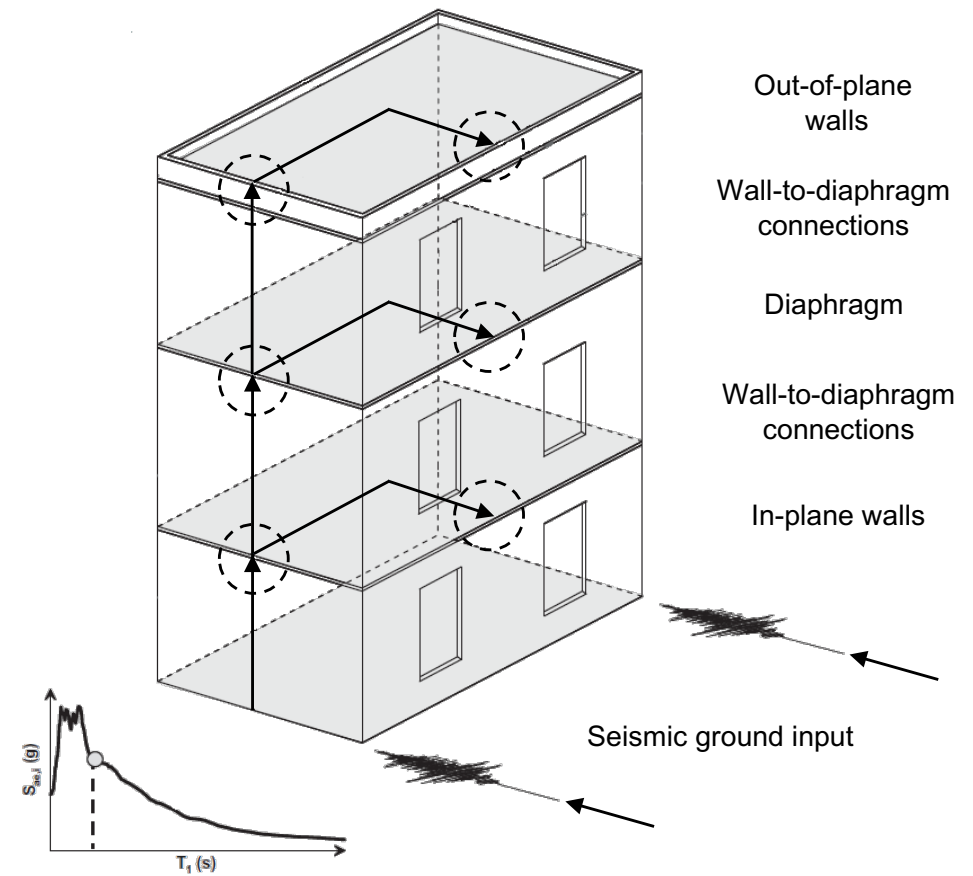
Seismic response of URM buildings

□ Dynamic response



Seismic response of URM buildings

□ Dynamic response

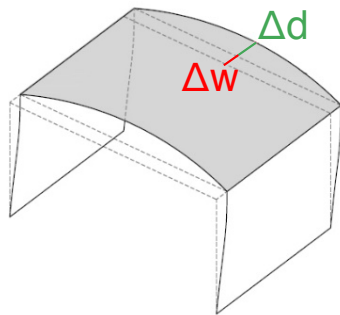


Seismic response of URM buildings

□ Dynamic response

□ Timber floors

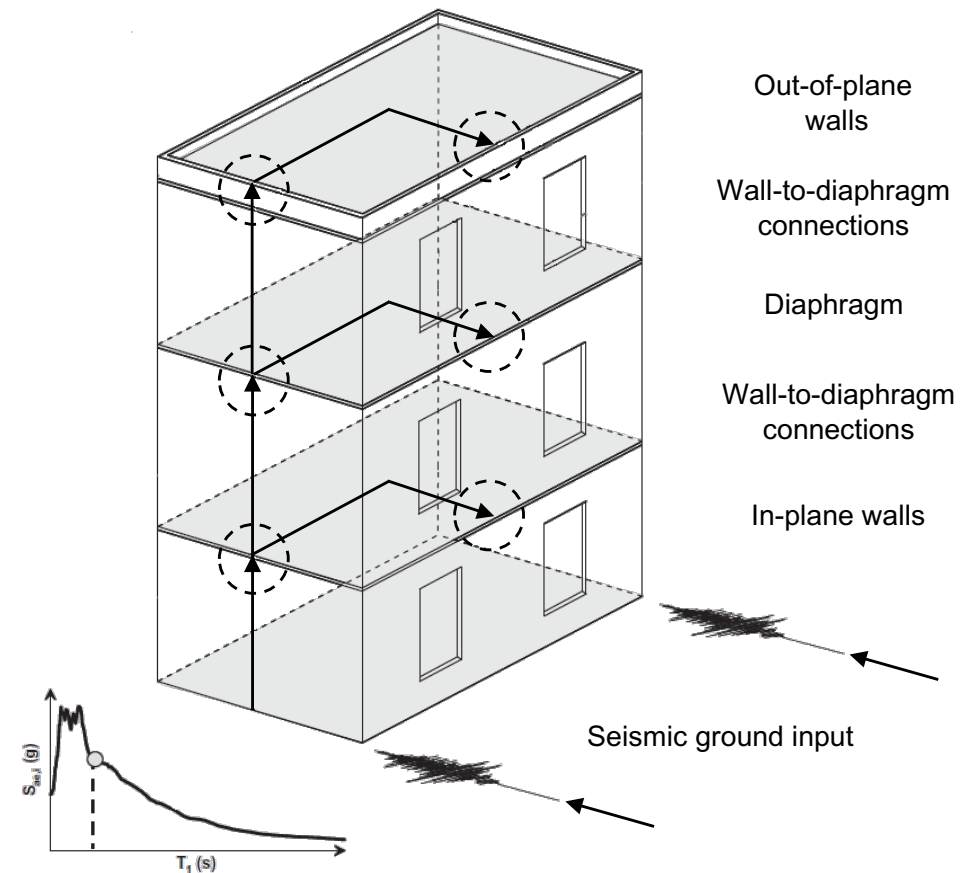
- Flexible diaphragms (low in-plane stiffness)



$$\Delta d \geq 1.1 \Delta w \text{ (EC8)}$$

$$\Delta d \geq 2.0 \Delta w \text{ (ASCE 41-13)}$$

- Poor WD connections (not able to transfer load)

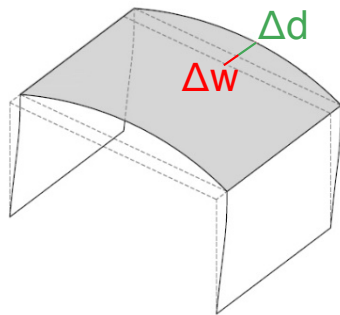


Seismic response of URM buildings

□ Dynamic response

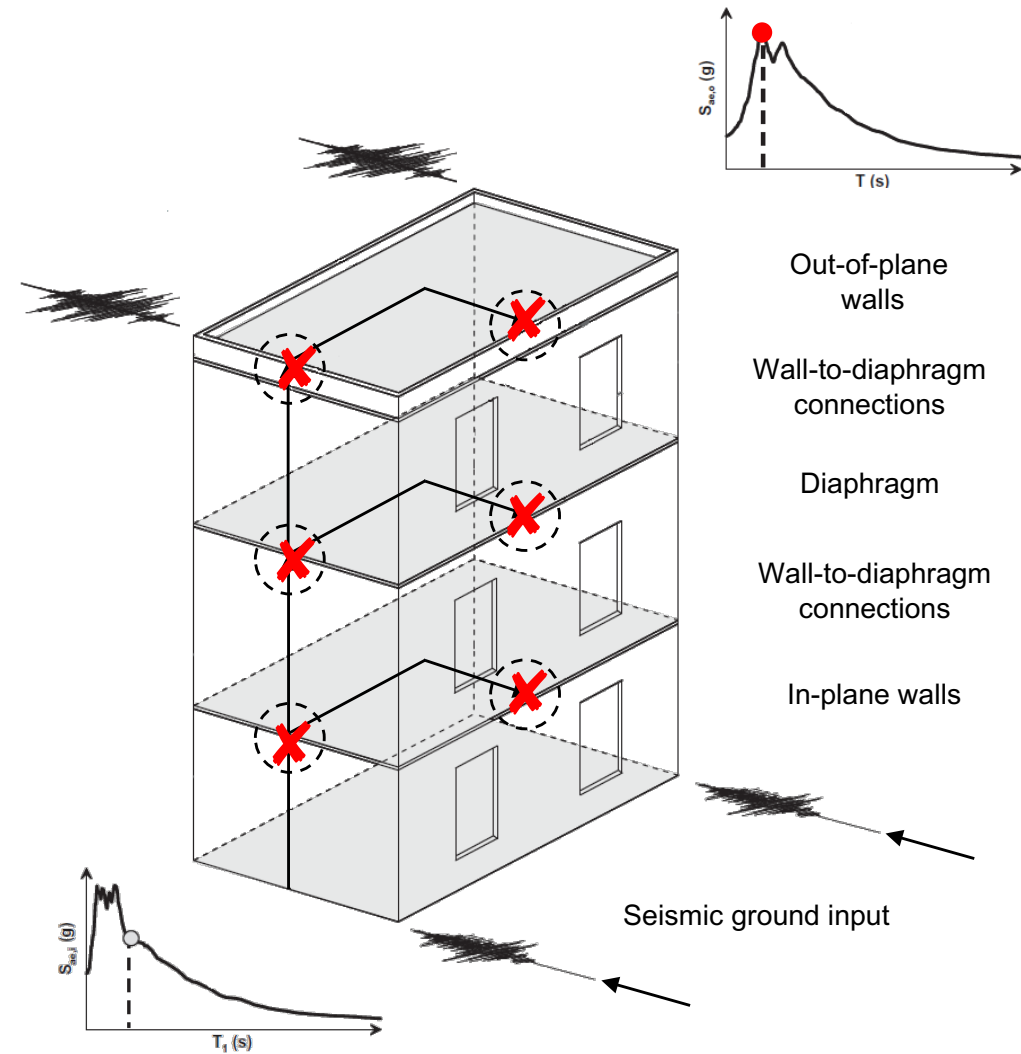
□ Timber floors

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Experimental tests – Building level

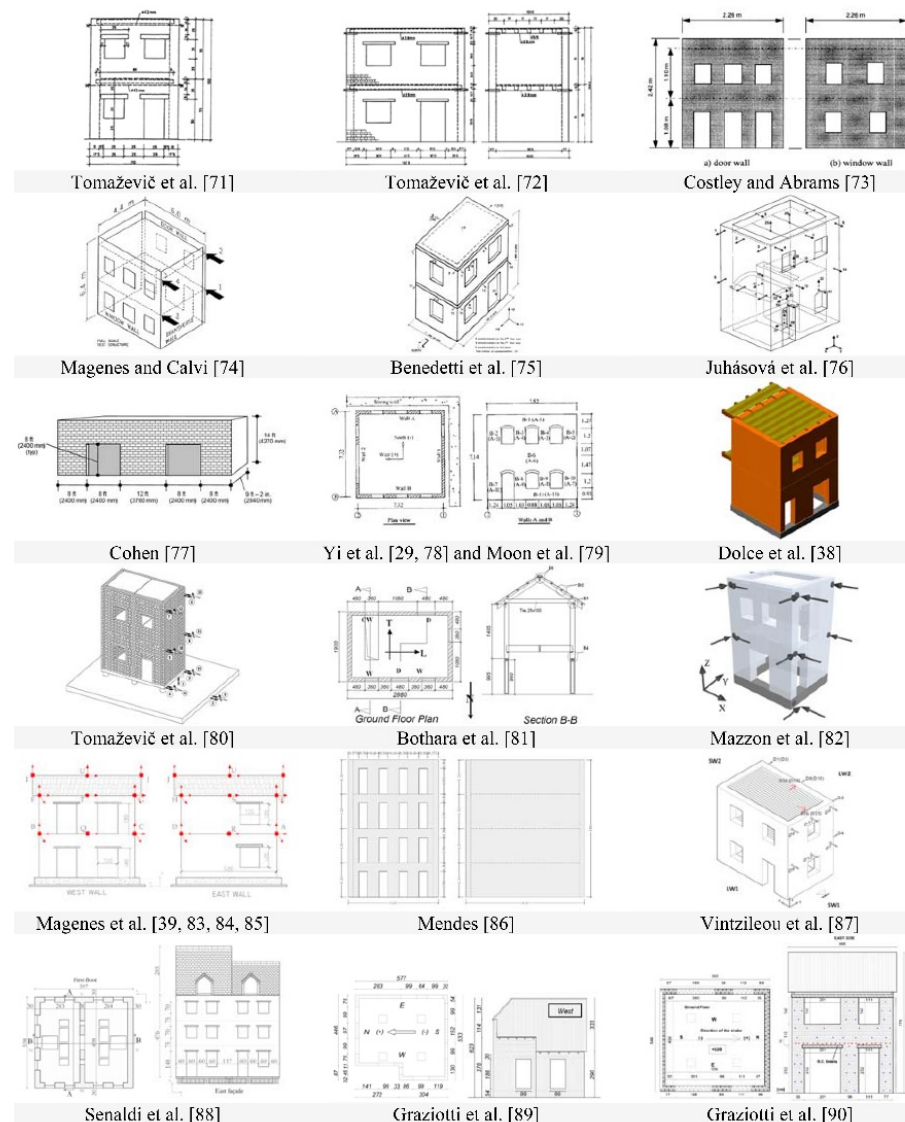
- ❑ Overall structural behaviour
- ❑ Systemic interventions

❑ Stiffer diaphragms

- Torsional effects
- Other failure mechanisms

❑ Limitations

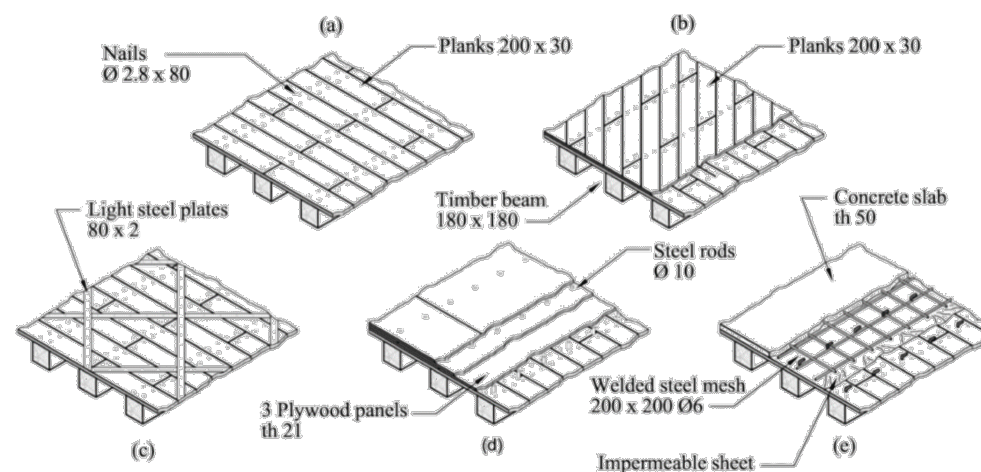
- Large variety
- Limited number of specimens
- Focused on masonry



Experimental tests – Component level

□ Timber diaphragms

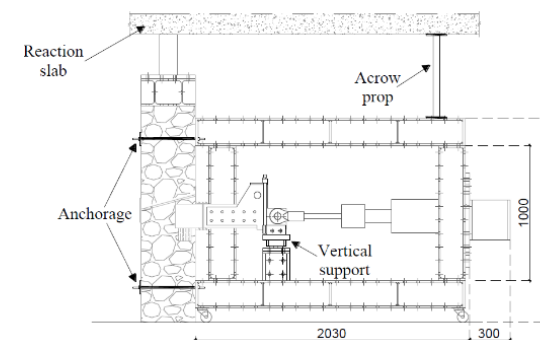
- In-plane stiffness
- Different strengthening techniques



Giongo et al. (2011)

□ Wall-to-diaphragm connections

- Very limited information



Moreira (2015)

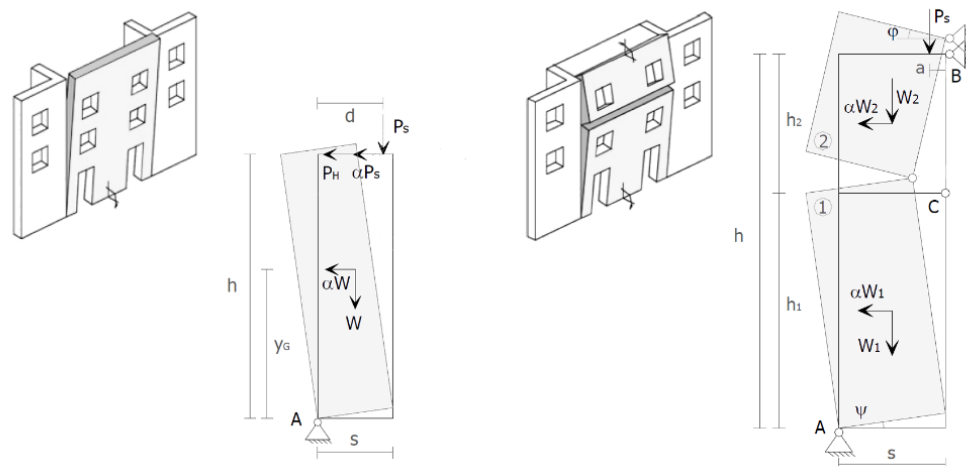
Modelling and analysis – Local out-of-plane behaviour

□ Kinematic analysis

□ Simple and efficient tool

□ Limitations

- Idealised boundary conditions
- Displacement demand depends on the presence of flexible diaphragms



ULS verifications

$$a_0^* \geq \frac{a_g(P_{vR})S}{q}$$

Force-based

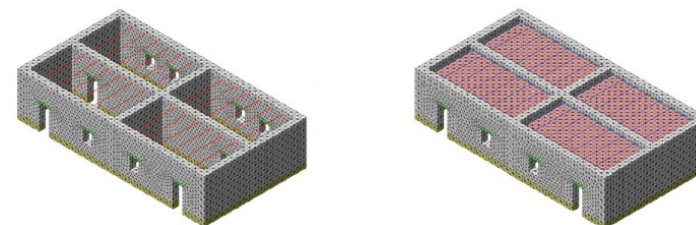
$$d_u^* \geq S_{De}(T_s)$$

Displacement-based

Modelling and analysis – Global behaviour

□ Numerical models

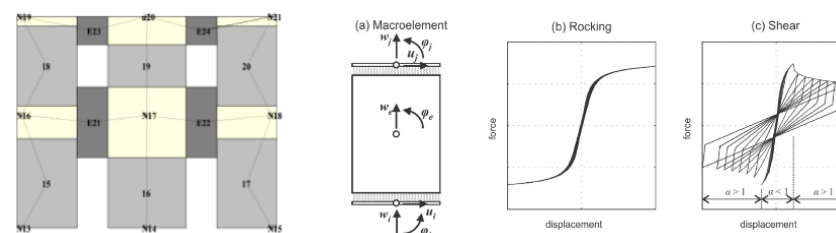
- Refined FE models
- Macro-element models



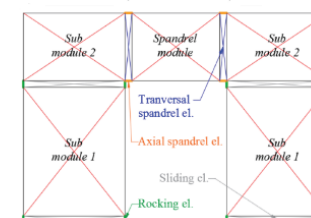
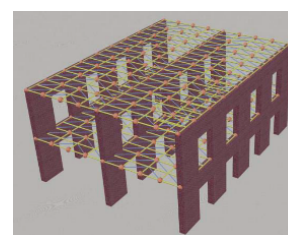
Ortega et al. (2018)

□ Assumptions

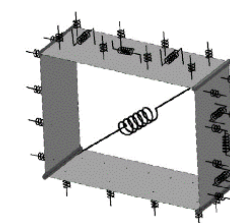
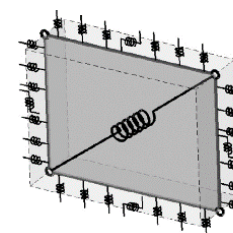
- Diaphragms:
Linear elastic behaviour
- WD connections:
Hinged or fixed restraints



Cattari et al. (2015)



Scotta et al. (2016)



Pantò et al. (2016)

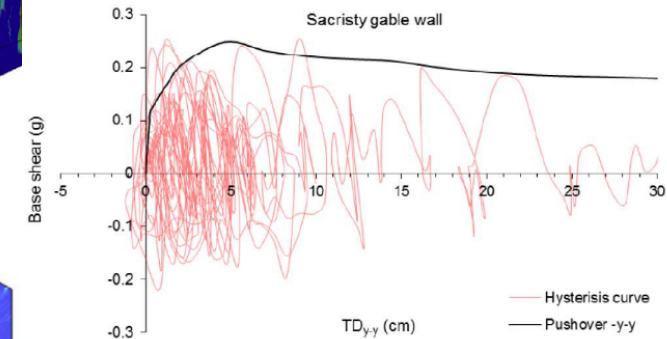
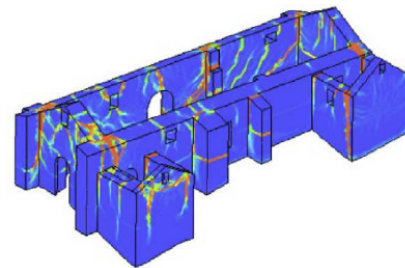
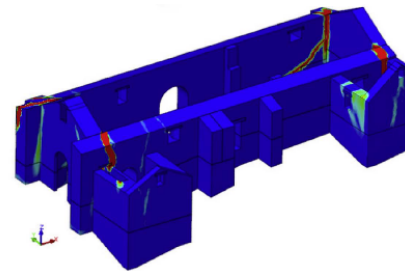
Modelling and analysis – Global behaviour

□ Analysis

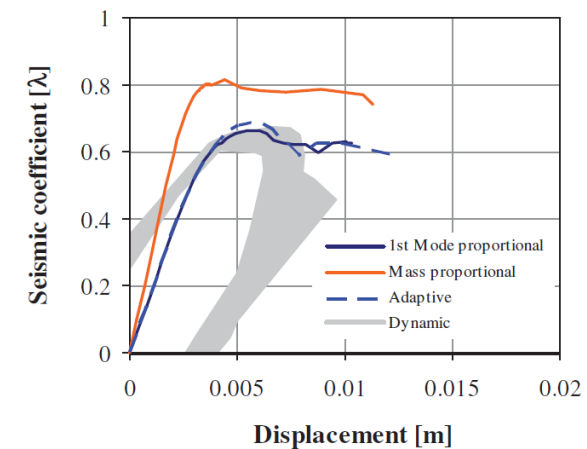
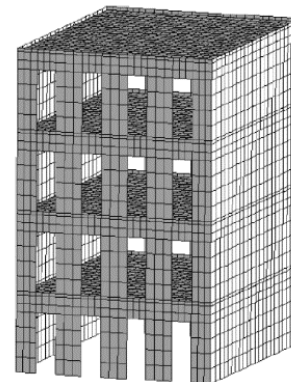
- Time-history
- Pushover

□ Assumptions

- Lateral load pattern
- Control node



Karanikoloudis and Lourenço (2018)



Mendes and Lourenço (2010)

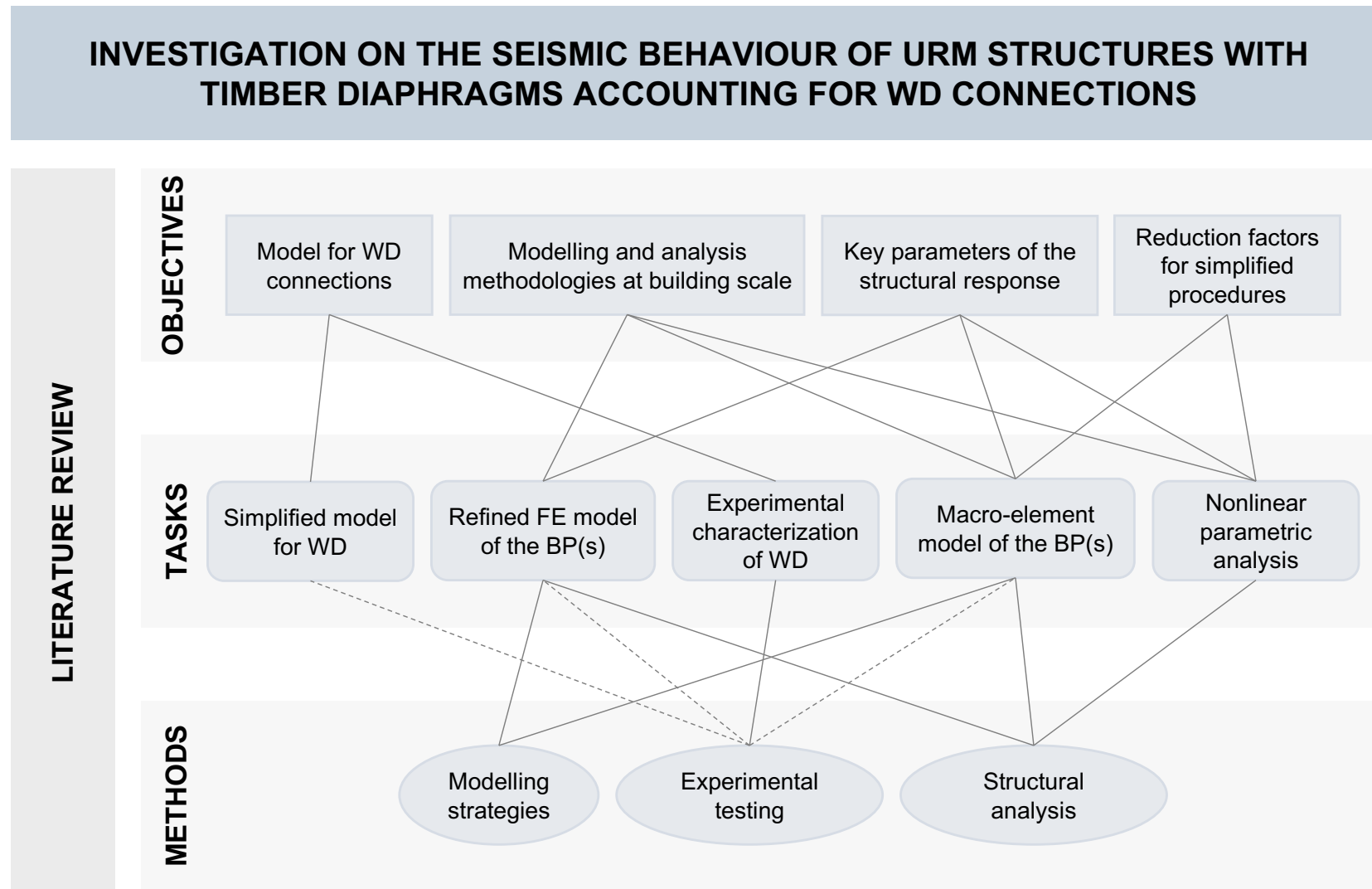
Final remarks

- ❑ Diaphragm stiffness and efficiency of WF connections significantly influence the seismic behaviour of URM structures
- ❑ Interaction between out-of-plane and in-plane responses should be evaluated
- ❑ Need to better understand and implement the behaviour of WD connections
- ❑ Modelling and analysis of URM buildings are challenging, especially if timber floors are present

Research methodology

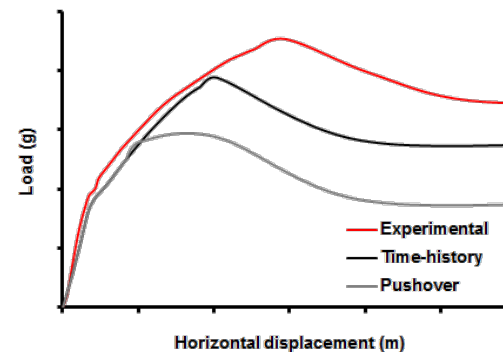
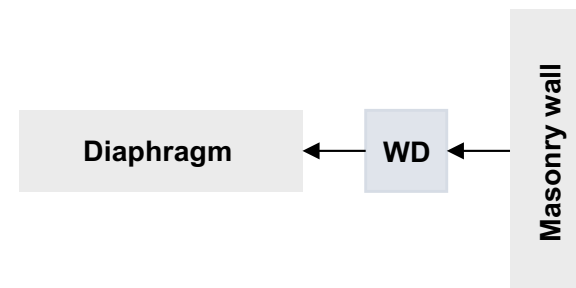
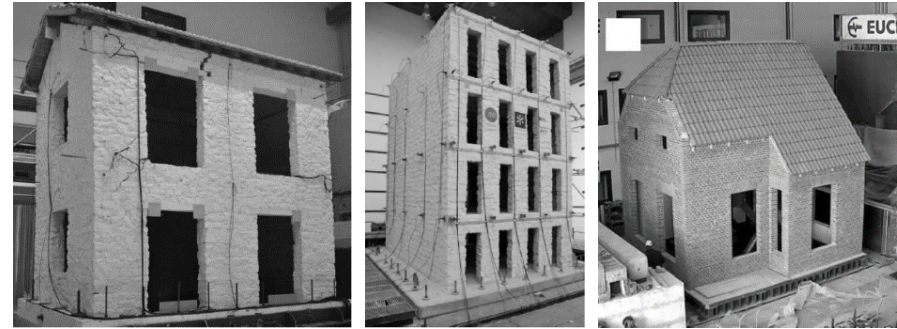
Objectives, tasks and methods
Features, boundaries and assumptions
Timeline

Objectives, tasks and methods



Features, boundaries and assumptions

- ❑ Prototype building(s)
- ❑ Focus on WD connections
- ❑ Control the transfer to diaphragms
- ❑ Different modelling and analysis techniques
- ❑ Nonlinear parametric analyses



How much is the accuracy?
Advantages and limitations?

Timeline

Task	2016	2017				2018			2019			2020		
	Sept. Dec.	Jan. Apr.	May Aug.	Sept. Dec.	Jan. Apr.	May Aug.	Sept. Dec.	Jan. Apr.	May Aug.	Sept. Dec.	Jan. Apr.	May Aug.		
T1														
T2														
T3														
T4														
T5														
T6														
T7														
								1		2		3	4	5

Future publications (at least, 1, 3 and 5 are journal papers):

1. Applicability of refined FE modelling and nonlinear analysis for URM structures with flexible diaphragms accounting for the nonlinear behaviour of wall-to-floor connections
2. On the modelling of the nonlinear behaviour of wall-to-floor connections for URM buildings with timber floors
3. A comparative study of modelling and nonlinear analysis approaches for URM structures with flexible diaphragms
4. Nonlinear analyses within a parametric framework on URM buildings with timber floors
5. Reduction factors to account for the nonlinear behaviour of wall-to-floor connections and diaphragm in-plane stiffness when assessing the seismic behaviour of URM with timber floors

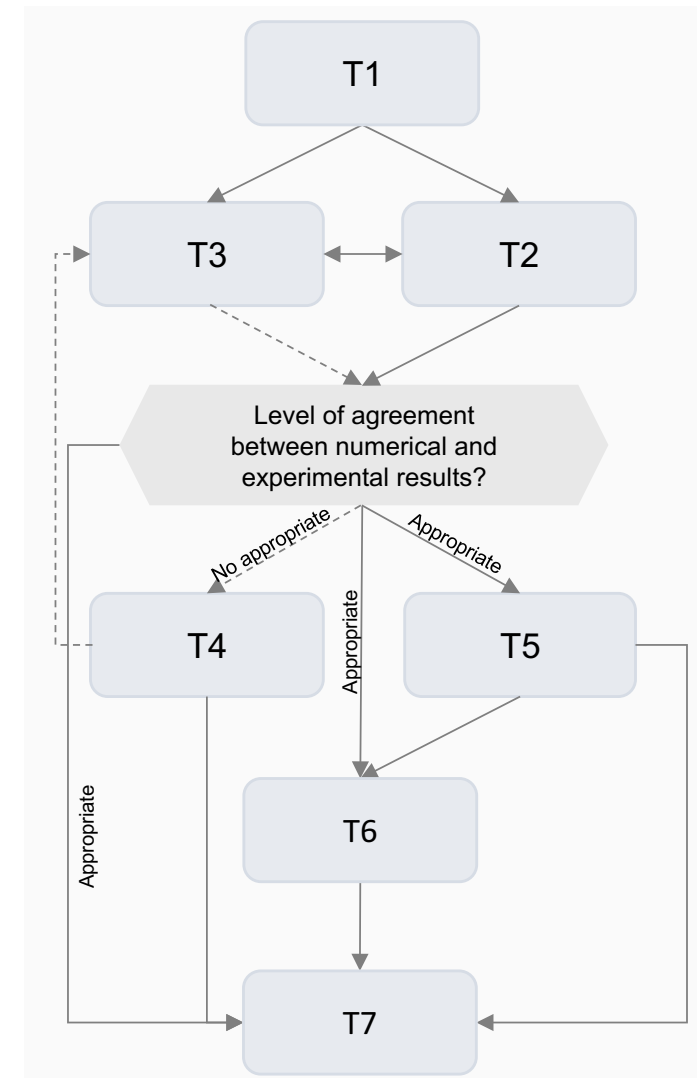
Meccanica (2018) 53:1931–1958
<https://doi.org/10.1007/s11012-017-0720-3>



NEW TRENDS IN MECHANICS OF MASONRY

Engineering simulations of a super-complex cultural heritage building: Ica Cathedral in Peru

Maria Pia Ciocchi · **Satyadhrik Sharma** · **Paulo B. Lourenço**



Work in progress

Model of the prototype building 1

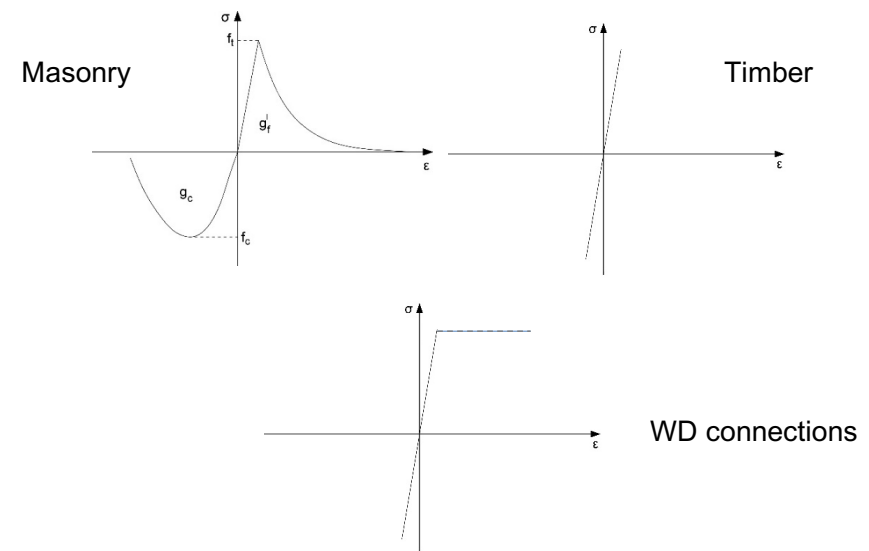
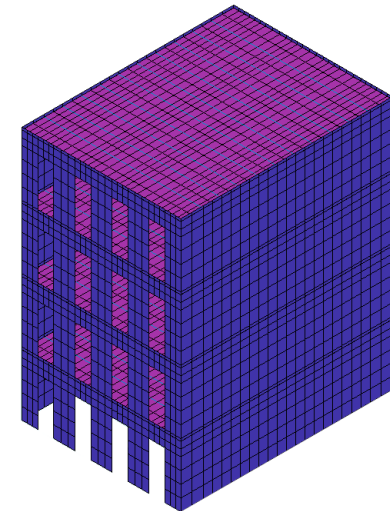
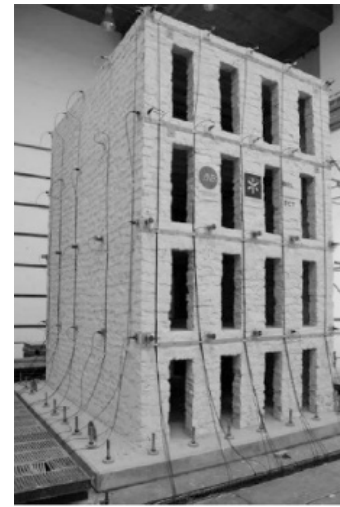
□ Modelling

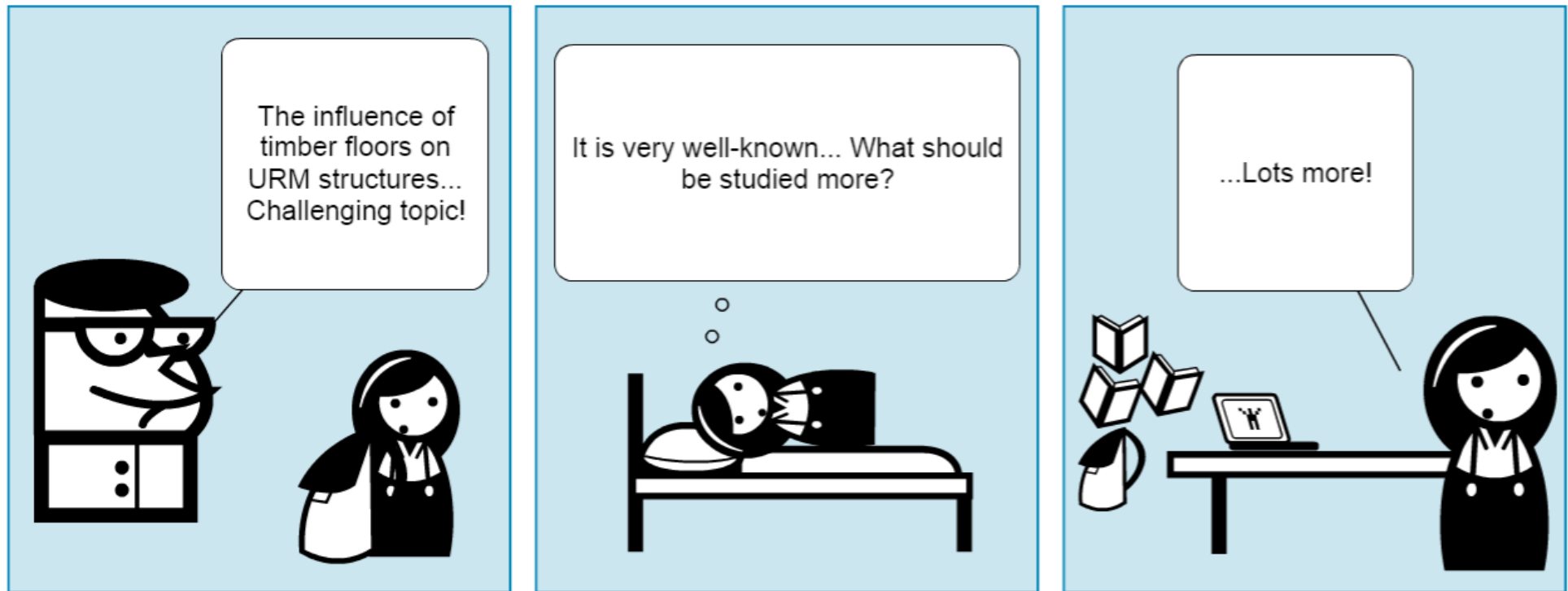
- Masonry walls: Shell elements
- Diaphragms: Shell and beam elements
- WD connections: Spring or interface elements

□ Materials

- Masonry: Total Strain Rotating Crack model
- Timber: Isotropic linear elastic
- WD connections: ?

➡ Experimental tests
on WD connections





To be continued...

Thank you

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