COORDINATOR:
UNIVERSITÀ DEGLI STUDI DI PADOVA

Case Study
Monastery of Jerónimos, Lisbon, Portugal

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Department of Civil Engineering
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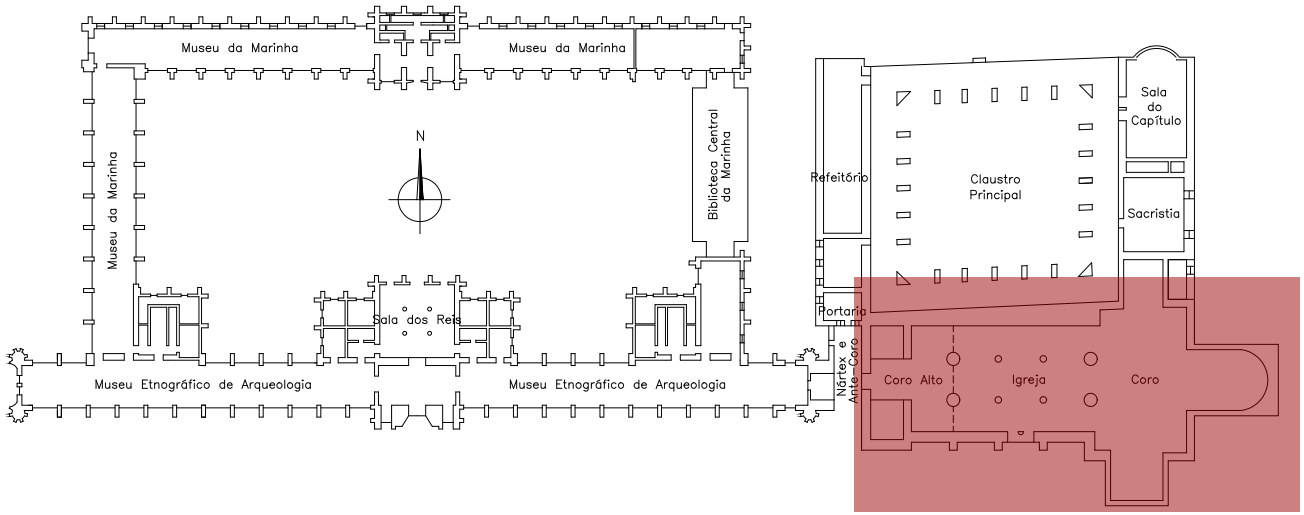
Description



The crown asset of Portuguese heritage buildings

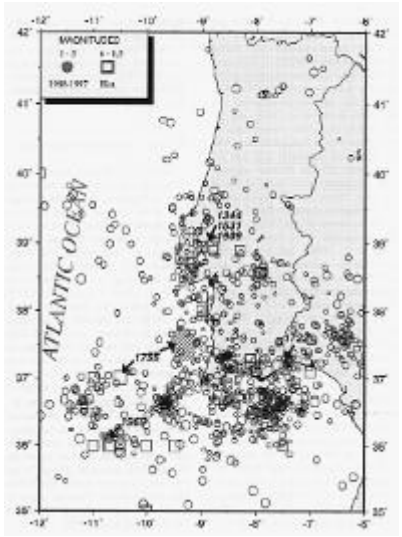
Construction from 1499

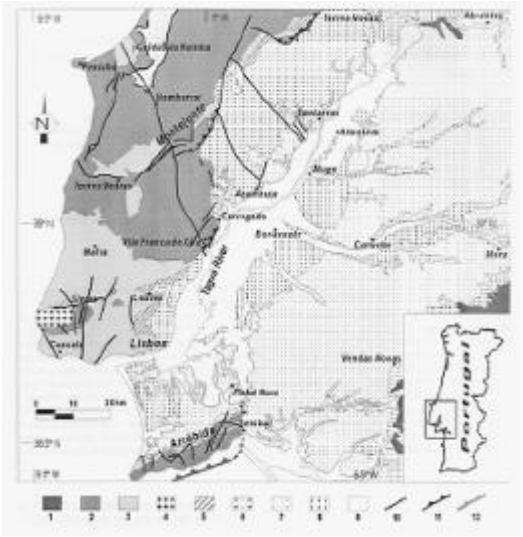
Built with limestone

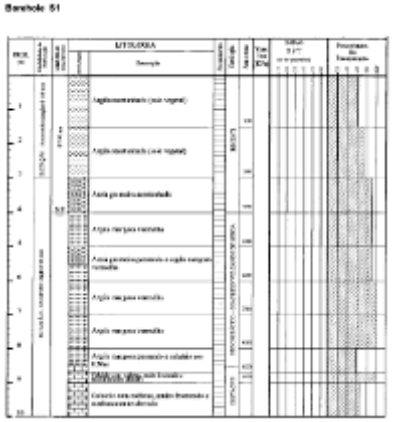
Considerable dimensions in plan, more than 300 × 50 m², and an average height of 20 m (50 m in the towers)

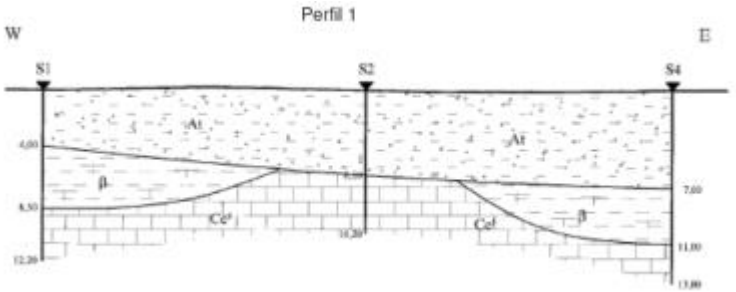
Evolves around two courts. The larger court is bordered by a long arcade of two levels that hosts the Ethnographic Museum of Archaeology and the Maritime Museum. The smaller court or the Cloister is bordered by the Church, the Sacristy, the Chapter Room, the Refectory

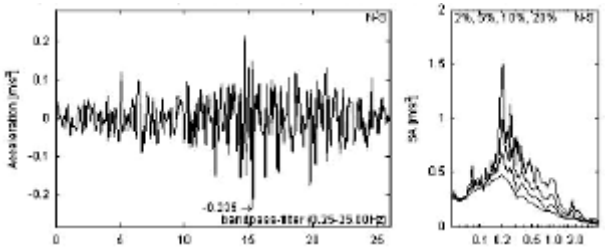
Local Seismicity







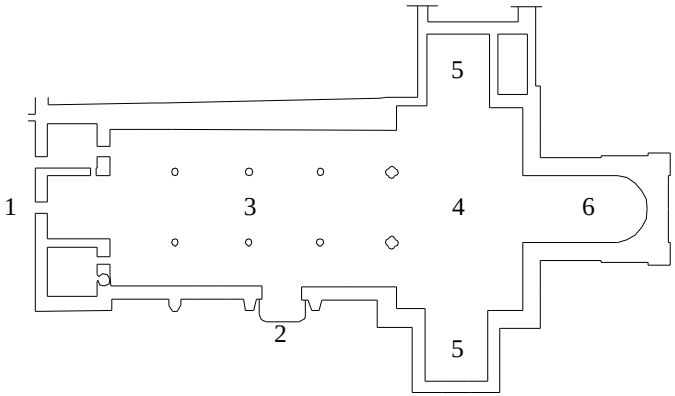


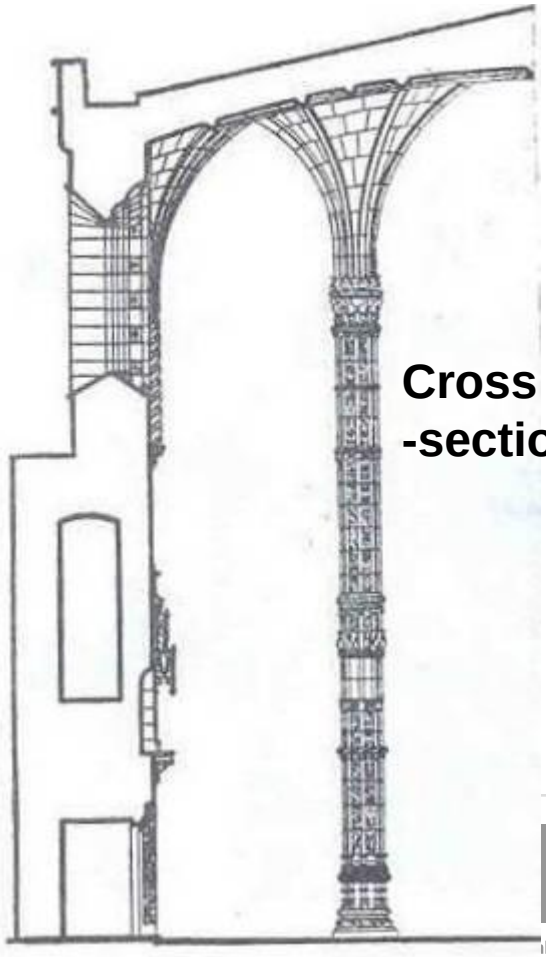


Gathered data

Church

Views





Cross -section

In situ investigation

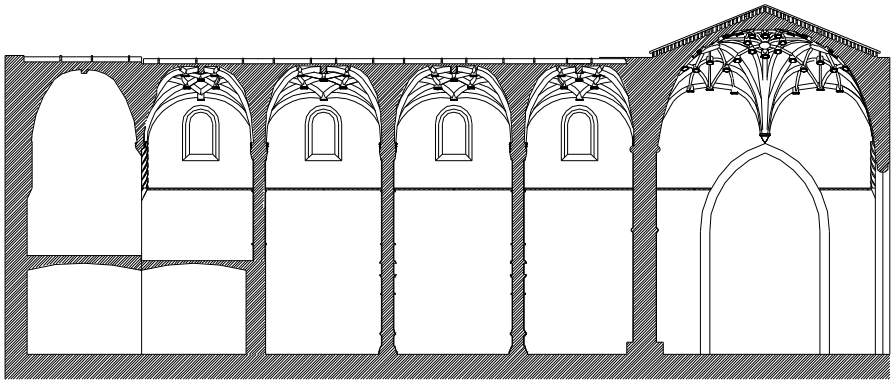
Tiles removal for visual inspection

Radar inspection

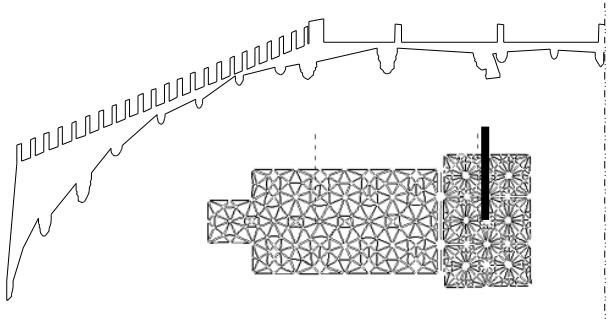
Wallets for supporting tiles (20th century)

Ribs visual inspection

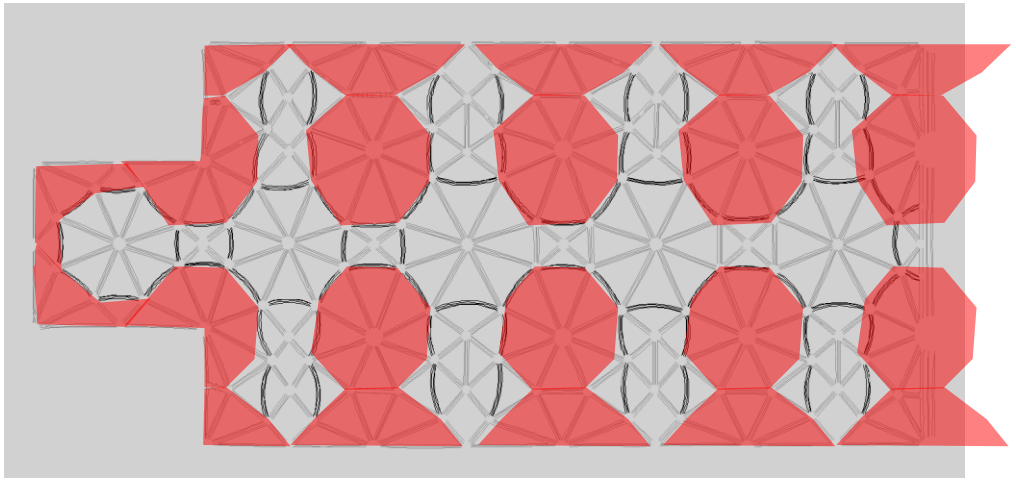
In situ geometrical survey



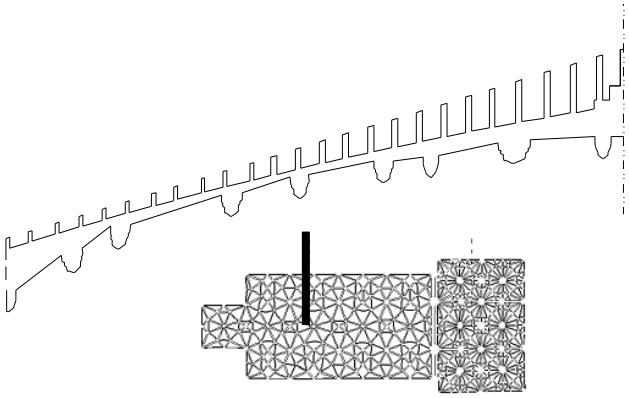
Longitudinal cross-section



Transept cross-section

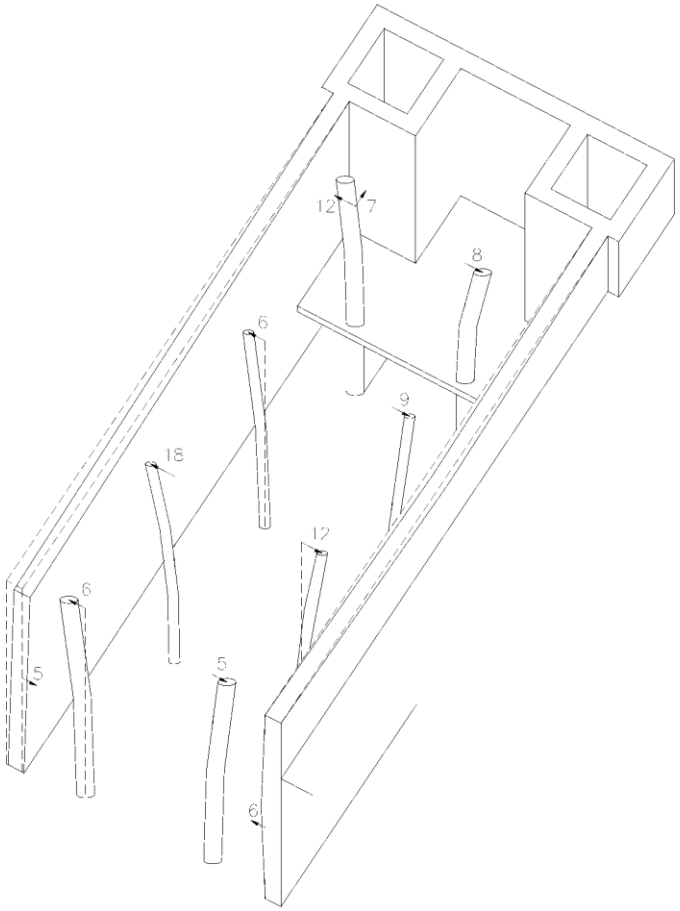


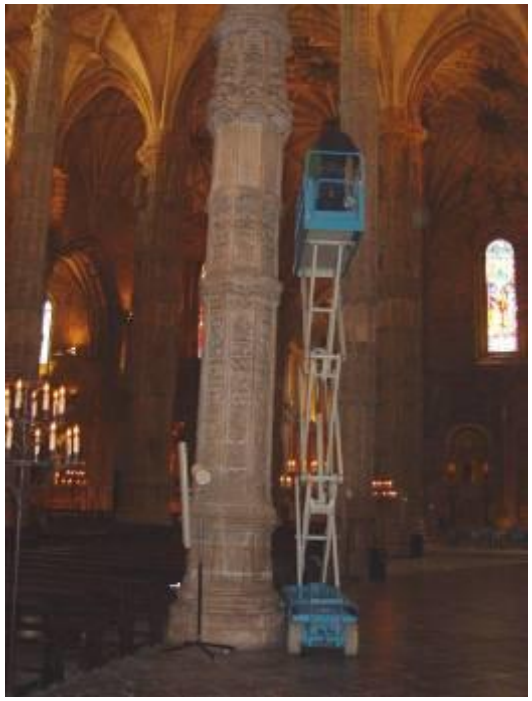
Plan of the nave



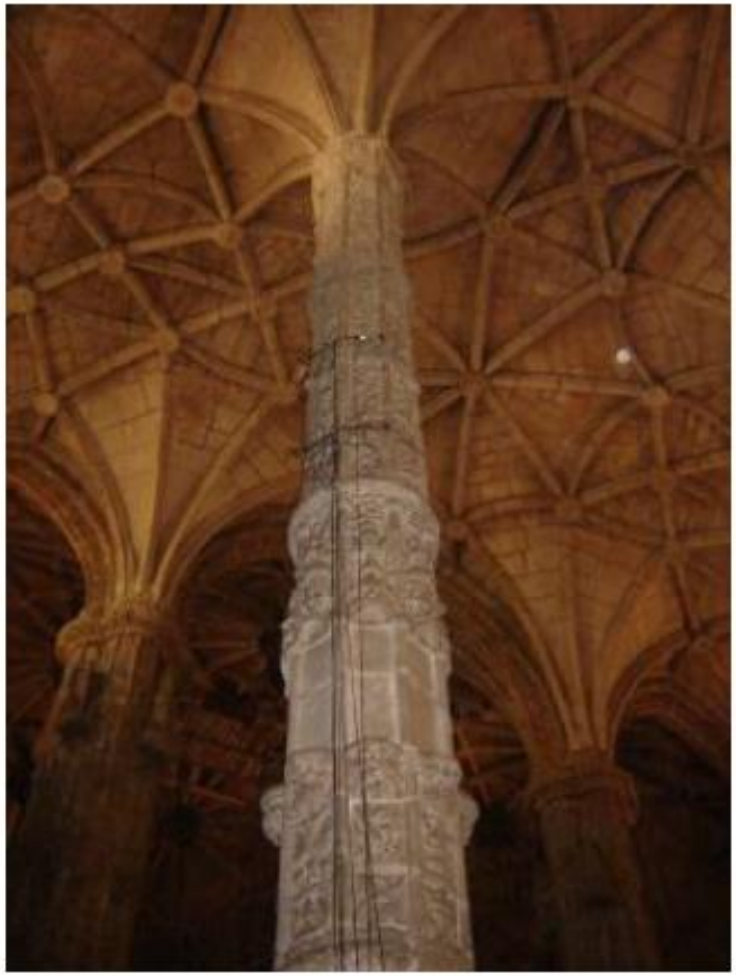
Nave cross-sections

Tilting of the columns and GPR of the columns

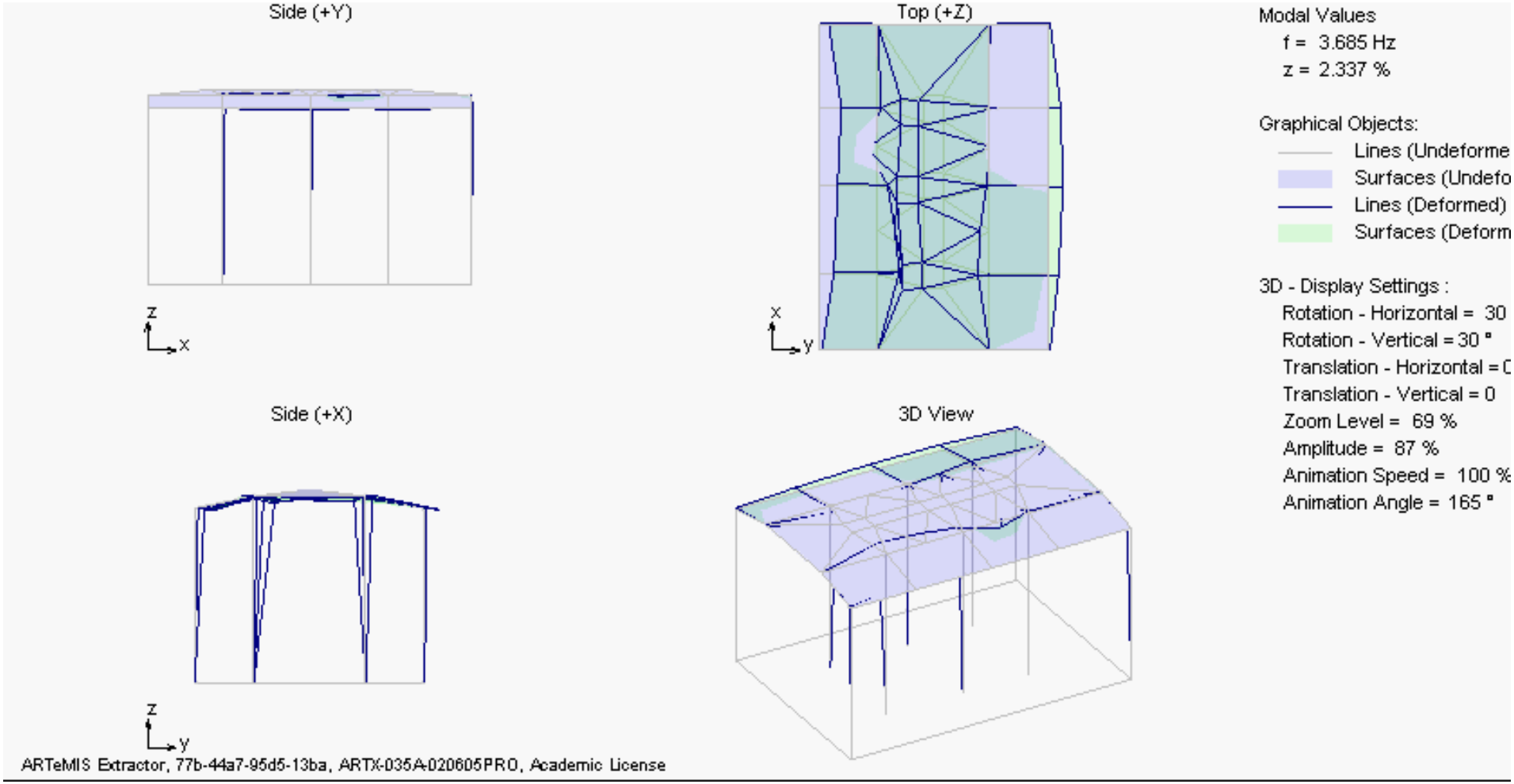




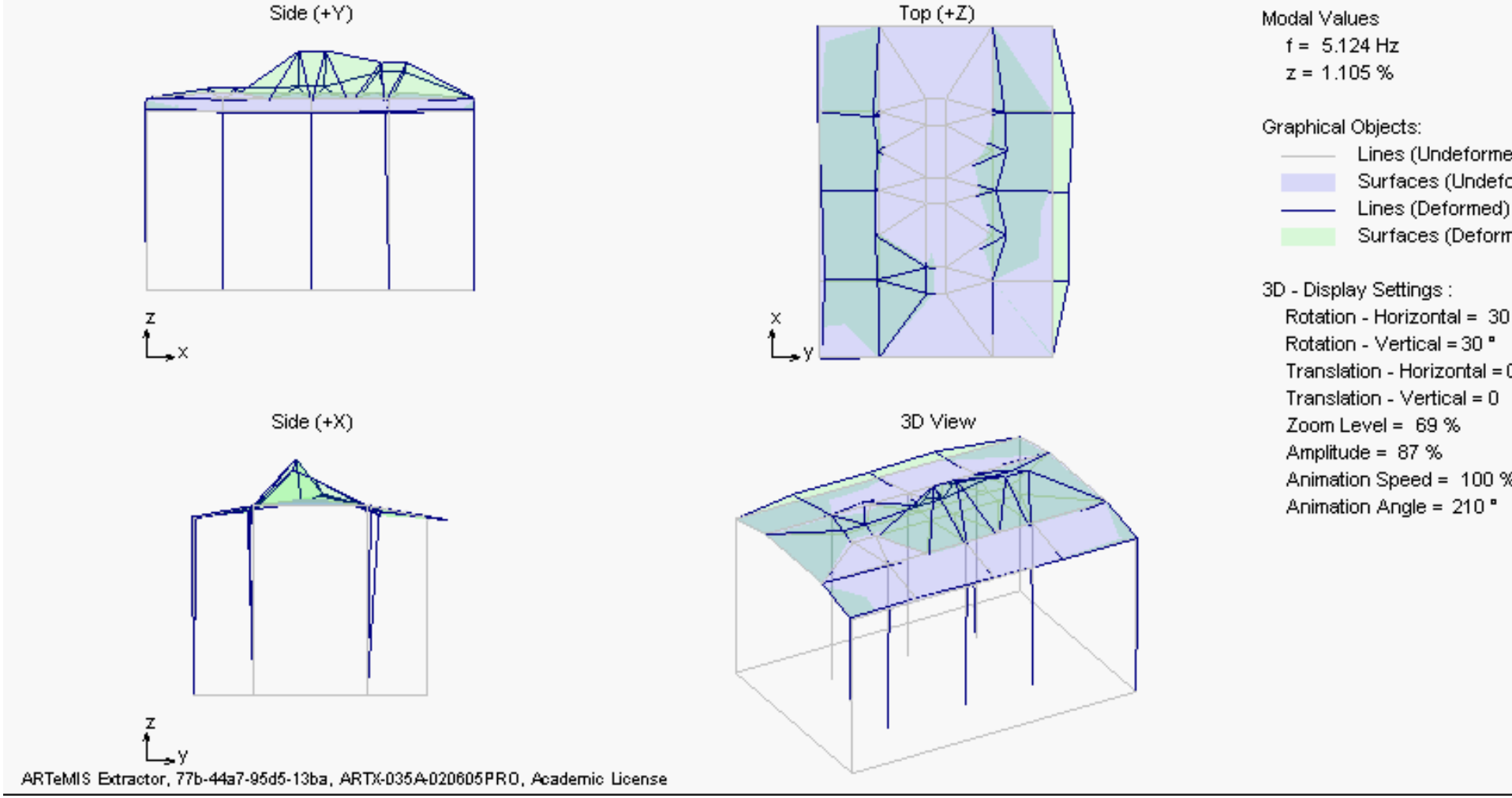
Modal Identification of the Church



Mode I


Side (+Y)
Z
X
Top (+Z)
X
y
Modal Values
f = 3.685 Hz
z = 2.337 %
Graphical Objects:
Lines (Undeforme
Surfaces (Undefo
Lines (Deformed)
Surfaces (Deform
3D - Display Settings :
Rotation - Horizontal = 30
Rotation - Vertical = 30 °
Translation - Horizontal = 0
Translation - Vertical = 0
Zoom Level = 69 %
Amplitude = 87 %
Animation Speed = 100 %
Animation Angle = 165 °
Side (+X)
Z
y
3D View
ARTeMIS Extractor, 77b-44a7-95d5-13ba, ARTX-035A-020605PRO, Academic License

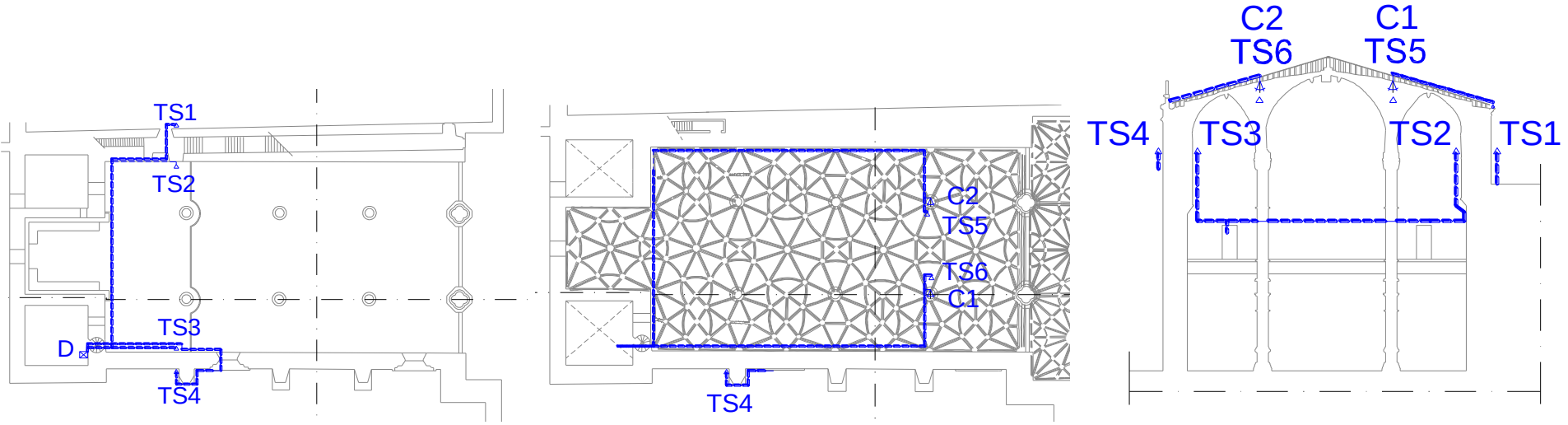
Mode II


Side (+Y)
z
x
Top (+Z)
x
y
Side (+X)
z
y
3D View
Modal Values
f = 5.124 Hz
z = 1.105 %
Graphical Objects:
Lines (Undeforme
Surfaces (Undefo
Lines (Deformed)
Surfaces (Deform
3D - Display Settings :
Rotation - Horizontal = 30
Rotation - Vertical = 30 °
Translation - Horizontal = 0
Translation - Vertical = 0
Zoom Level = 69 %
Amplitude = 87 %
Animation Speed = 100 %
Animation Angle = 210 °
ARTeMIS Extractor, 77b-44a7-95d5-13ba, ARTX-035A-020605PRO, Academic License

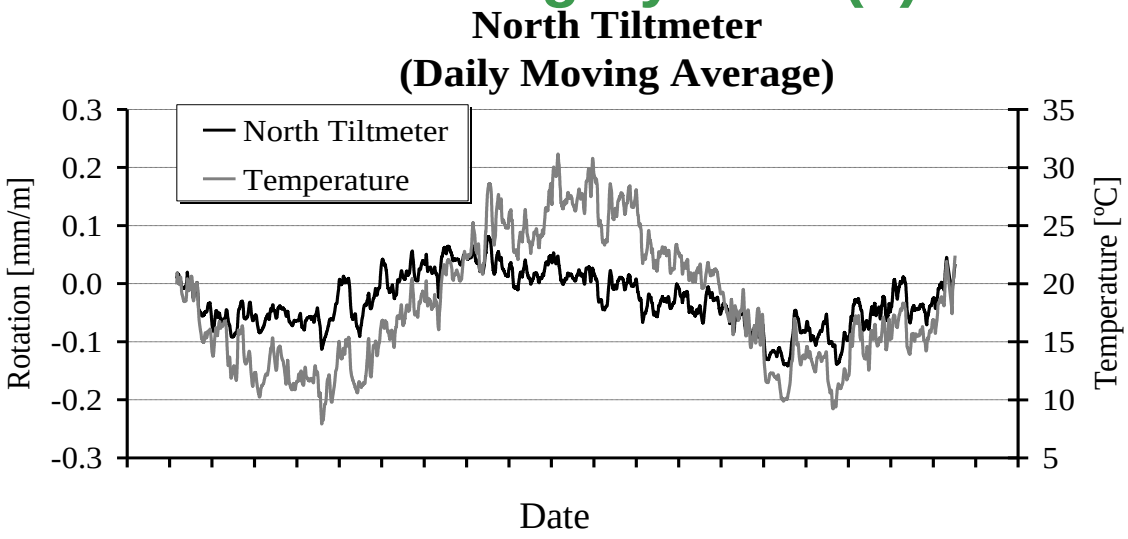
Static Monitoring System (I)

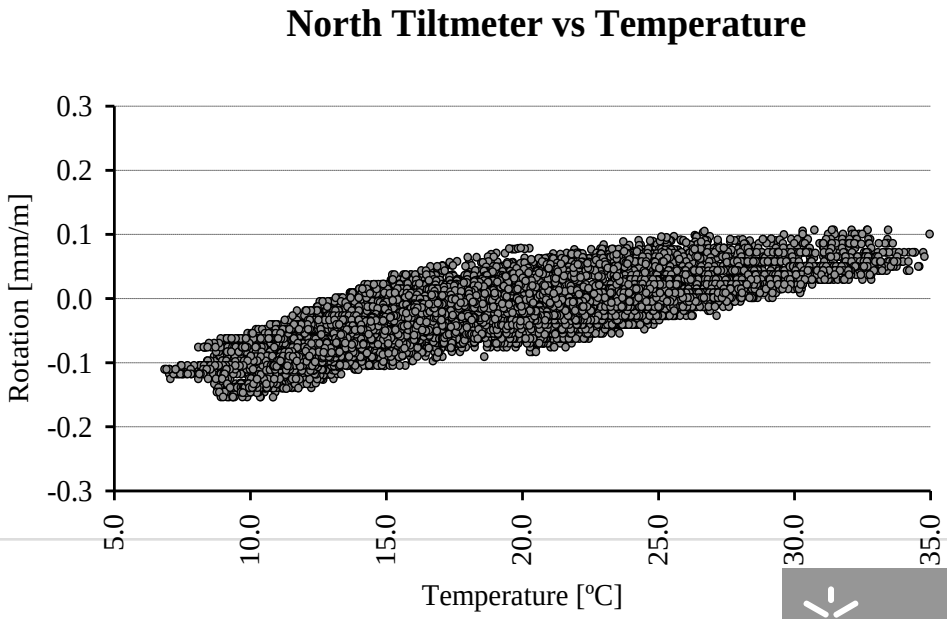
Measure deformations and temperature variations of two columns in the main nave

The system is focused on the columns structural observation, because they are the best measure of the nave structural behavior



Static Monitoring System (II)

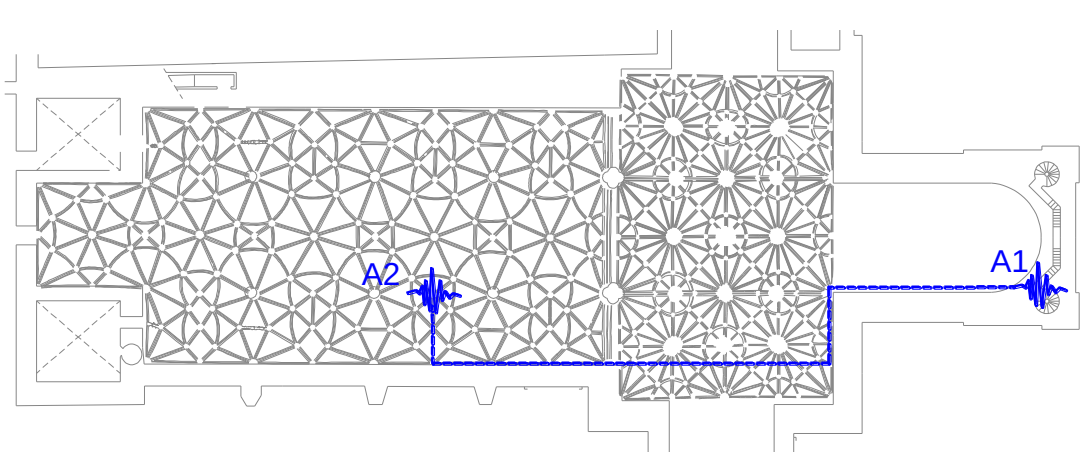


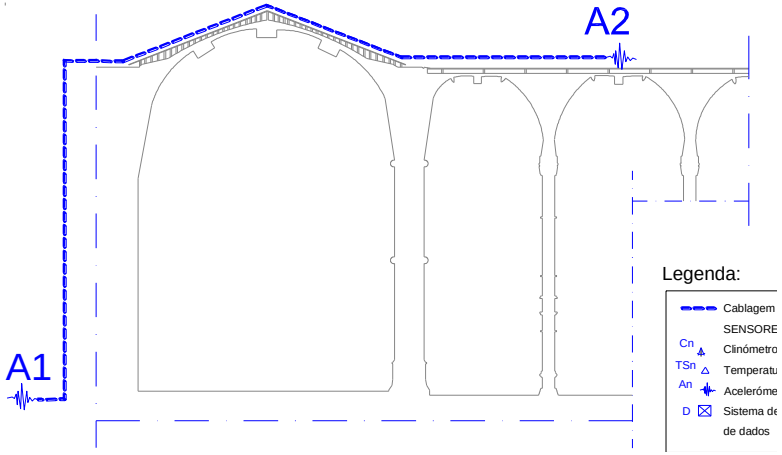


Dynamic Monitoring System (I)

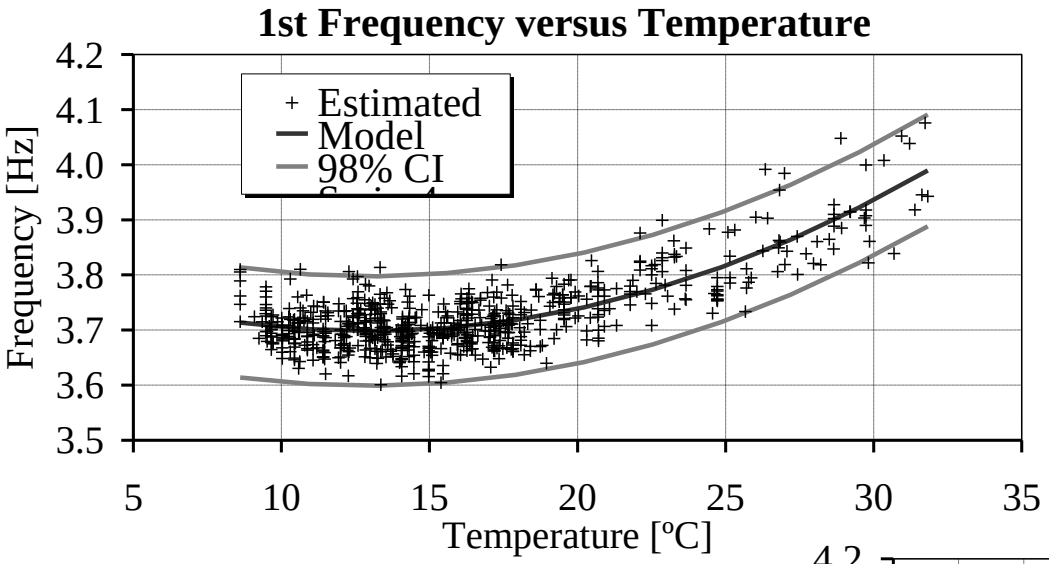
Accelerations measurements in two points: in the base and in the main nave

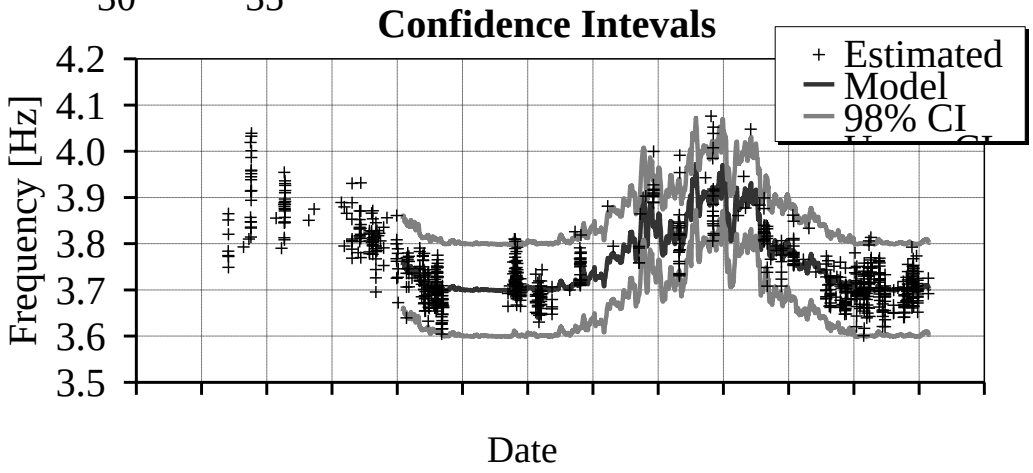
Due to the different technical characteristics and sampling rates data acquisitions, the dynamic monitoring system is physically separated from the static one.



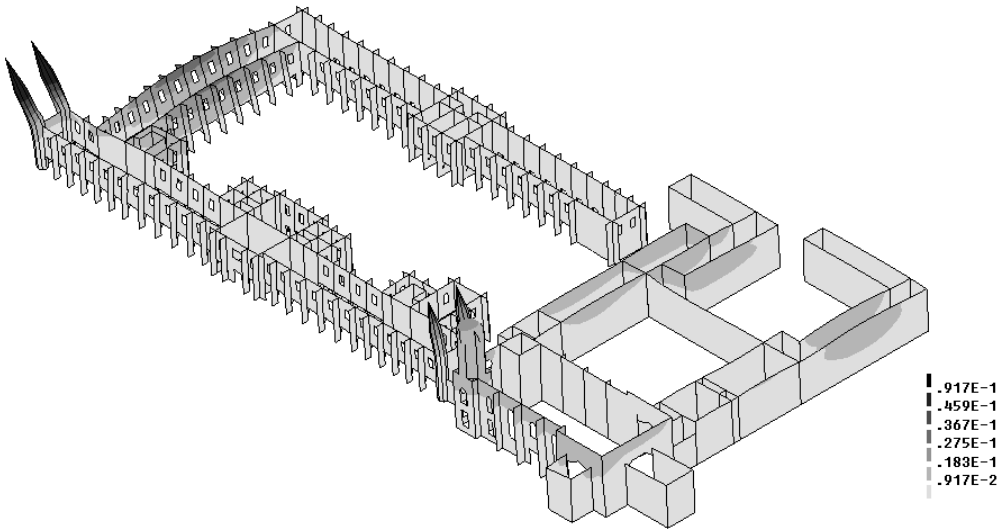


Dynamic Monitoring System (II)





Full Building Analysis

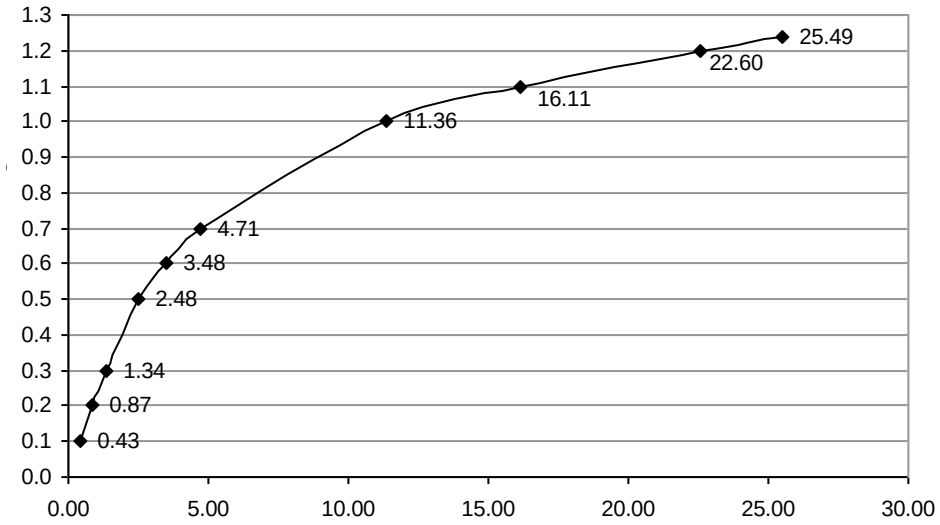


Deformed mesh

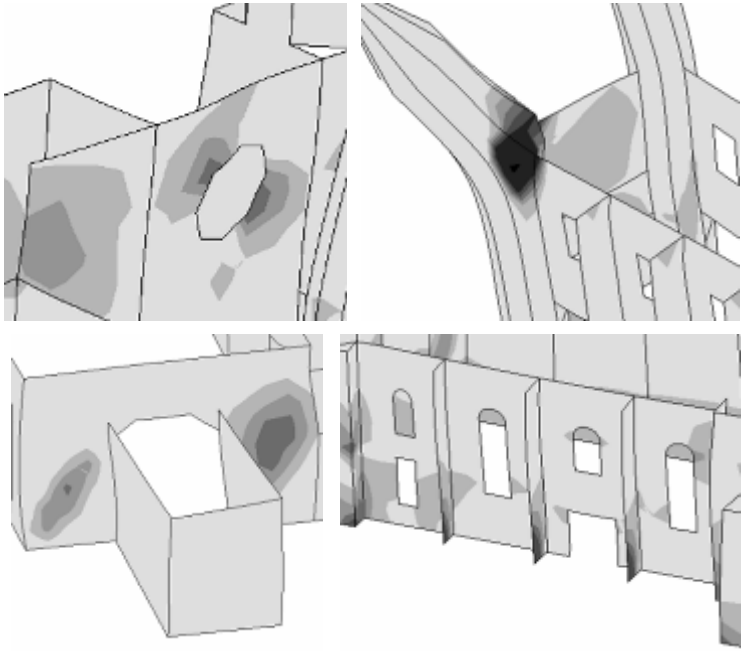
Full model with 135.000 dof

Modal superposition

Non-linear with equivalent static loading

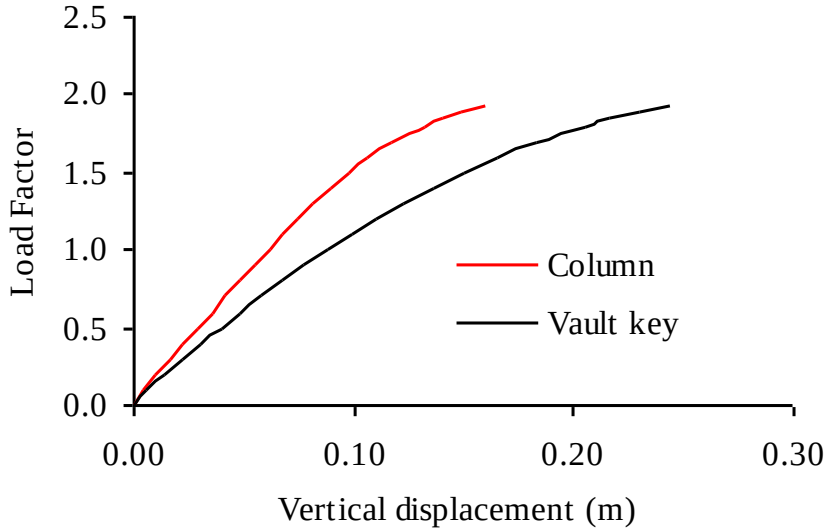


Load-displacement diagram



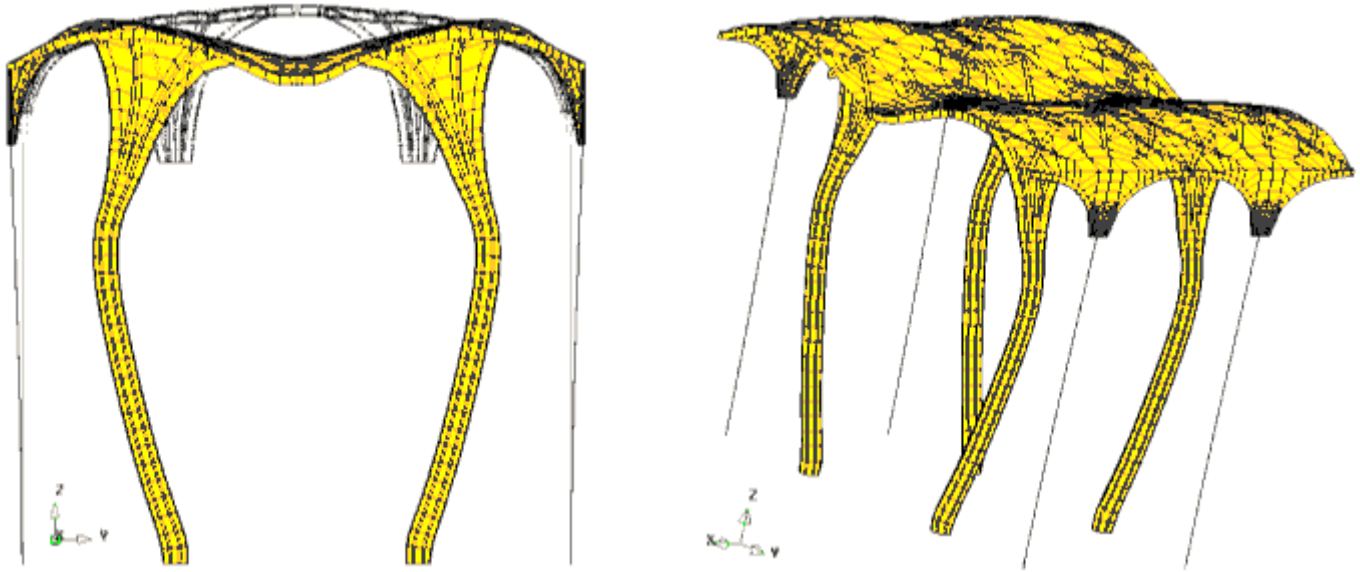
Details

Nave Analysis



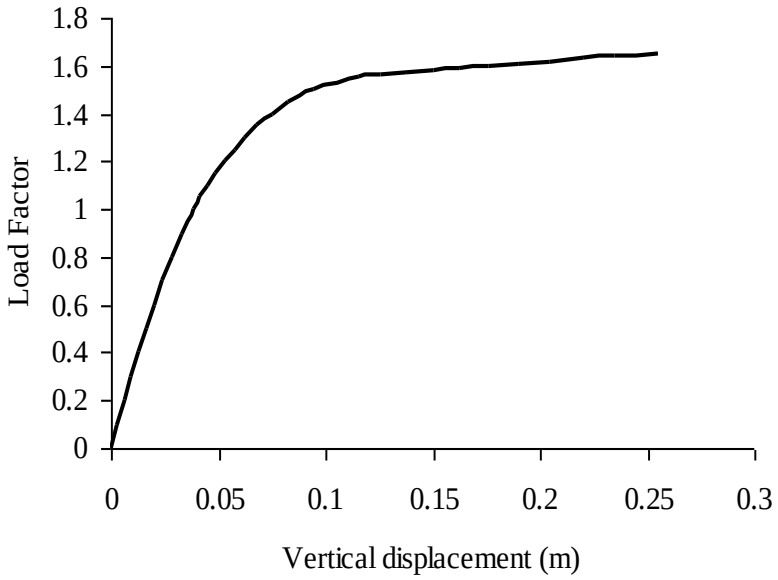
Load displacement diagram

Non-linear Analysis:
Loading = Self-weight
f_t = 0
$f_{c,\ masonry}$ = 6 N/mm²
$f_{c,\ infill}$ = 1 N/mm²

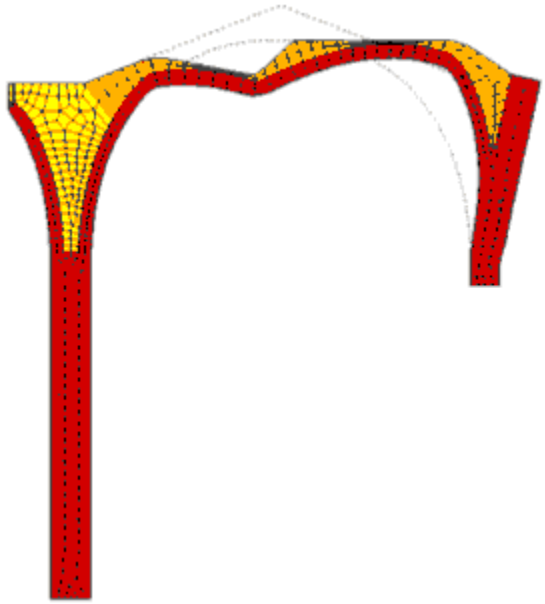


Incremental deformed mesh

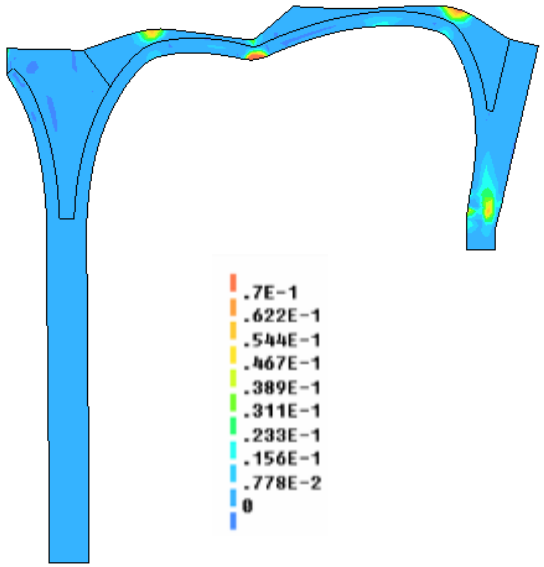
Transept Analysis



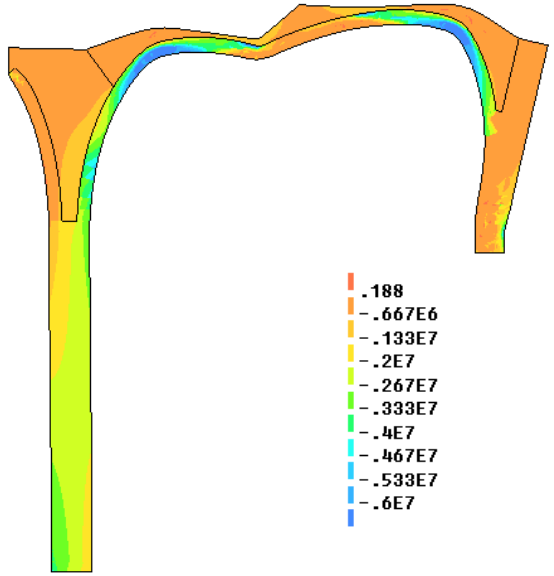
Load-displacement diagram



Incremental deformed mesh



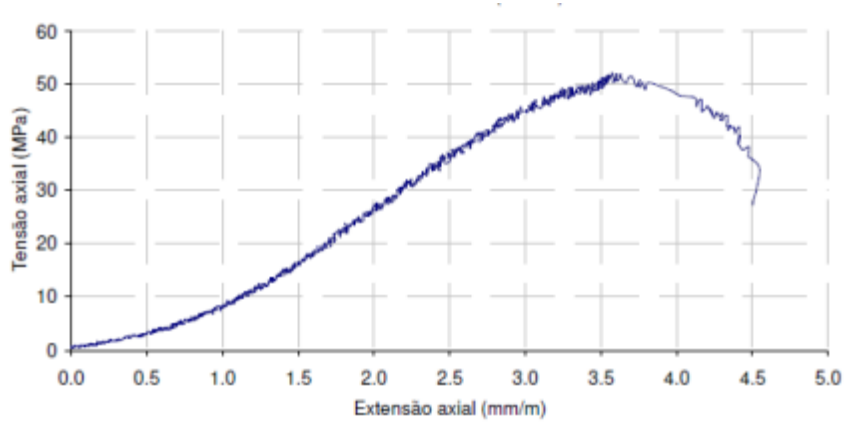
Max. principal strains



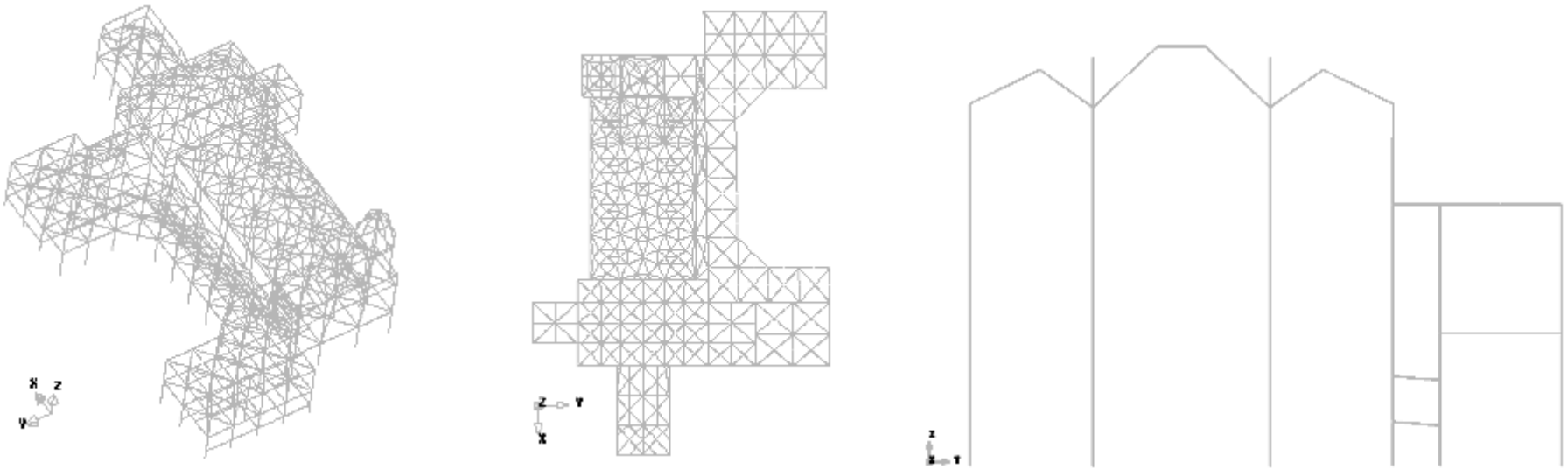
Min. principal stresses

Laboratory Testing

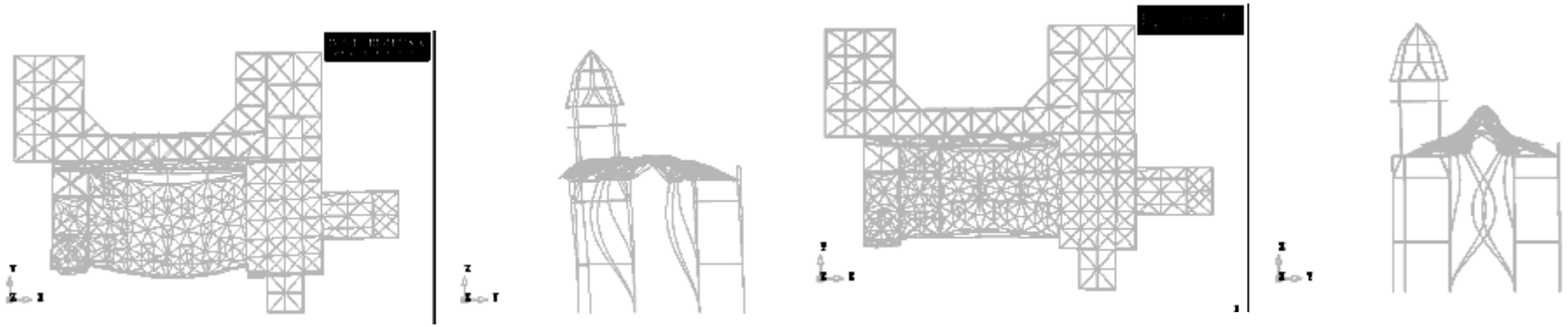
Stone and masonry testing



Model for Dynamic Analysis

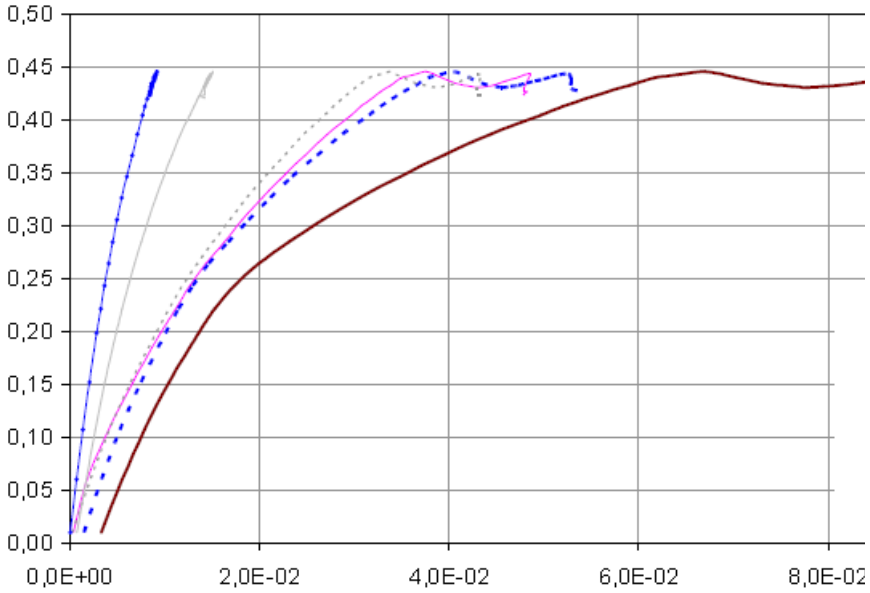


3D beam element model

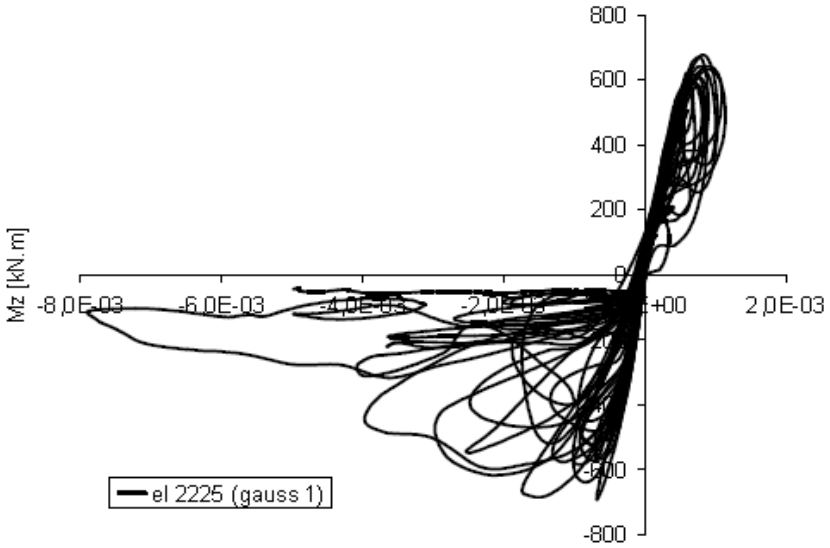


Calibration of the model – Dynamic identification

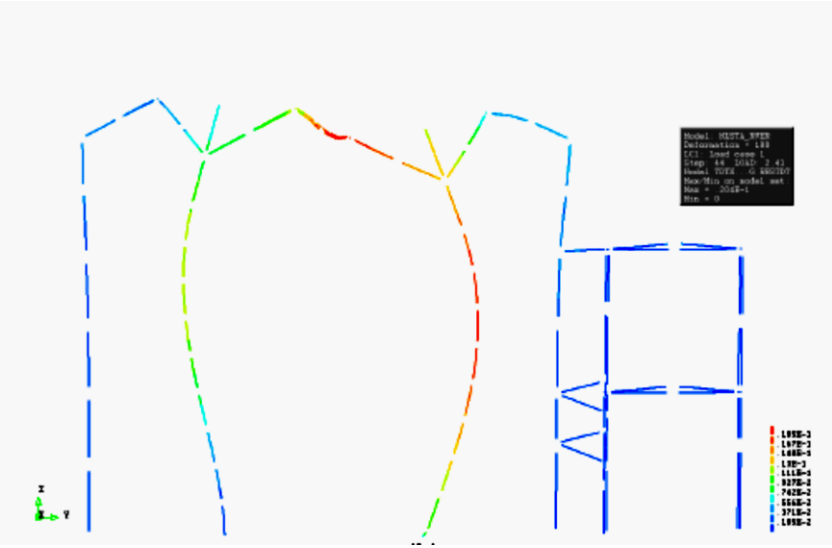
Results



Seismic action vs. horizontal displacement envelop for different nodes

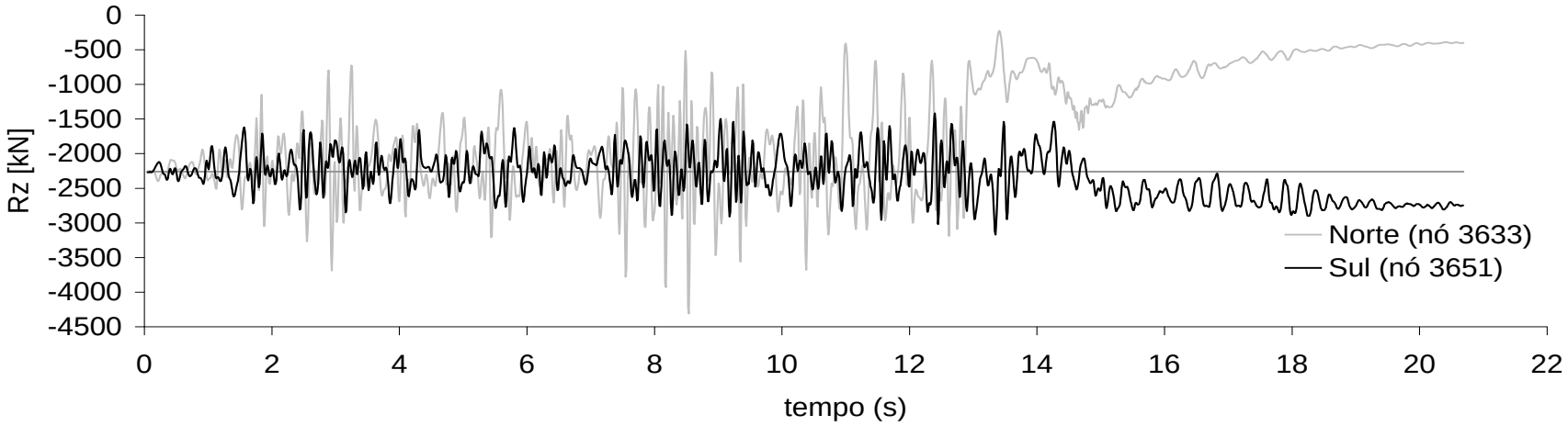


Example of column response in dynamic analysis

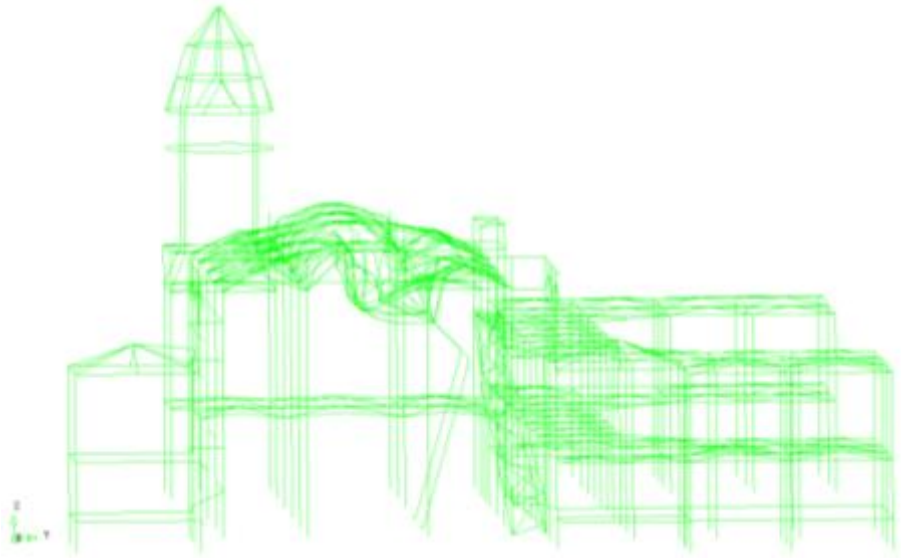


Example of collapse mechanism

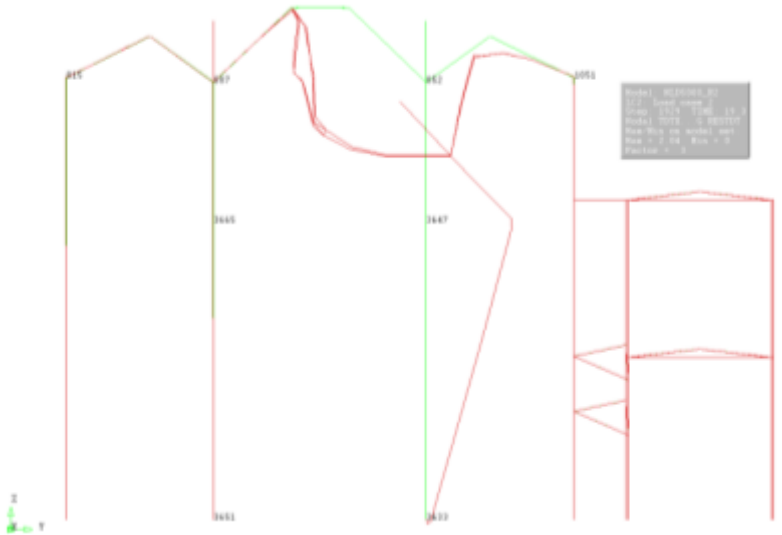
5000 yrp earthquake



Vertical reaction in the columns

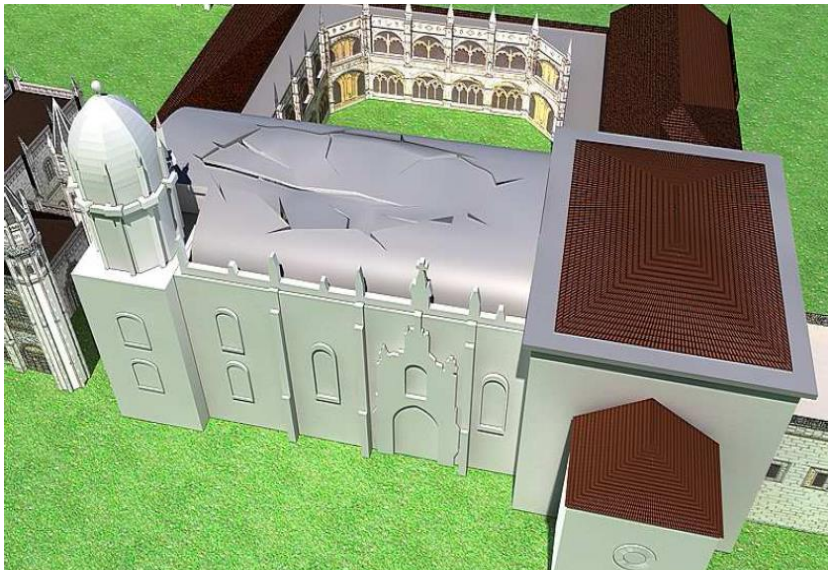


General view of the failure mechanism

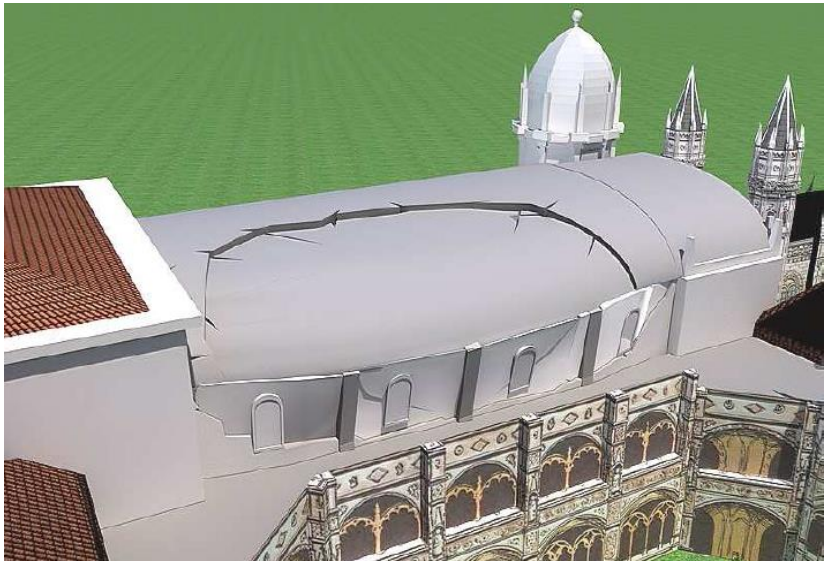


Failure mode for the church

Virtual Collapse Mechanisms



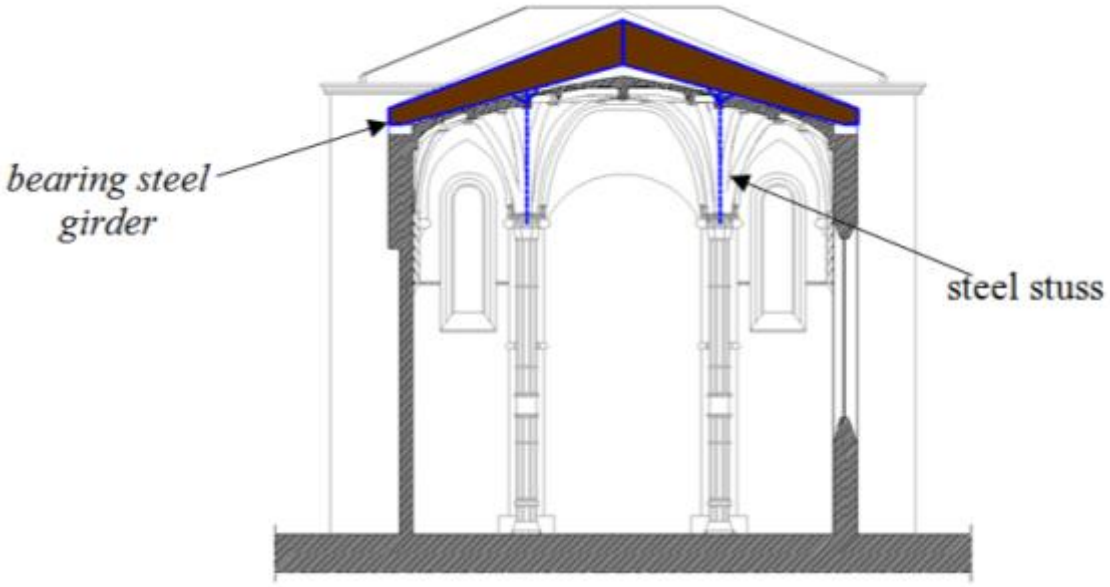
Vertical loading



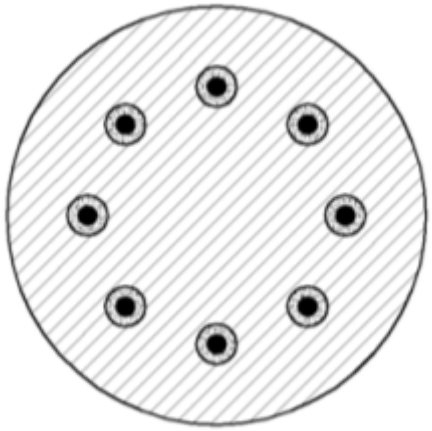
North façade

South façade

Possible Strengthening Measures



1: Pre-stress the columns
2: Load transfer
3: Increase column strength



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