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SEISMIC VULNERABILTY ASSESSMENT OF OLD BUILDINGS

Rita Bento

Department of Civil Engineering and Architecture, IST

United Nations Educational, Scientific and Cultural Organization

Instituto Dom Luiz

FUNDAÇÃO LUSO-AMERICANA

USGS science for a changing world

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SUMMARY

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INTRODUCTION

- A reasonable amount of curve sets for the **physical vulnerability** assessment of individual buildings, covering the most common European typologies (RC and URM) is currently available in Europe.
- Less common building typologies still lack of fragility/vulnerability curves.
- Nowadays, the seismic vulnerability of old masonry structures and possible retrofitting solutions are still a main concern.
- The response of this type of structures to strong earthquakes is still an open research subject

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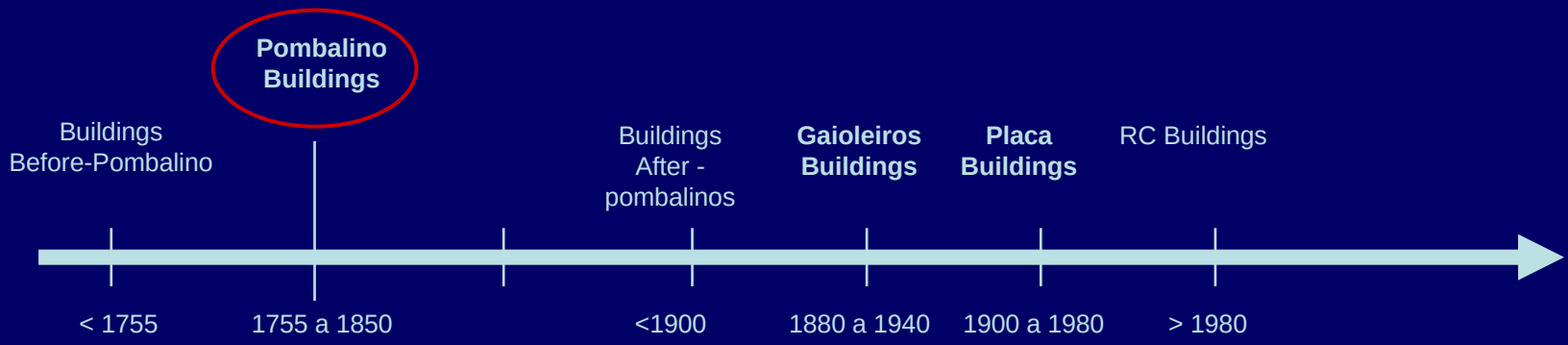
INTRODUCTION

- Lisbon has a patrimonial value in old constructions => Need of Preservation
- Some were built with anti-seismic concerns – Pombalino Buildings
- Other have been designed to withstand gravity loads => Vulnerable groups (e.g. Gaioleiro Buildings)
- These buildings have suffered material degradation and significant structural modifications as the time went by



MAIN CONCERNS:

→ What is the seismic vulnerability of these old buildings?

→ Which are the adequate retroffiting solutions?

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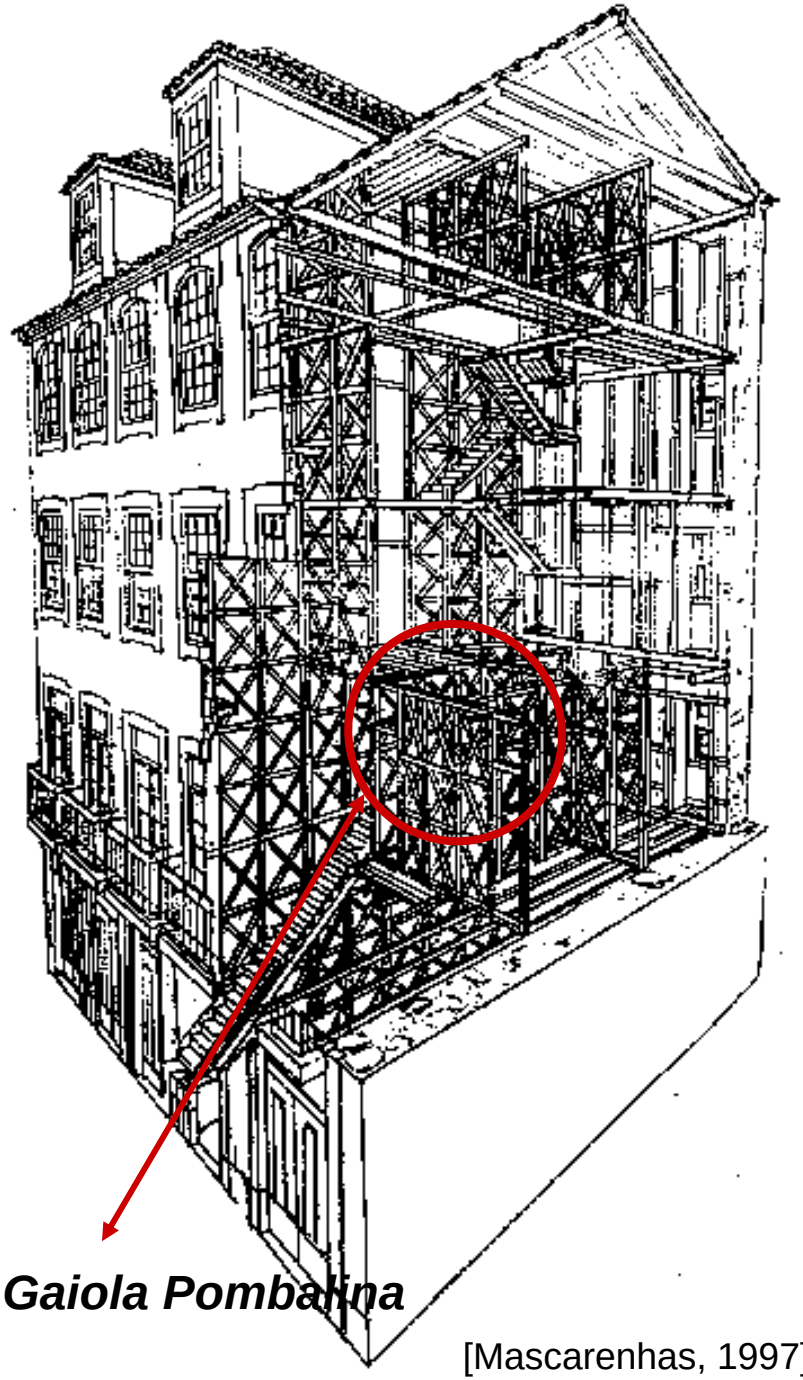
Pombalinos Buildings (1755-1850)

- After 1755 Lisbon Earthquake, masonry buildings were built with a 3D wood structure named *Gaiola Pombalina.* The *Gaiola* structure is like a cage made of vertical and horizontal elements braced with diagonals.



Gaiola Pombalina

[Mascarenhas, 1997]

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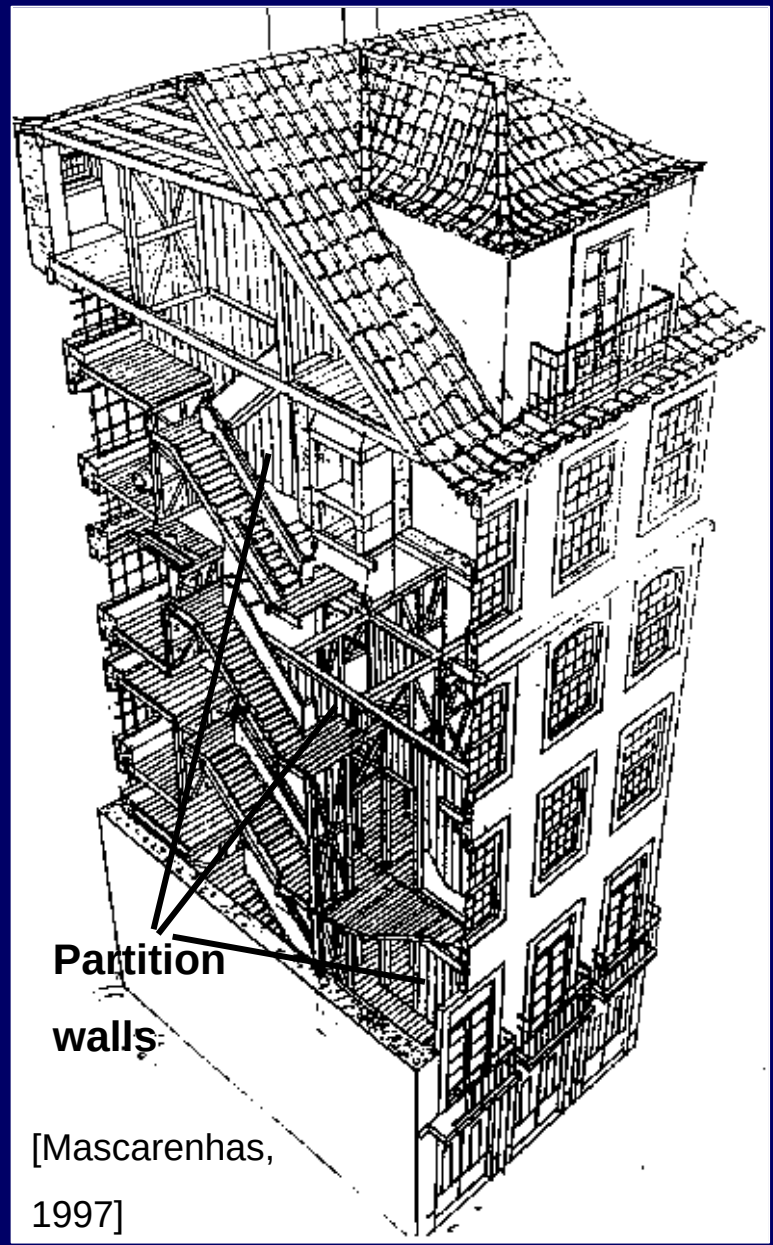
‘Gaioleiros’ Buildings (1880–1940)

- As time went by, the wood elements were progressively removed in new constructions
- The diagonal elements gradually disappear
- Interior walls were replaced with masonry or wood-partitions
- In time, masonry becomes the only structural material.



[Mascarenhas, 1997]

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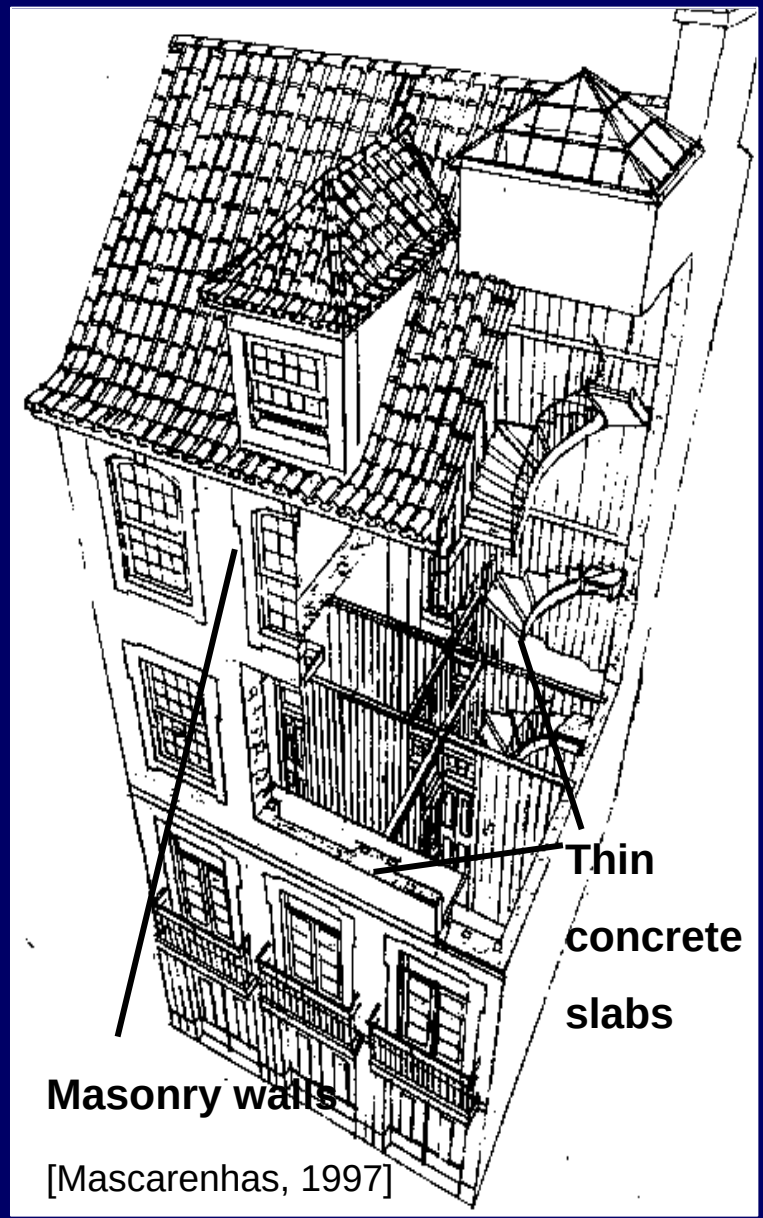
'Placa' Buildings (1900 - 1980)

- At the most recent masonry buildings, wood floors were replaced with thin concrete slabs. Selft weight was increased.

⇩

- As the result of construction evolution, old masonry buildings became less resistant to horizontal loads



[Mascarenhas, 1997]

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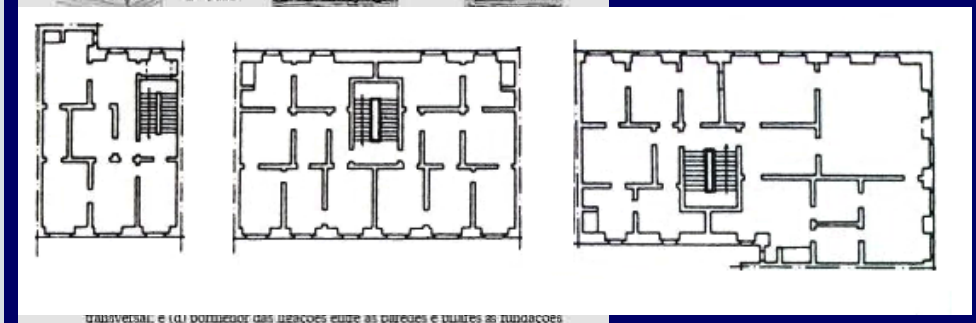
'POMBALINO' BUILDINGS



- Soils layers with very poor load bearing capacity, over which lay the rest of the constructions destructed by 1755 earthquake.
- Foundations include small wooden piles with small diameter. Above them is applied a net of wooden beams.
- Orthogonal Plan
- Bi-symmetrical Quarters
- Small backyard in its interior

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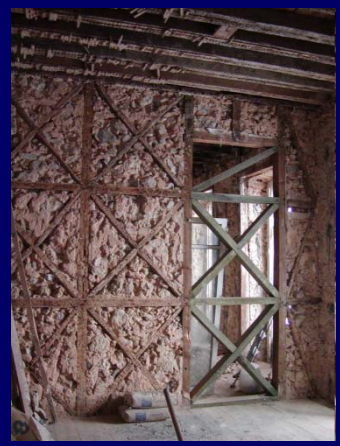
'POMBALINO' BUILDINGS



- Ground floor - System of vaults made of blocks of ceramic masonry and stone arches
- 3-D timber structure, Gaiola Pombalina, enclosed in interior masonry walls
- Façades of masonry with variable thickness
- Buildings in a quarter sharing middle walls (*meeiras*)
- Partition walls are wooden panels without structural functions
- Floors are wooden slabs and should be considered as flexible diaphragms

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'POMBALINO' BUILDINGS

Structural Modifications

- ✓ Cut off of stone columns at ground level
- ✓ Open larger shop windows in structural walls
- ✓ Demolition of interior walls
- ✓ Increase number of stories
- Introduction of different structural/non structural elements
- Modifications of floors - rigid
- Degradation of materials
- Occupation of the interior backyard

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SEISMIC VULNERABILITY MODELS

- a) **Observational** - Damage Probability Matrices defined on statistical base starting from data of post-earthquake damage building classes

- b) **Typological-Empirical** – Based on the definition of a vulnerability index, calibrated by post-earthquake damage survey or resulting from the macroseismic scale definition

- c) **Mechanical** – A whole class of buildings is represented by a capacity curve (aimed to describe the dynamic response of an equivalent SDOF)

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SEISMIC VULNERABILITY MODELS

- **Mechanical** approach is privileged; is the one adopted by the current trends of research and used by the latest applications in the seismic risk field.

- For the seismic vulnerability of old buildings the **Mechanical** approach is the best option given the specificness of the constructions. For that non-linear static analyses could be used, and, in particular cases, non-linear dynamic analyses so as to validate the previous. The numerical models to be used could be:

  - **Macro-elements** — Cost-effective tool
  - **Finite elements** — Most used

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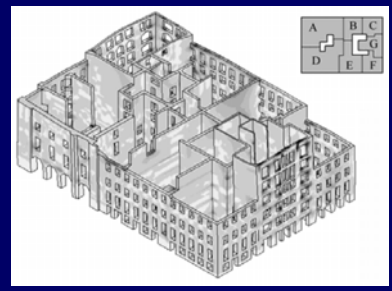
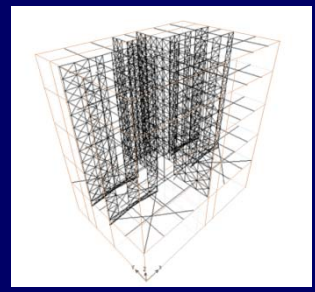
PREVIOUS RESEARCH WORK

Based on Finite Element Analyses

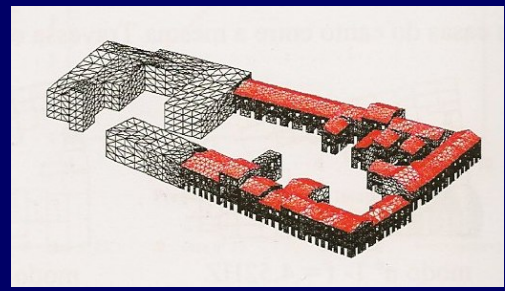
- MSc Thesis *Análise Experimental e numérica de Estruturas Históricas de Alvenaria*, Luís Ramos, Universidade Minho, 2002



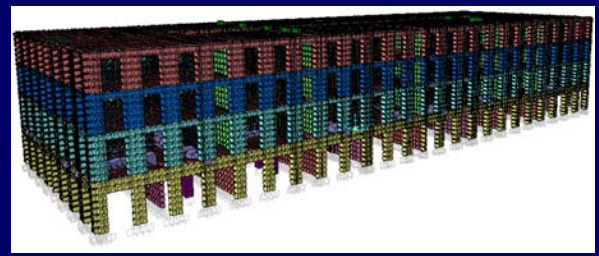
- MSc Thesis *Vulnerabilidade Sísmica de Estruturas Antigas de Alvenaria*, Rafaela Cardoso, IST, 2002



- MSc Thesis *Identificação Dinâmica e Análise do Comportamento Sísmico de um Quarteirão Localizado na Cidade da Horta – Ilha do Faial*, Nuno Neves, FEUP, 2004



- Research Project *Análise Sísmica de um Quarteirão Pombalino*, ICIST, Mafalda Monteiro, Mário Lopes & Rita Bento, 2004.



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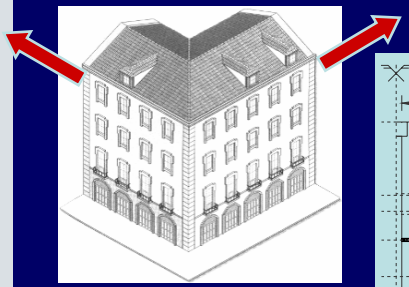
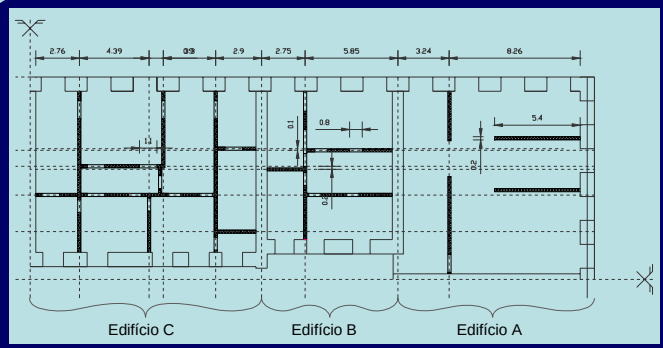
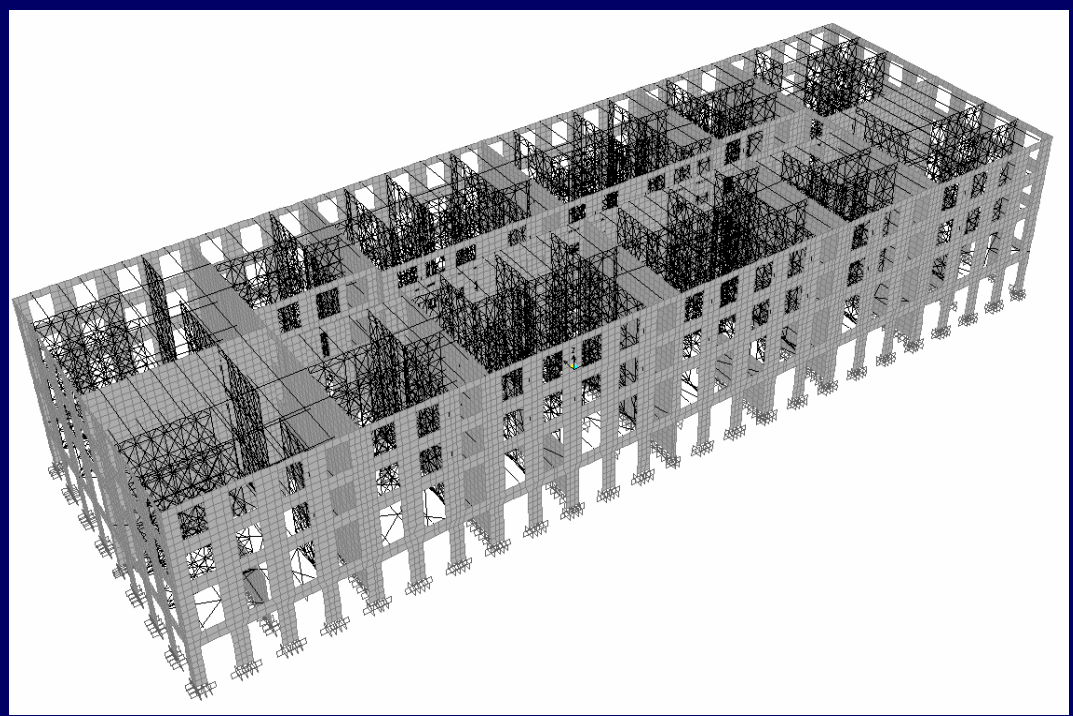
SEISMIC BEHAVIOUR OF A POMBALINO QUARTER

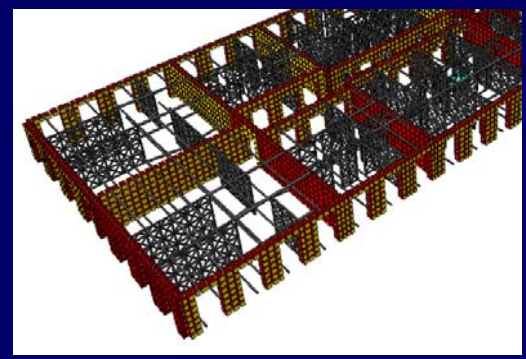


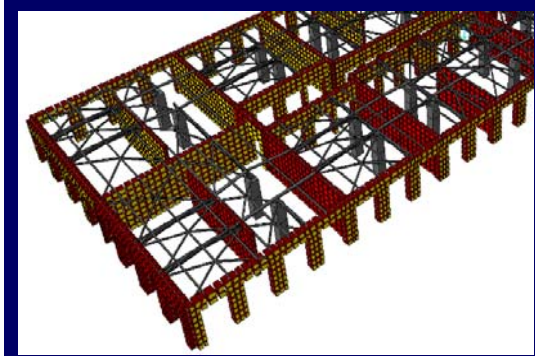


Modelling:

- Two symmetric axes
- Beam and plate finite elements
- Strength of Frontal = wood
- Floors distortional stiffness null
- Masses concentrated
- The stiffness of the frontal' diagonals reduced







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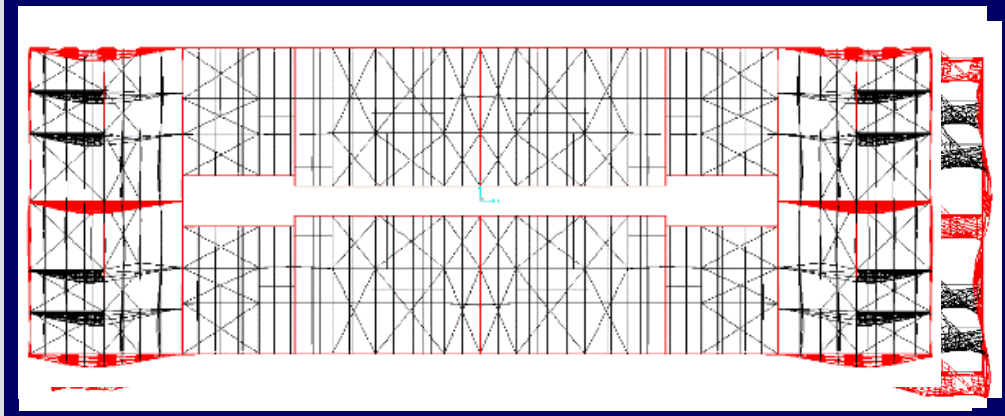
SEISMIC BEHAVIOUR OF A POMBALINO QUARTER

Dynamic Characteristics

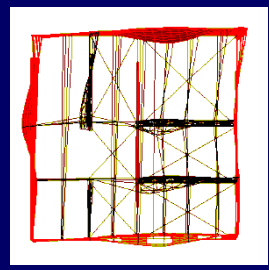
Typical - Quarter:



2º
1.49Hz

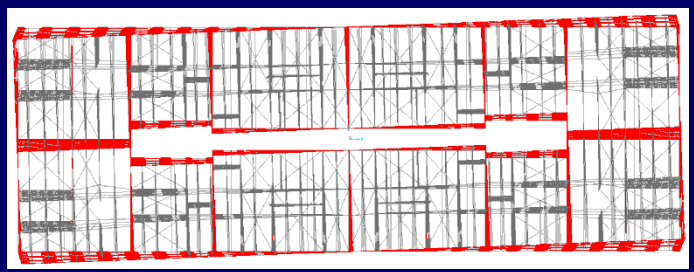
... 25º
3.39Hz

Corner Building (isolated):



6º
4.00Hz

Typical - Quarter with rigid diaghram:



Remarks:

- → Typical-Quarter does not have a rigid body behaviour
- → Sharing middle walls decrease global torsional effects
- → It does not exist the rigid diaghram effect (wooden diagrams have a limited resistance to distortion)

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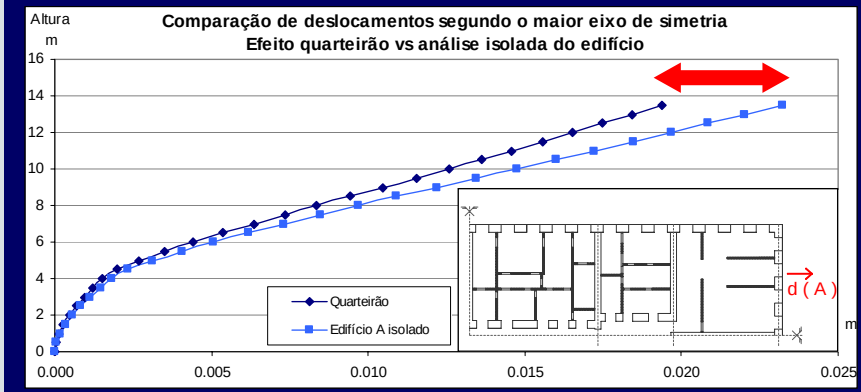
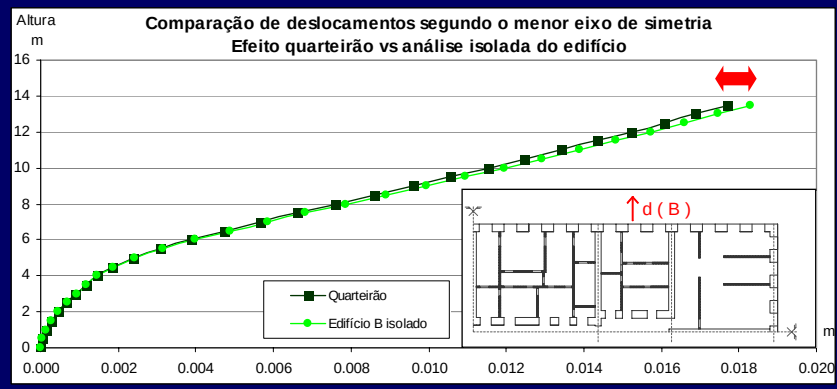
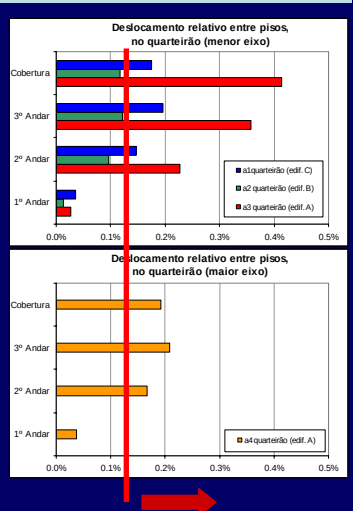
SEISMIC BEHAVIOUR OF A POMBALINO QUARTER

Horizontal Displacements – Typical - Quarter *vs* Isolated Building:



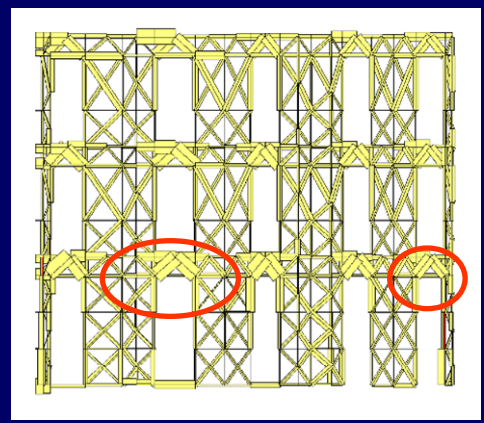


Relative Displacements:

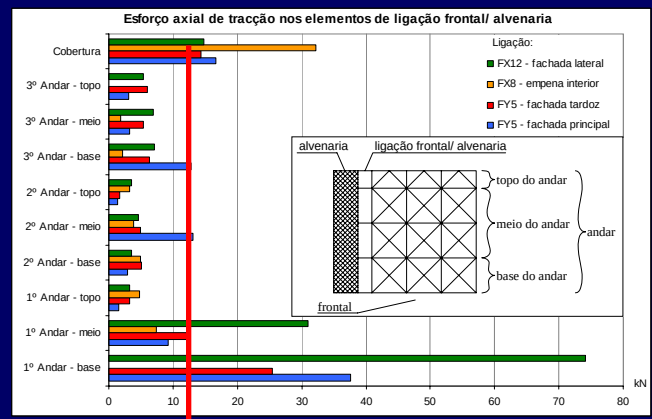


High level of Degradation!

Axial Forces in *Frontal*:



Connections bt Frontal & Masonry walls:



Connections in Failure!

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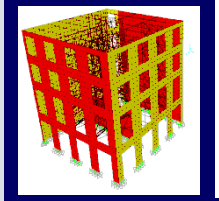
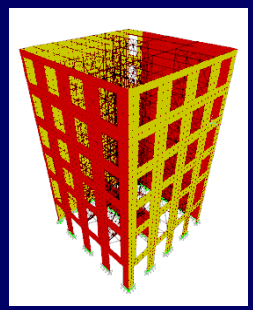
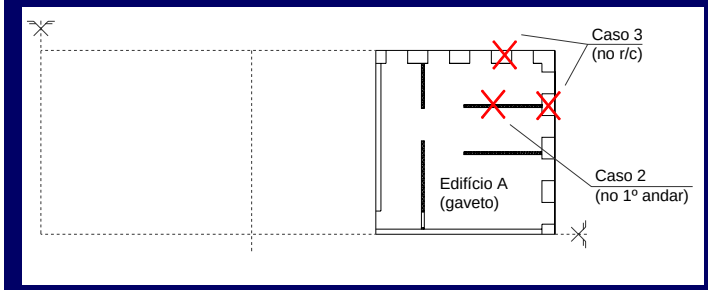
SEISMIC BEHAVIOUR OF A POMBALINO QUARTER

Structural modifications – Isolated Building







Study Cases:

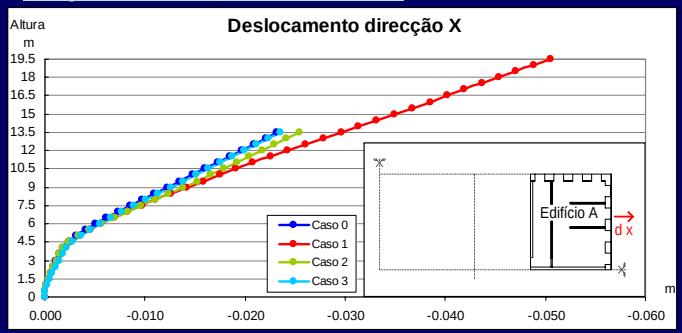
0 – reference

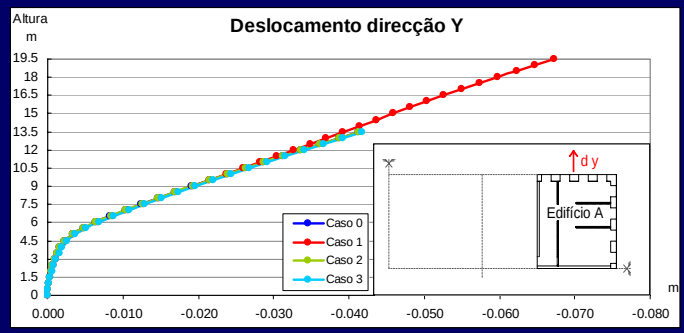
1 – more 2 stories at the top of the building

2 – cut off of columns in ground floor

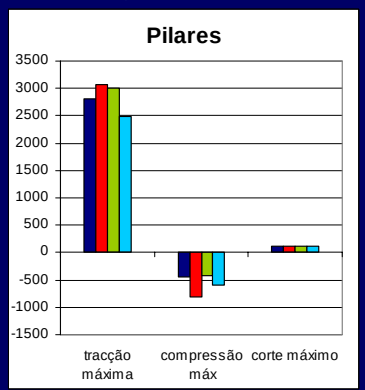
3 – demolition of frontal in 1st floor

Façades Displacements:

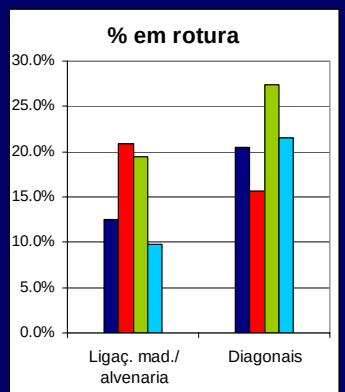




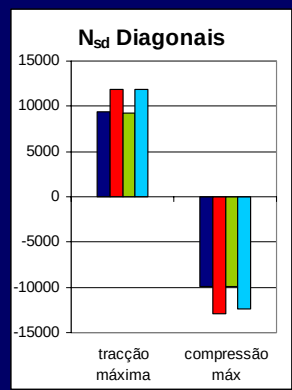
Masonry stresses:

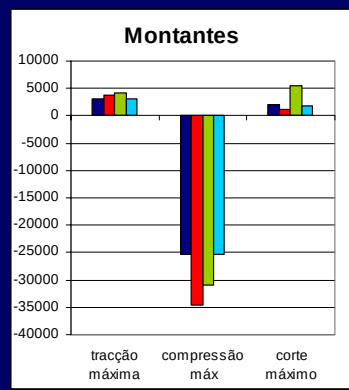


Connections:



Maximum Stresses in Frontal:





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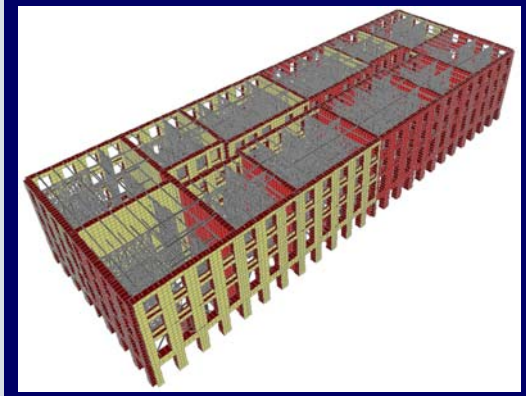
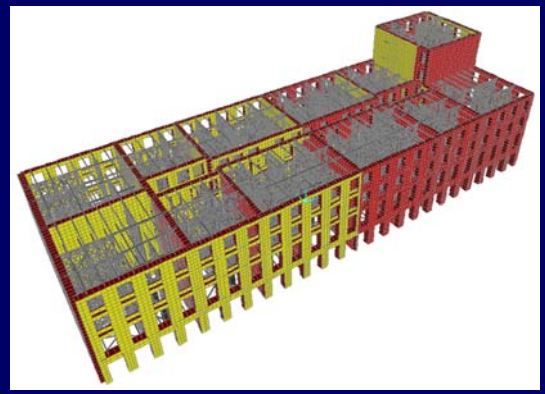
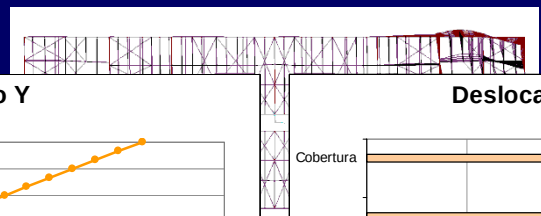
Global Study



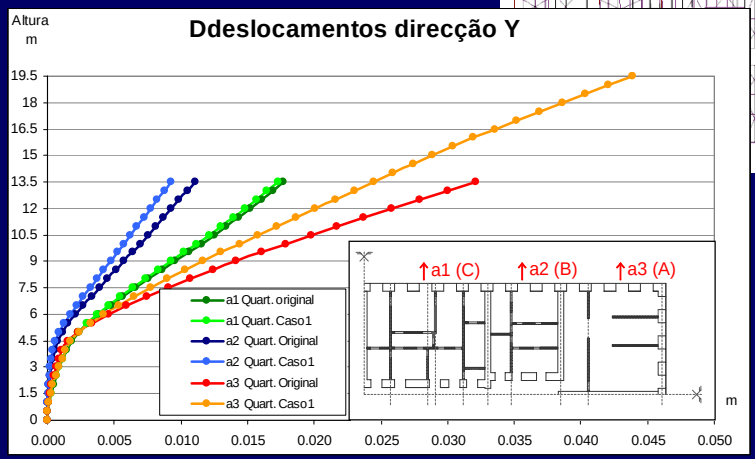


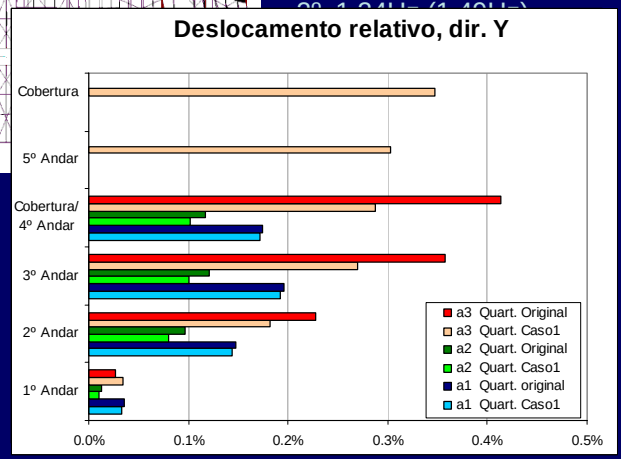
Modes	Original	Case 1
1º	1.49Hz	1.14Hz
2º	1.49Hz	1.24Hz
3º	1.65Hz	1.76Hz
4º	1.65Hz	1.99Hz
...10º	2.41Hz	2.42Hz

Displacements:



1º 1.14Hz (1.49Hz)





Original

Original

-- Case 1

Case 1

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FINAL COMMENTS

- Additional developments concerning the derivation of **fragility curves** are still required for particular, less common, building typologies, namely old masonry buildings.

-Experimental evidence, whenever possible, is valuable to backup theoretical and numerical studies, both for validation and calibration reasons. In the case of old constructions it is even more valuable as the variety of configurations and materials is high – a constitutive model which is valid for one type may not be valid for another

Experimental studies need to be carried out

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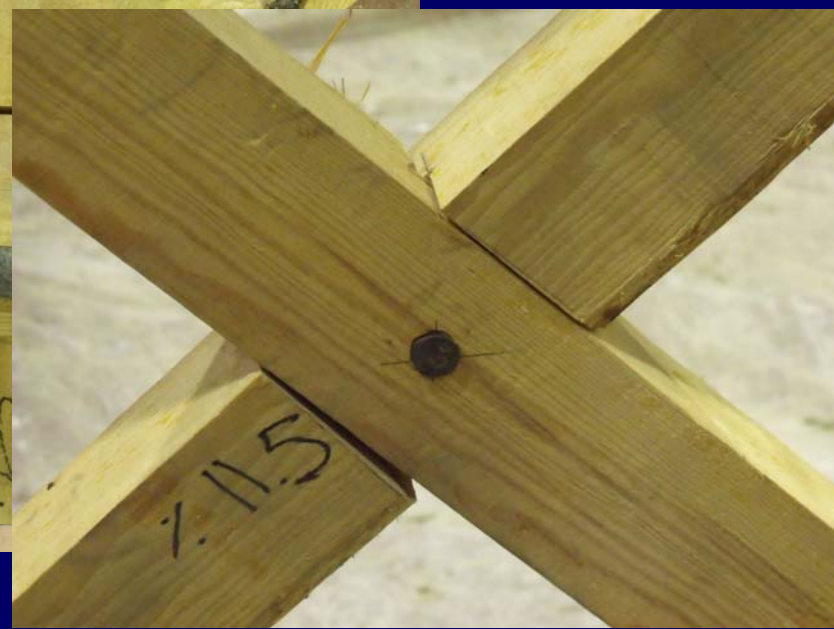
FINAL COMMENTS

- Portuguese national research **project** PTDC/ECM/100872/2008 named ‘Seismic Vulnerability Analysis of Old Masonry Buildings’ starts this month. It y it poses to old masonry **ntal** testing on



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Thank you!