MONITORING SYSTEMS & STRATEGIES

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CONTENTS

(A) SHM systems installed in CH buildings in "operating" conditions

AIMs: 1) to assess the actual structural response of reference behavioral models;
2) to identify ongoing damage processes;
3) to validate strengthening intervention already carried out;
4) to reduce/calibrate strengthening interventions (observational method)…

(B) SHM systems installed in CH buildings damaged following a major seismic event

AIMs: 1) prioritization of the interventions;
2) to ascertain the stationariness of the observed damage;
2) to validate provisional strengthening intervention;
3) as early warning for the most endamaged structures during the strengthening intervention….

Cases studies

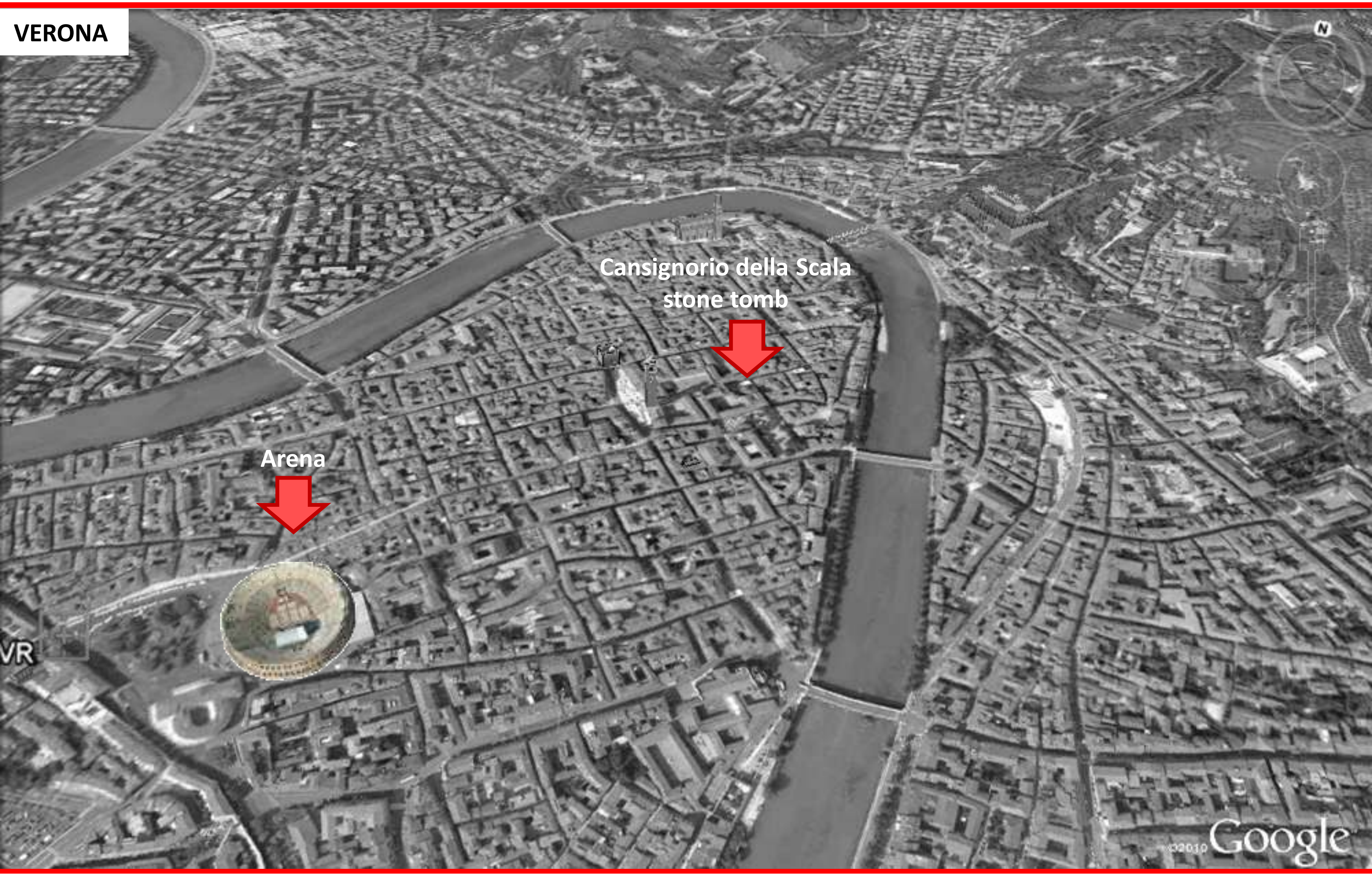
(A)

- *Cansignorio della Scala stone tomb in Verona*
- *Arena of Verona*
- *Frari bell tower*
- *Qutb Minar – New Delhi, India*
- *St. Sofia church in Padua*
- *Bertoliana library in Vicenza*
- *Cappella degli Scrovegni in Padua*
- *Conegliano Cathedral, Treviso*
- *David Tower, Old Jerusalem, Israel*

(B)

- *Spanish Fortress in L'Aquila*
- *St. Marco church in L'Aquila*
- *St. Biagio d'Amiterno & St. Giuseppe dei Minimi in L'Aquila*
- *St. Agostino church in L'Aquila (Nagoya University)*
- *St. Silvestro church in L'Aquila (Nagoya University)*
- *Civic Tower in L'Aquila (Nagoya University)*

VERONA



CANSIGNORIO DELLA SCALA STONE TOMB

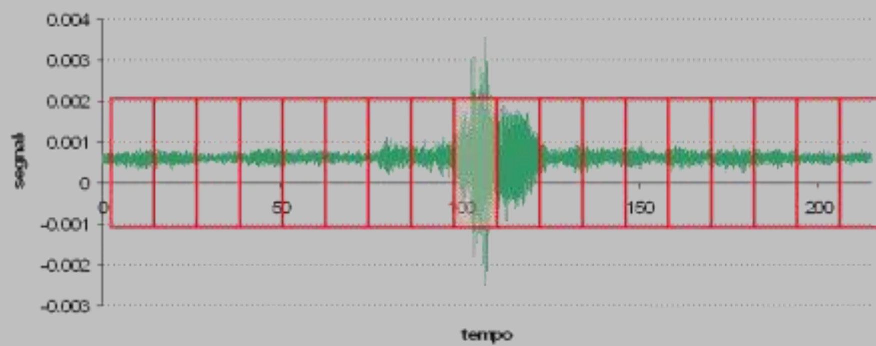
INSTALLED SENSORS (Dec 2006)

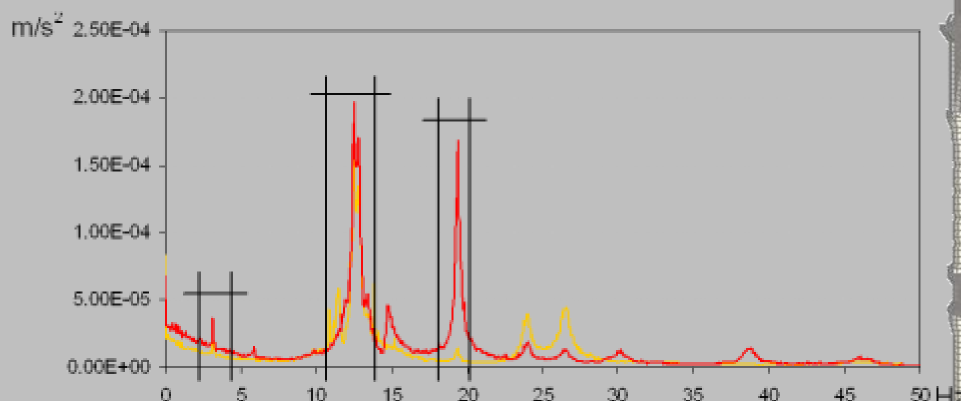
6 single axis accelerometers

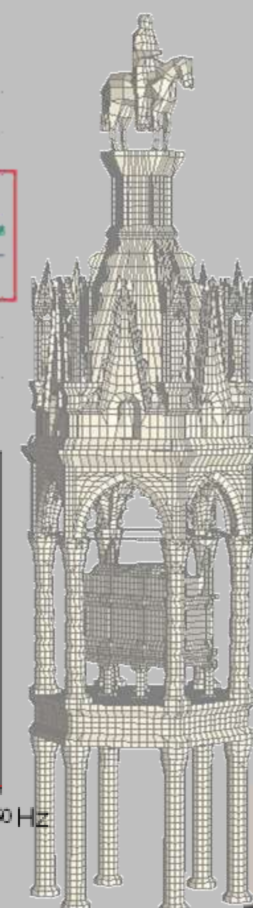
1 Temperature + RH sensor

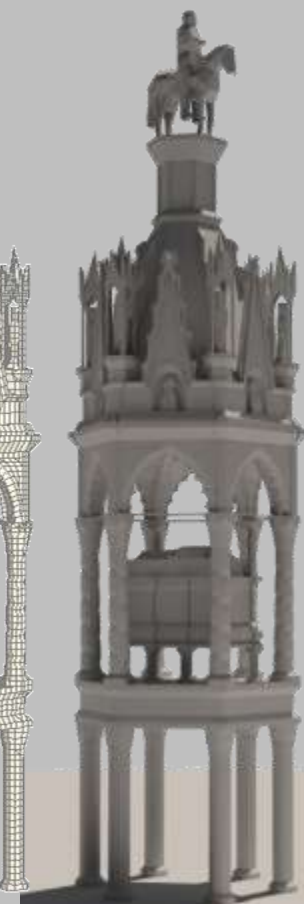
2 LPDT (crack detection)

1 - Design of a static & dynamic SHM system on the Cansignorio stone tomb – Nov 2005;
2 - FE modeling of the stone tomb after the Laser Scanning technique – Mar 2006;
3 - Dynamic – Jun 2006;
4 - Installation of the static & dynamic SHM system on the Cansignorio stone tomb – Dec 2006;

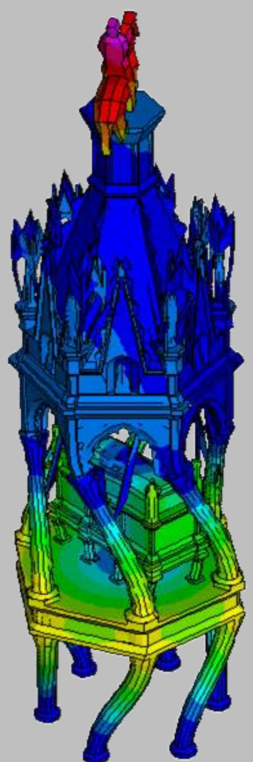


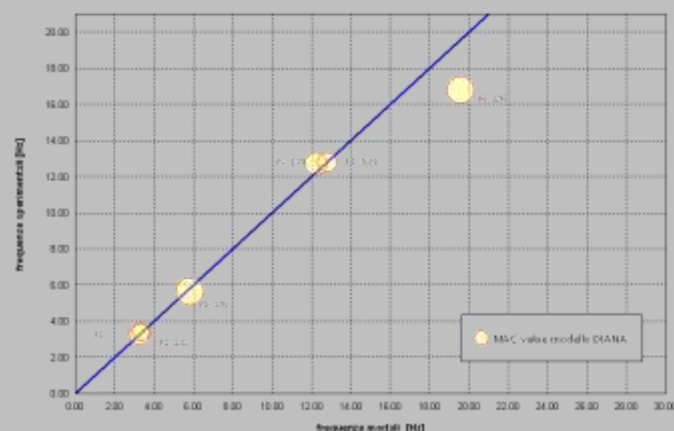


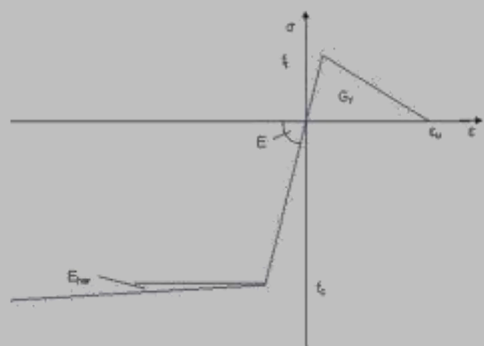


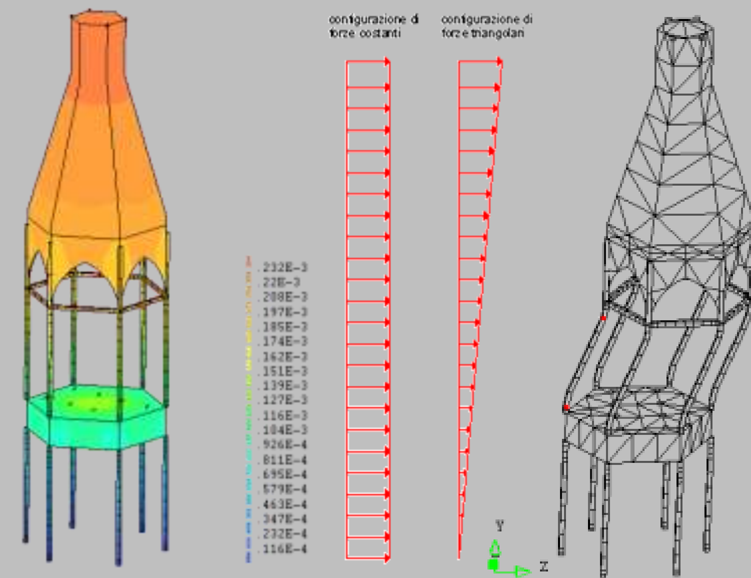


Linear & non linear FE models creation for the safety state of the monument assessment on the bases of the experimental activities and SHM

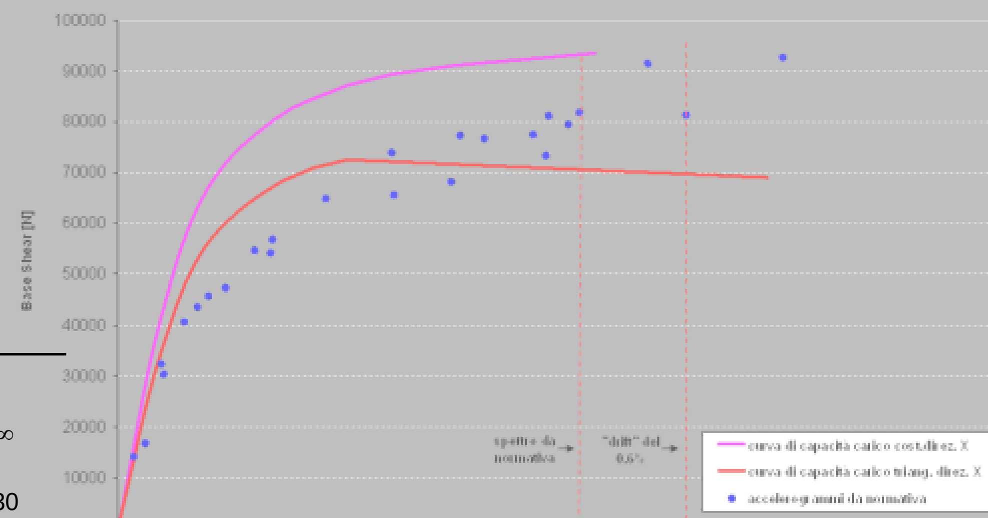






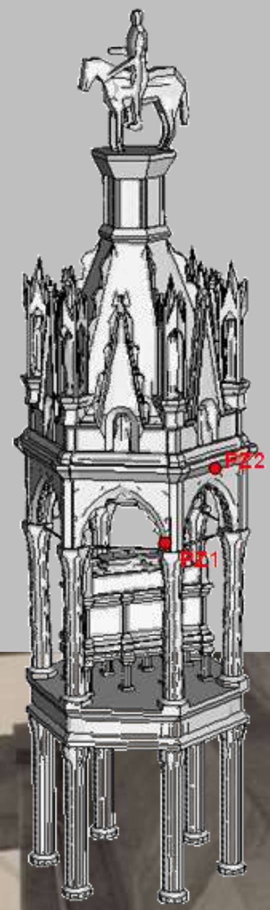


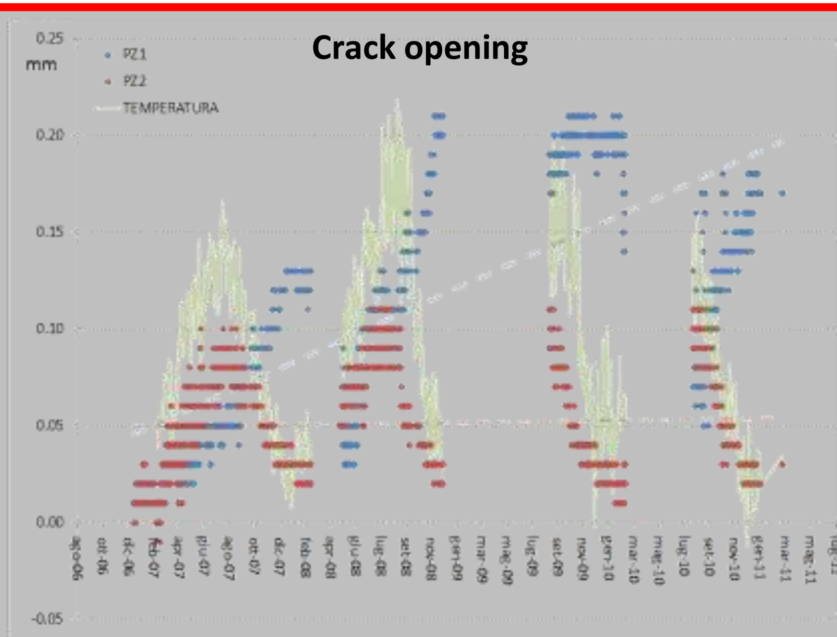
Tensile strength	f_t	[MPa]	0.1	0.2	0.3	0.5	
Fracture energy	G_f	[J/m^2]	10	20	50	100	∞
Compressive strength	f_c	[MPa]	3	5	10	20	30

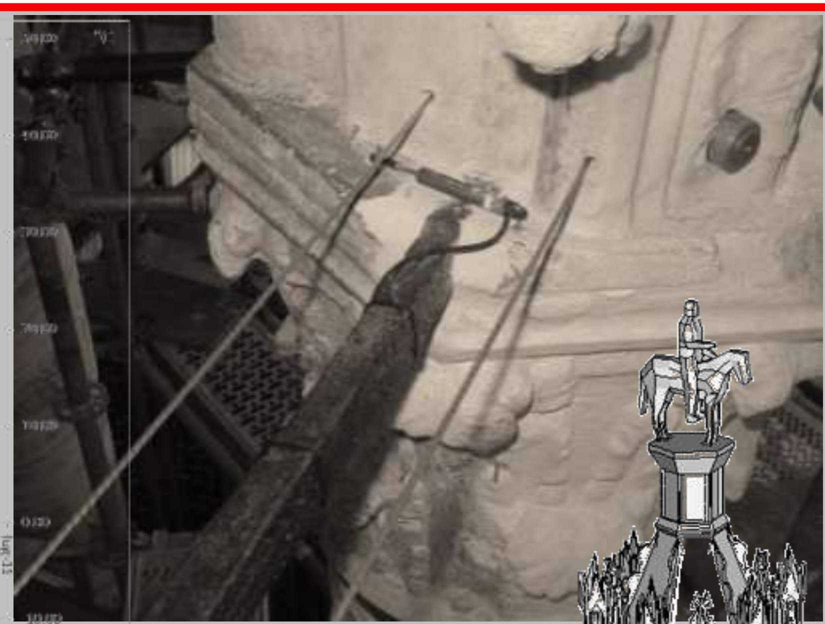


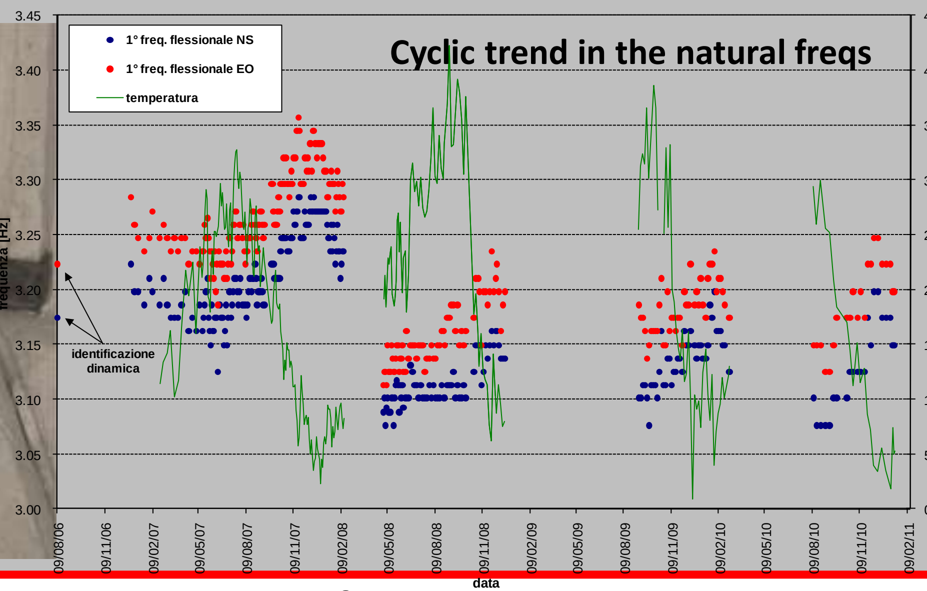
Monitoring Systems & Strategies

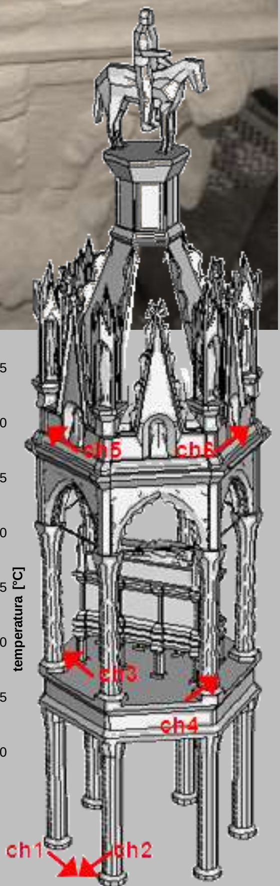
Prof. Claudio Modena



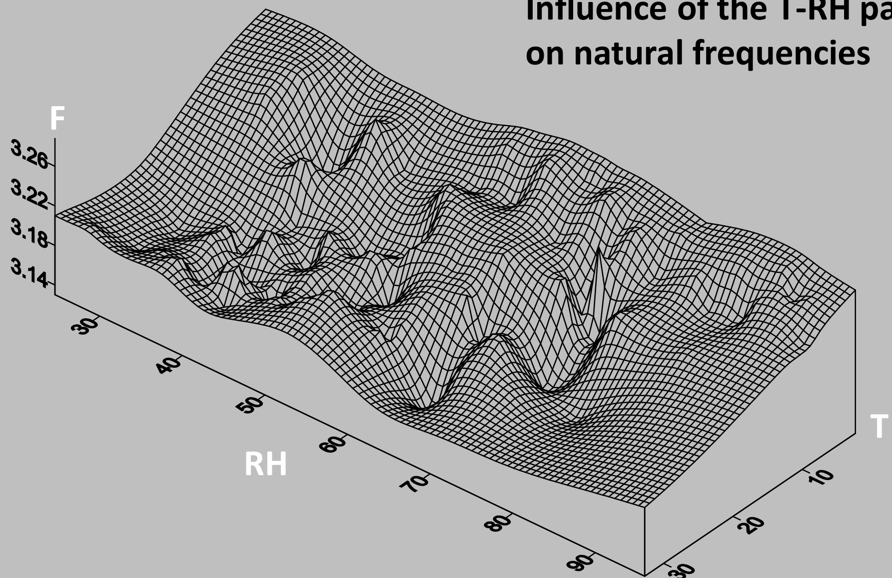




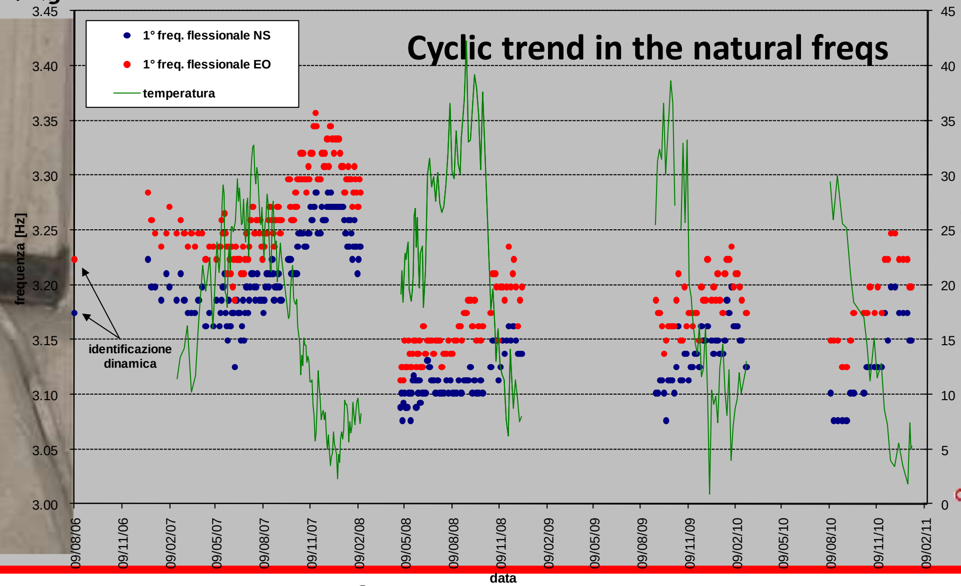




Influence of the T-RH parameters on natural frequencies



Cyclic trend in the natural freqs



Linear & non linear FE models creation for the safety state of the monument assessment on the bases of the experimental activities and SHM

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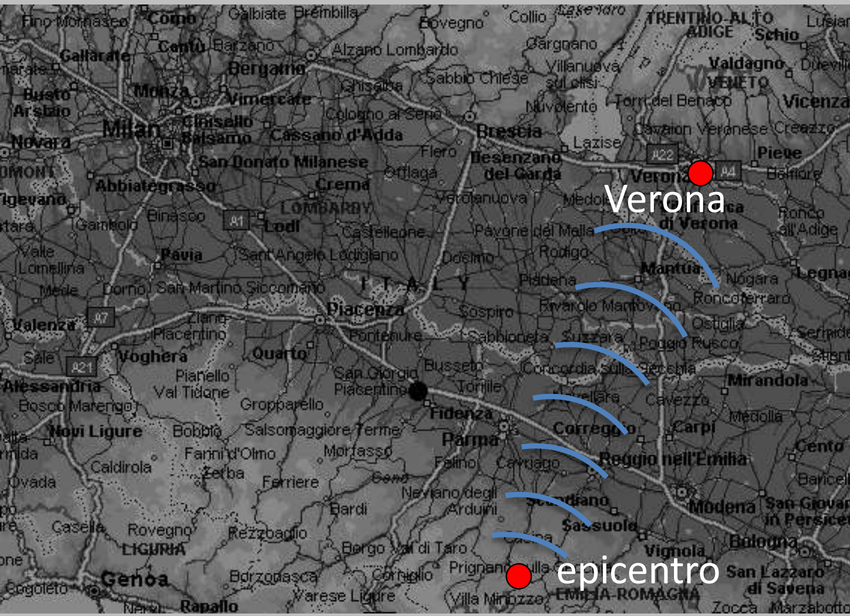
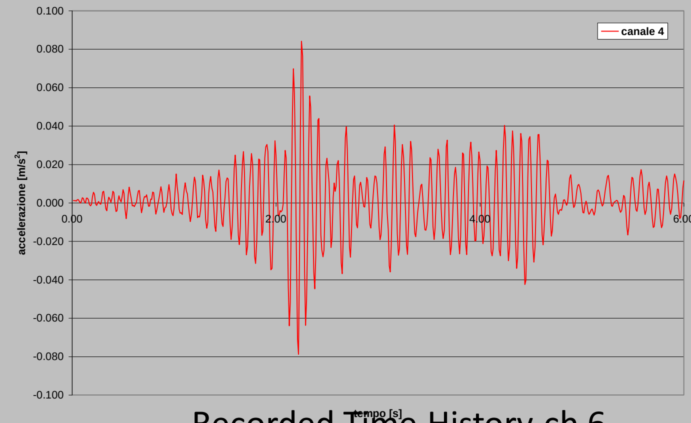
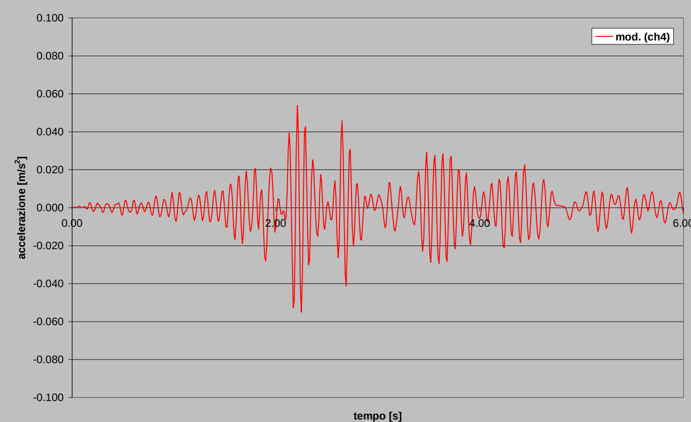
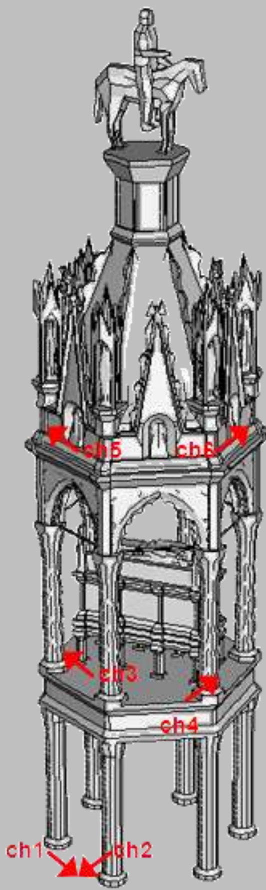




Recorded Time History ch 6





Model updating to match the recorded accelerations

Corresponding accelerations of the non linear FE model under dynamic analysis, by using the recorded ground motion as analysis input

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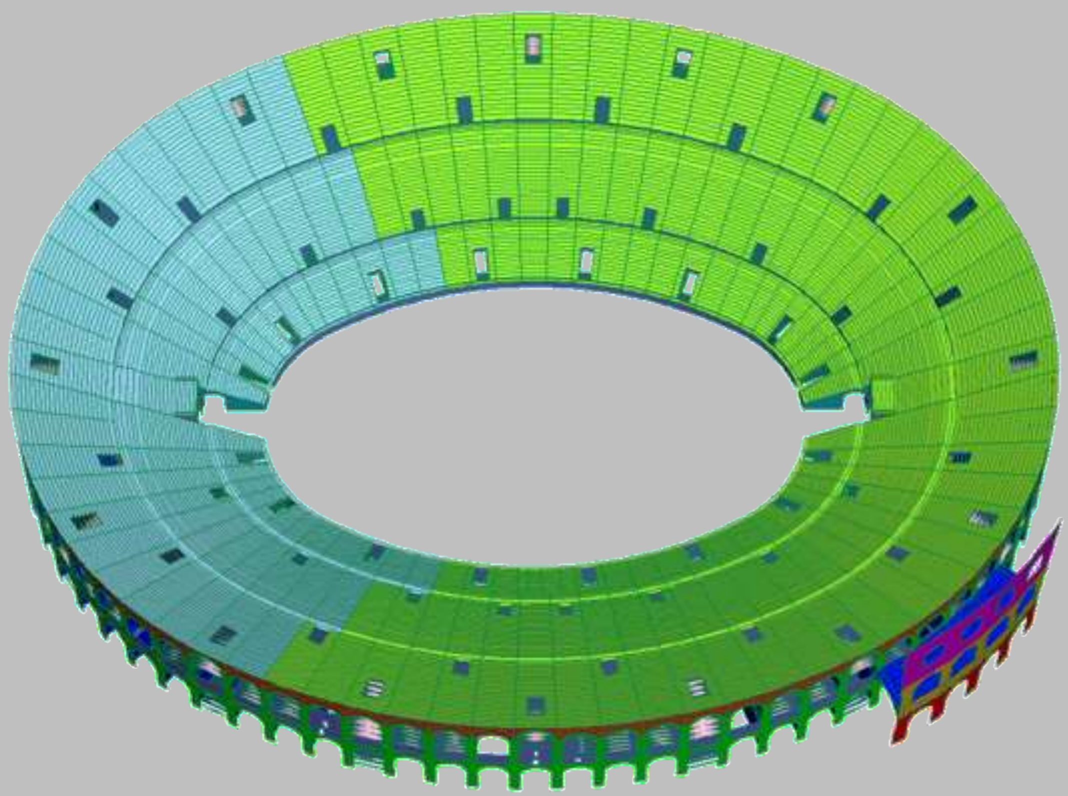
ARENA OF VERONA

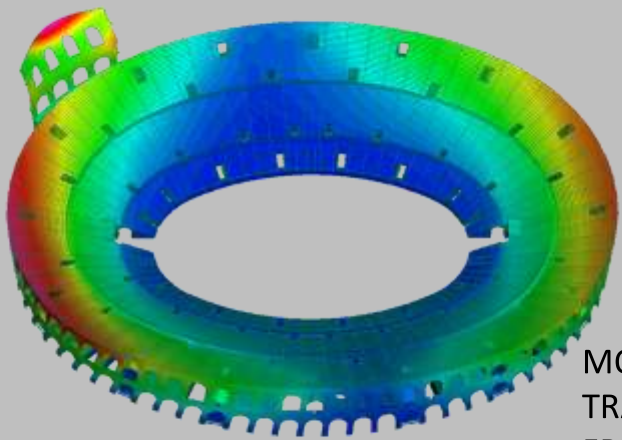
INSTALLED SENSORS (2010-11)
16 single axis accelerometers
4 Temperature + RH sensor
20 LPDT (crack detection)

Because of the complexity and huge dimensions of the monument, for simplification reasons the masonry was modeled as a isotropic, homogeneous and continuum material, with linear elastic constitutive law.

3-4 nodded 2D elements were employed (plates): such approximation was considered the most appropriate since the structural elements of the Arena (walls and vaults) have a prevailing 2D layout.

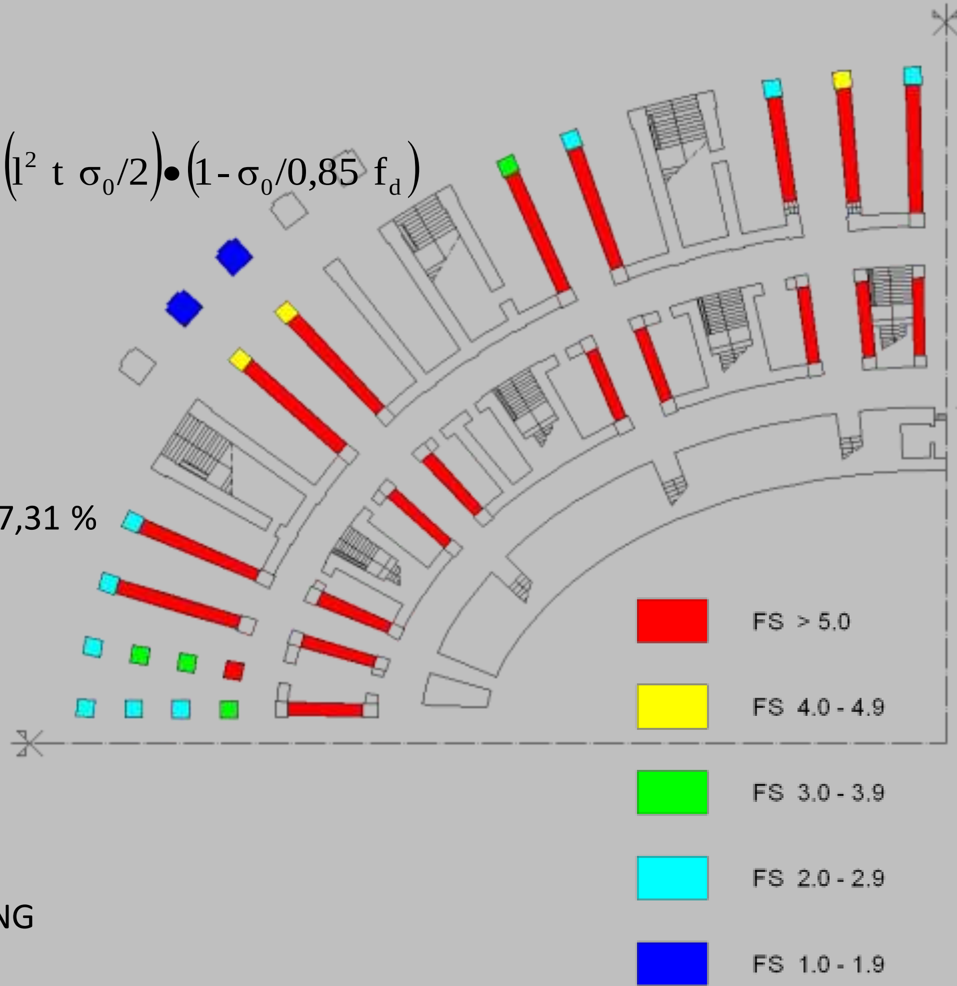


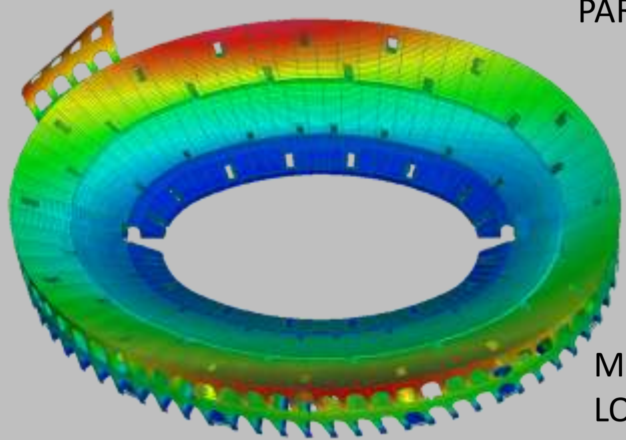
Natural Frequency Analysis was considered in order to assess the eigenmodes and values, and subsequently to Spectral Response Analysis. Safety requirements are met for the walls resisting skeleton of the Arena.



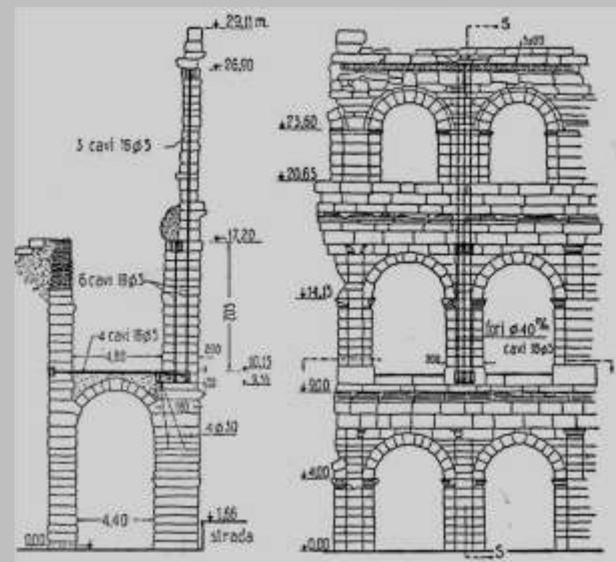
MODE 5
TRANSVERSE BENDING
FREQ: 5,30 Hz
PARTICIPATING MASS: 37,31 %

$$M_u = \left(l^2\ t\ \sigma_0/2\right)\bullet\left(1-\sigma_0/0{,}85\ f_d\right)$$

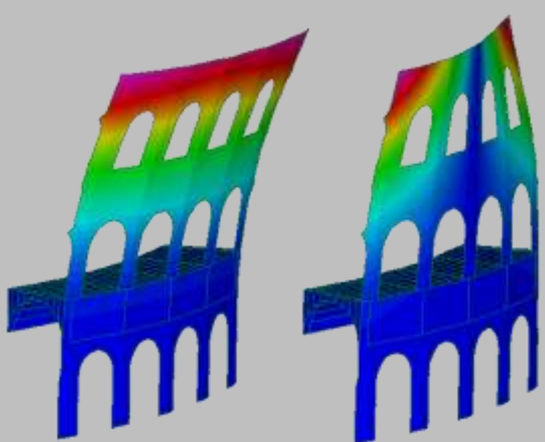


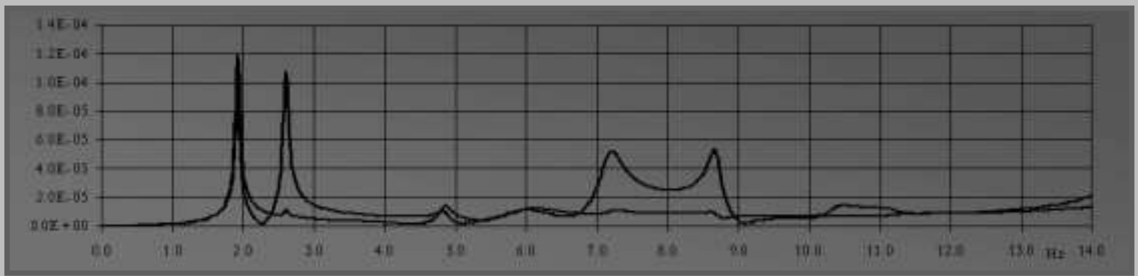


MODE 6
LONGITUDINAL BENDING
FREQ: 5,56 Hz
PARTICIPATING MASS: 52,19%

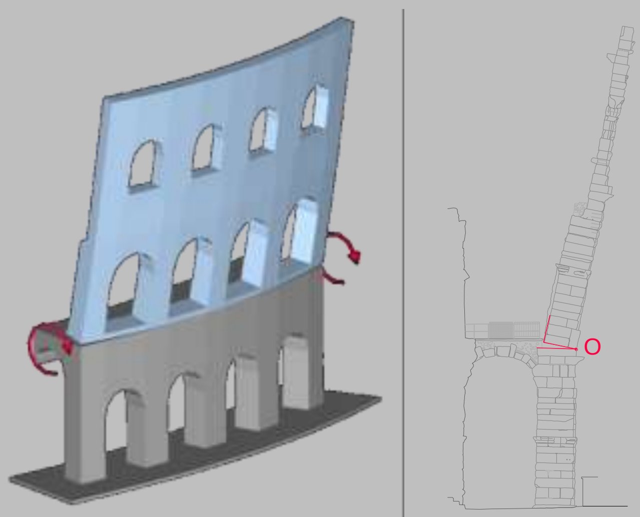


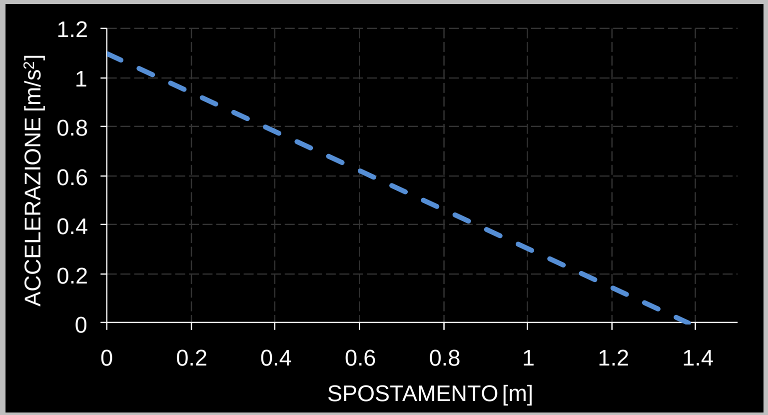
MODE n°	EXP FREQ [Hz]	FEM FREQ [Hz]
1	1,92	1,68
2	2,61	2,42
3	4,83	4,91
4	5,87	5,89
5	6,10	6,20
6	7,10	7,18



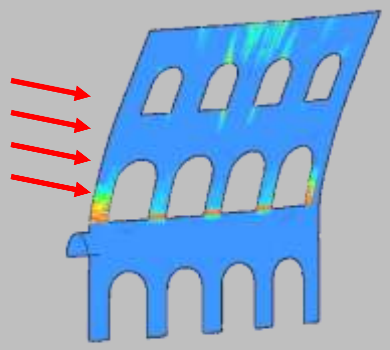


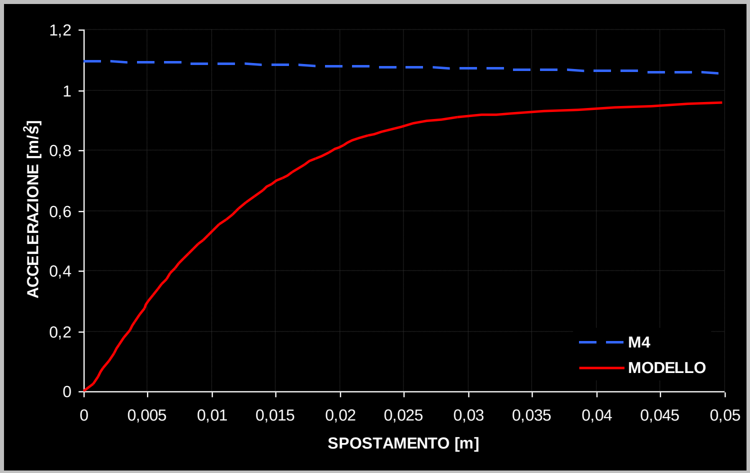
The so called "wing" of the Arena must however studied more in detail





KINEMATIC MODEL



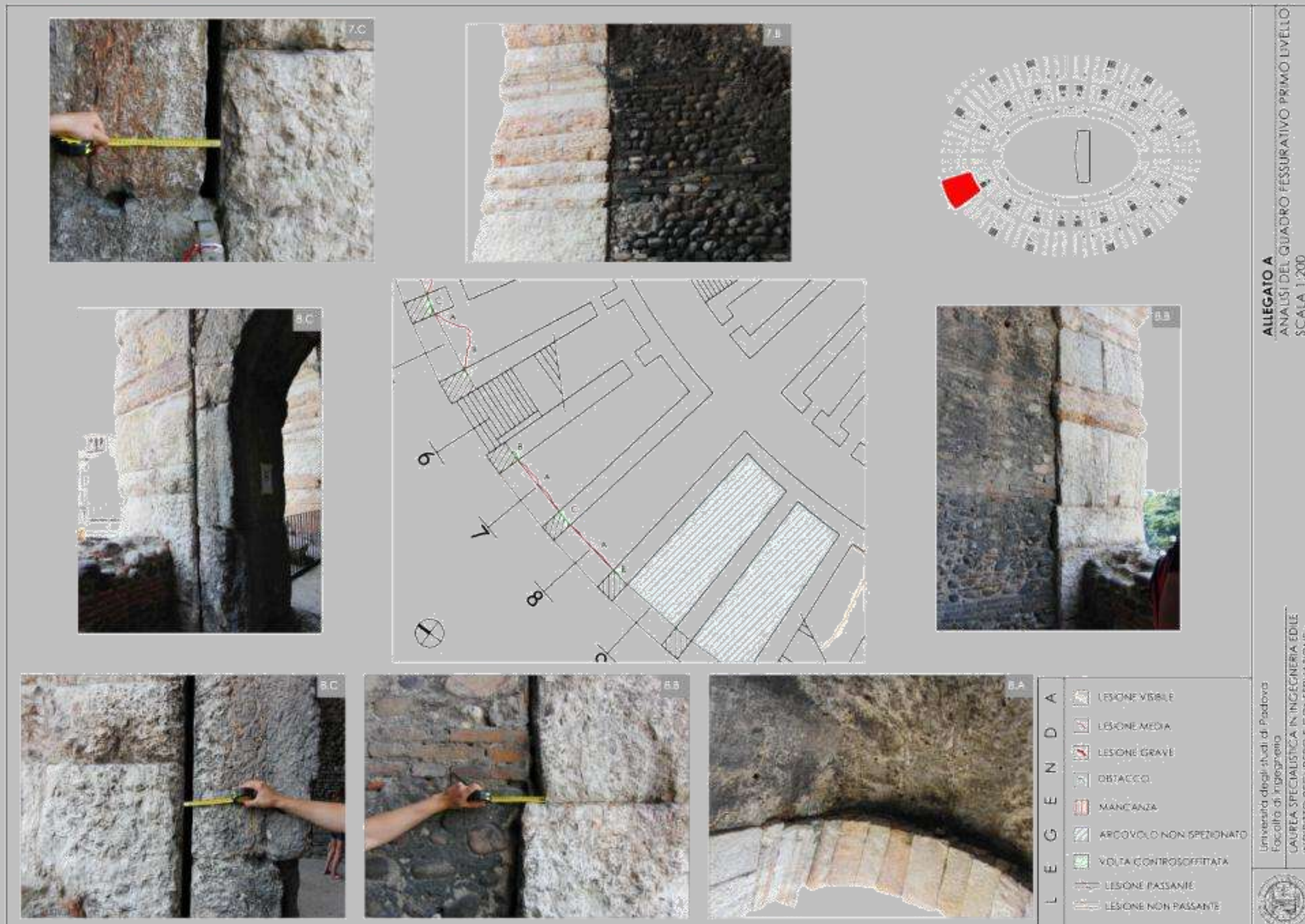


FE NON LINEAR

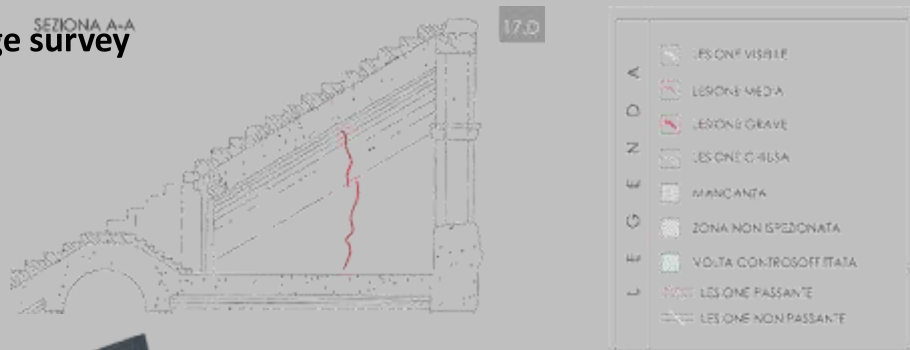
ISRAEL ANTIQUITIES AUTHORITY רשות העתיקות

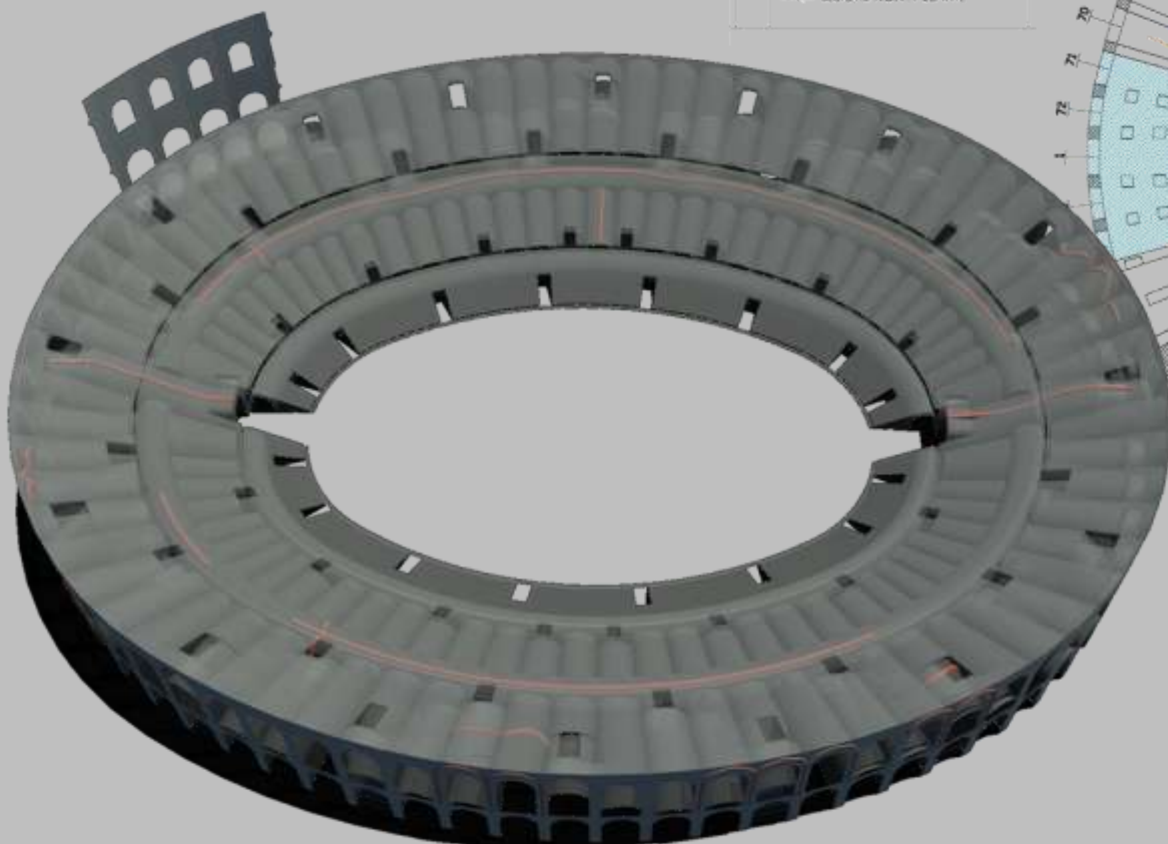
NIKER

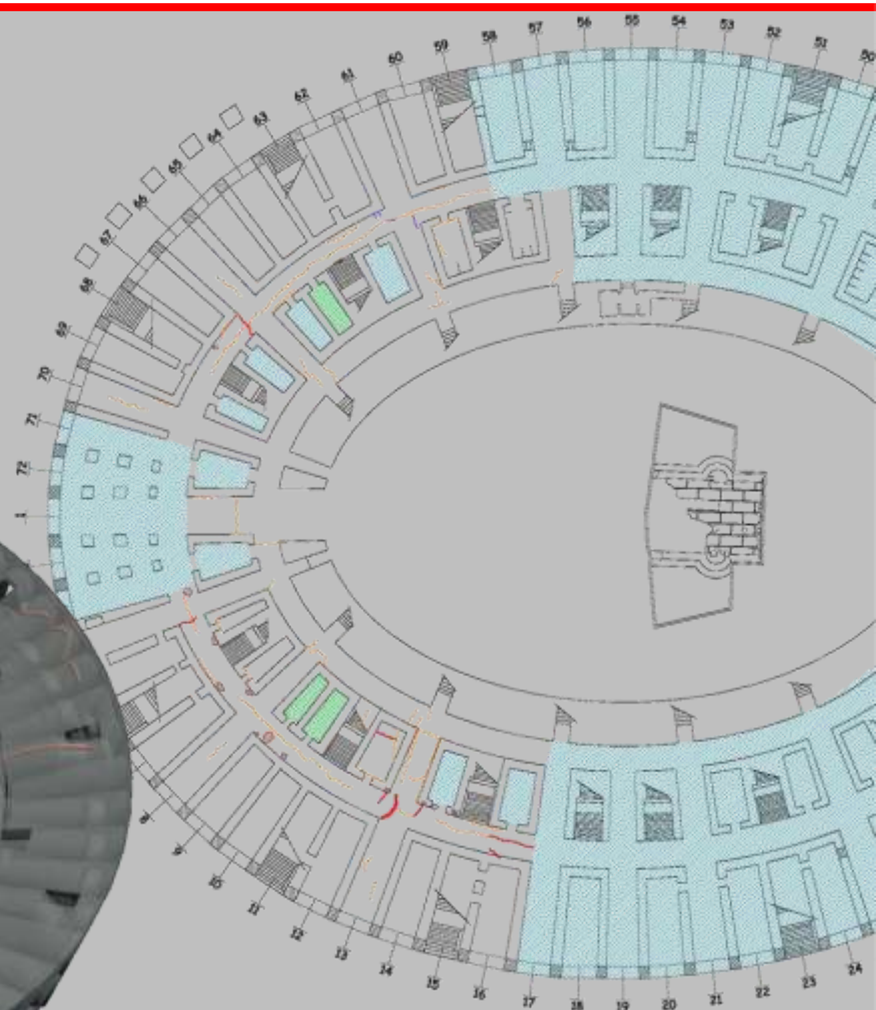
Damage survey forms



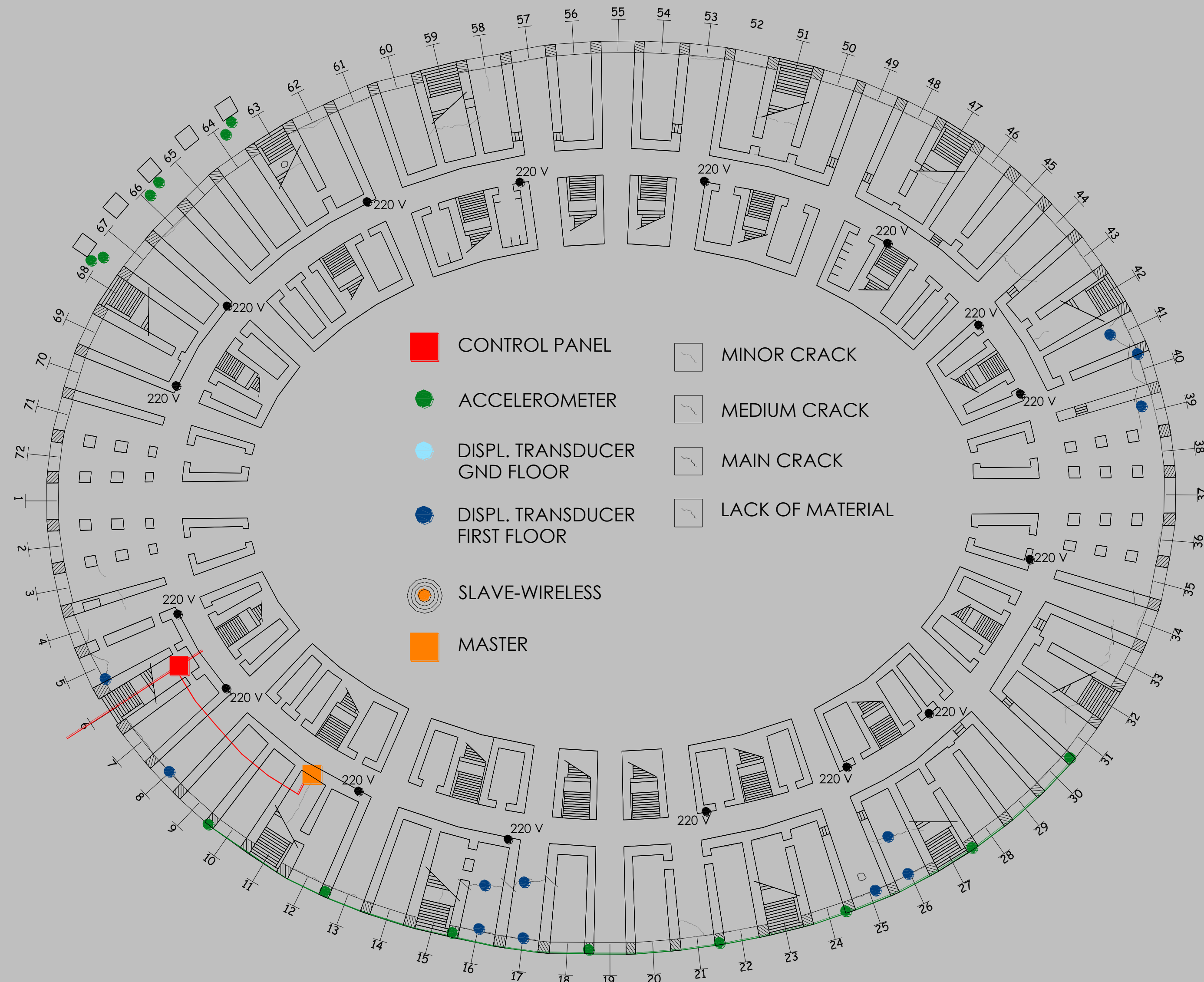
Damage survey forms



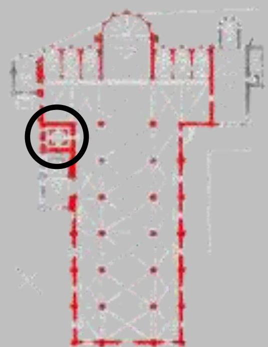


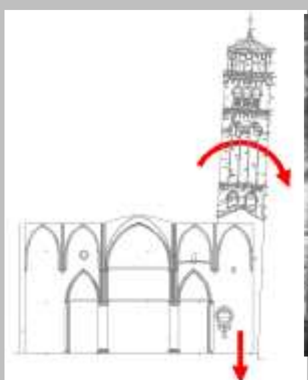


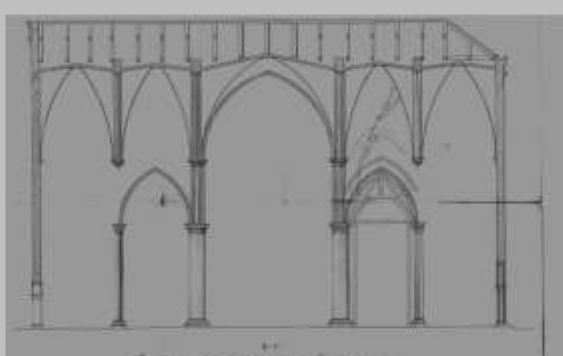
MONITORING SYSTEM GND FLOOR



INVESTIGATION AND MONITORING FOR THE DESIGN OF A STRENGTHENING INTERVENTION ON THE FRARI BASILICA – VENICE







The **Frari bell-tower**, built between 1361 and 1396, with its 9.50 m wide base side and **65.00 m tall**, shows a double pipe brick masonry structure, supporting the internal staircase: it was firstly conceived as a complete independent structure respect the basilica

The construction of the "present" Basilica, started in 1340 and finished in the second half of the XV century, entailed the **inclusion of the south-east corner of the structure of the bell-tower** inside the masonry walls of both transept and left aisle, at their junction.

The bell-tower started showing the first **signs of deterioration** at the end of the XVI century.

The **remarkable settlements** manifested by the bell-tower – in the first years of the 20th century, a differential settlement of about 0.30 m respect the basilica's structure and a **out of plumb** toward south-east of 0.765 m on a height of 42.5 m were reported – caused major **damages to the vaults** of the left aisle of the church, requiring necessary repair interventions on the masonry walls and at the level of the foundations.

MONITORING SYSTEMS & STRATEGIES

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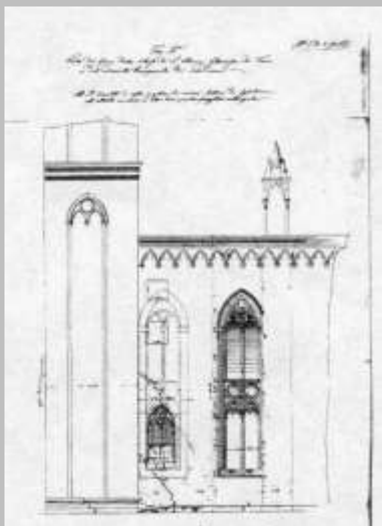
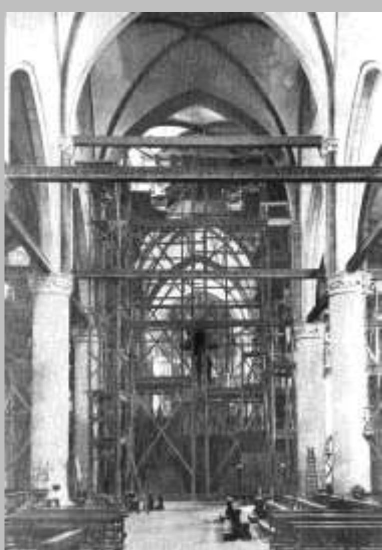




1) 1862 – 1866: first documented intervention on the structures of the bell-tower

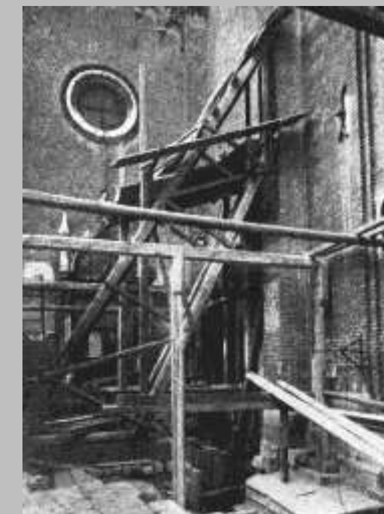
- demolition of the damaged wall section and successive reconstruction
- sustention of the rebuilt masonry wall (no new foundations) with a solid relieving arch (three brick layers)

2) 1867 – 1873: second repair intervention

- general restoration of the roof of the church
- disassembly and following reconstruction of the stone arch of the left aisle adjacent to the bell-tower
- partial substitution of brick units in correspondence of the most heavily damaged masonry wall parts
- positioning of stone ties (1.00 × 0.50 × 0.30 m), with subsequent plastering

3) 1902: the Frari bell-tower is studied and monitored to evaluate its continuative and progressive settlement

- **widening of the foundation bases** inadequate respect the bulk of the bell-tower: insertion of timber piles (made by larch, length 3.80 m, transverse dimensions 0.20 × 0.20 m), covered by a 2.00 m wide concrete bed
- all of the masonry walls were repointed with cement mortar that, in addition to restore the cohesion of the brick masonry, improved its strength



STRUCTURAL INTERVENTION IN THE 20TH CENTURY

1902: COLLAPSE OF THE BELL TOWER OF THE ST. MARK BASILICA

Monitoring of the venetian towers, including the "Frari" bell tower

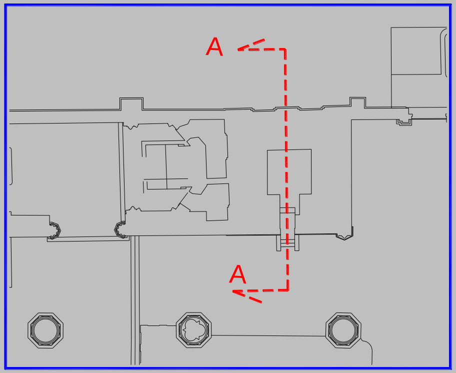
RESULTS OF THE MONITORING:

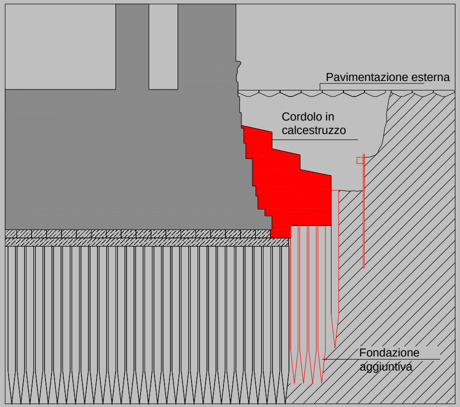
- **DIFFERENTIAL SETTLEMENT BETWEEN CHURCH AND TOWER: 30 cm**
- **OUT-OF-PLUMB: 76cm ON A HEIGHT OF 42.5m**

1903: Intervention on tower's foundations

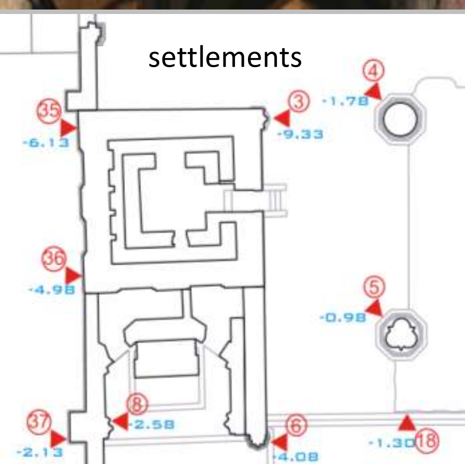
CONSEQUENCES:

- **Reverse of tower's rotation toward the church**
- **The new structural configuration caused the formation of widespread cracks and extensive damages on structural elements of the church directly connected to the bell tower**





SECTION A-A



Experimental investigations and monitoring

1990 - fotogrammetric survey;
- geotechnical investigations on the foundation’s soil;
- endoscopies;
- single and double flat-jack tests on the masonry elevation structures;
- sonic tests on steel ties;
- monitoring of the main cracks, by means of extensometers;
- positioning of clinometers (detection of rotations of the bell-tower).

⇓

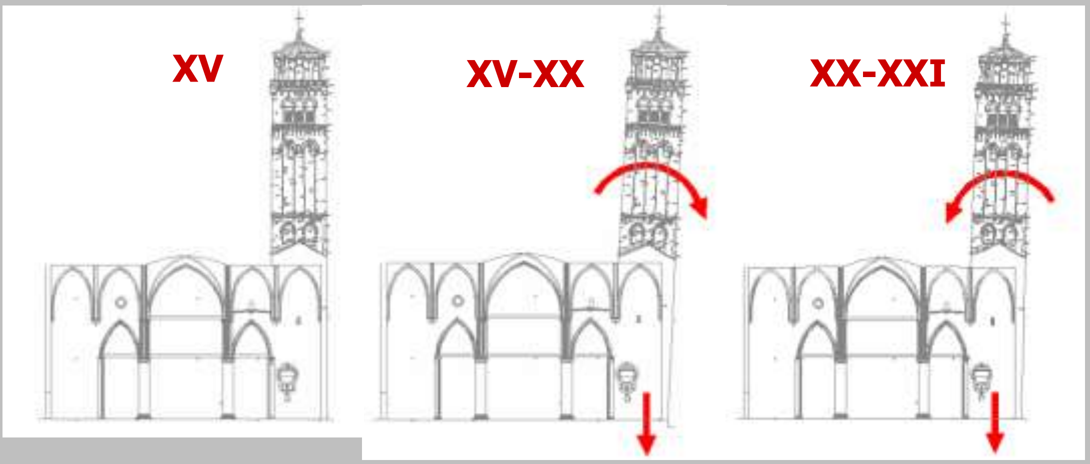
discrete stability of the tower structure; out of plumb of about 0.8 m

2000 - worrying sign of structural deterioration (new crack patterns; widening of already existing fissures; falling of small portions of plaster and bricks from the vaults).
- survey of differential settlements in different points of the complex

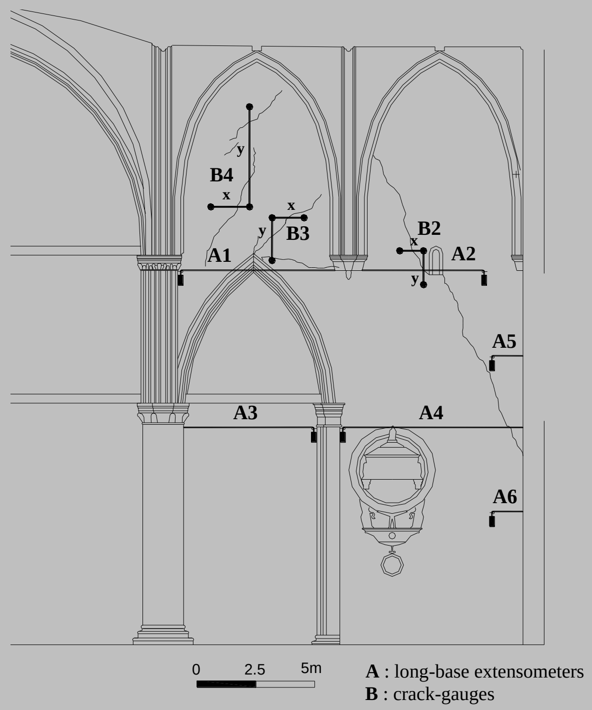
⇓

disconnectedness of the stone ashlars of the aisle arch adjacent to the bell-tower (differential settlement of the arch supports) → **installation of a timber prop**

average subsidence of the **structure of the church:** **- 10 ÷ - 20 mm**
average subsidence of the **area of the bell-tower base:** **- 49.8 mm East corner**
- 61.3 mm South corner
- 93.3 mm West corner



The differential settlements and the comparison between the fotogrammetric survey of 1995 and 2000, indicated that **the bell-tower is tilting in the opposite direction respect the "historical" tendency**, meaning that it is going back towards its vertical.

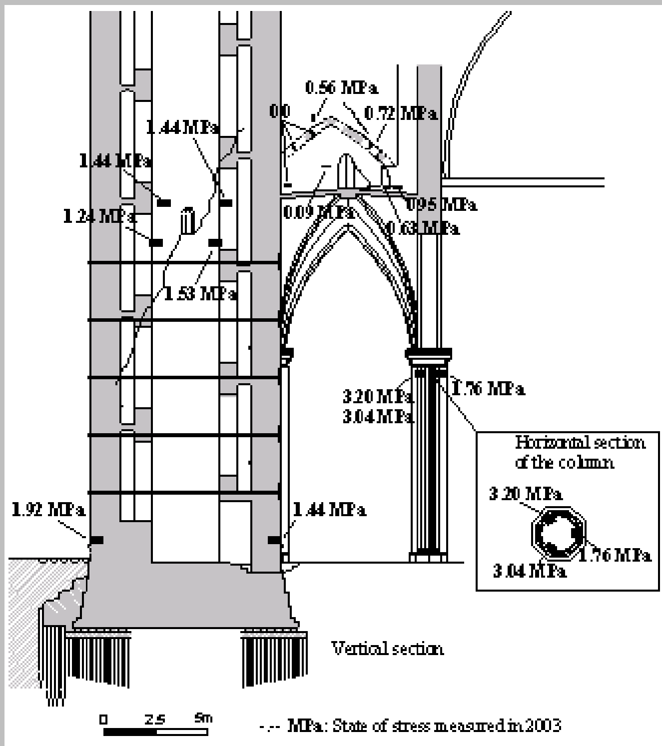


2001 automatic **monitoring system** (check of the deformations):

- **6 long base extensometers** relative displacements between the walls of the bell-tower and the adjacent structures of the basilica;
- **8 crack-gauges** installed on the main cracks of the South-West side of the bell-tower and of the wall above the stone arch.

⇓

the opening of the cracks is only partly caused by the settlement noticed at the foundations level



2003 investigation campaigns

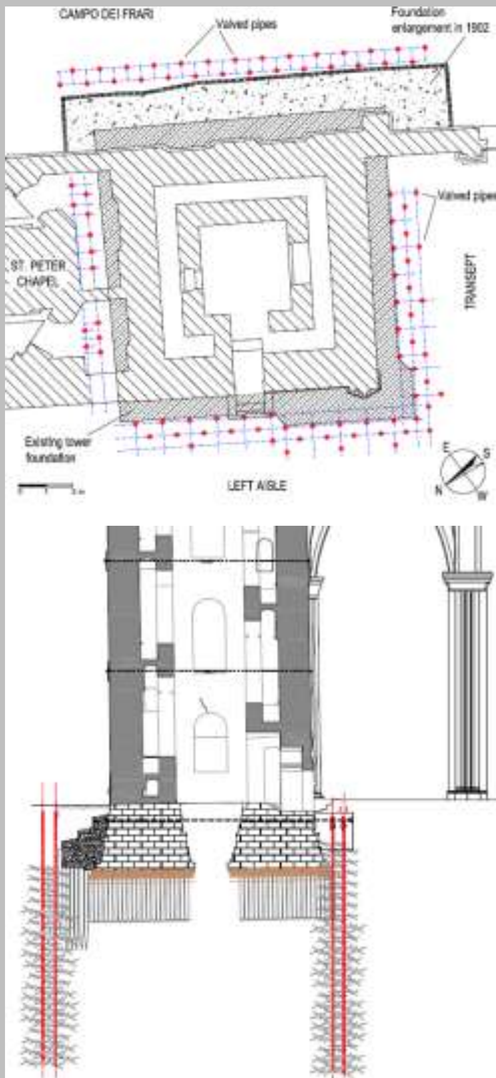
Flat-jack testing technique: to measure the existing state of stress on the masonry structures of the bell-tower and of the adjacent structures of the Basilica:

a) **Inside the bell-tower**, on both sides of an **inclined oblique crack** which runs along the South-West side of the tower: the similar stress values measured, at two different levels show that the crack, even if passing through the entire thickness of the wall, does not induce particular stress concentration.

b) **top of the column** sustaining the propped arch: very high values of compressive stress (1.76 MPa at the external side and 3.20 ÷ 3.04 MPa on the inner side).

c) **wall over the propped vault**, in correspondence of the upper area of the column: presence of a thrust line going from the bell-tower to the structures of the basilica → horizontal and vertical flat jack tests show states of stress of 0.56 ÷ 0.95 MPa.

SOIL FRACTURING INTERVENTION (2005-2006)



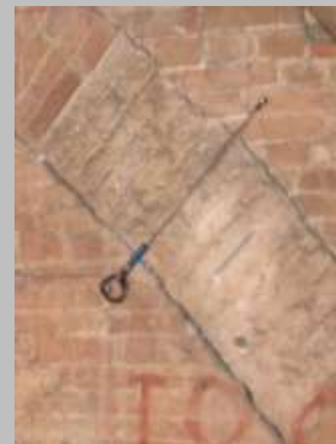
From the above-mentioned surveys, tests and inspections it was possible to assess the structural behavior of the church-tower complex and state that the tower couldn’t tolerate further differential settlements without serious consequences for the church’ structures.

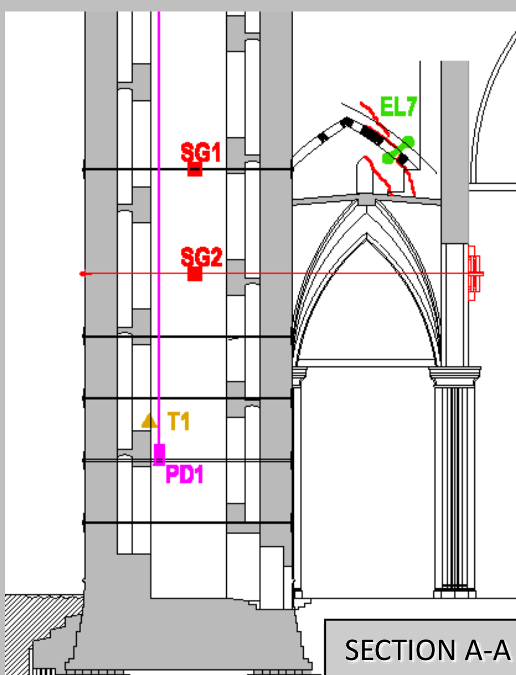
Thus it was necessary to intervene quickly, but also with great caution on tower’s foundations, in order to reduce its settlement’s speed and rotation.

It was decided to intervene directly on the clay soil around the stone basement of the tower in order to improve its the mechanical properties, through widespread and repeated injections of cementitious grout, under controlled conditions. Such injections produce expansions and/or fracturing of the soil around the injection pipes and for this reason the technique is called *soil-fracturing.*

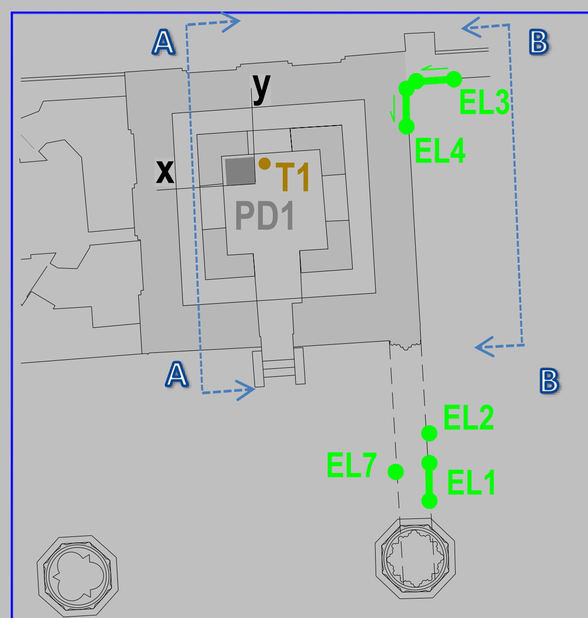
MONITORING SYSTEM

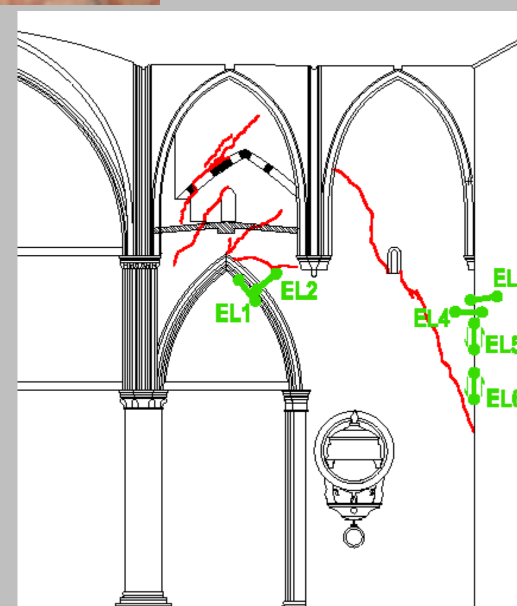
- Direct Pendulum
- Crack-gauges
- Strain Gauges
- Temperature sensors





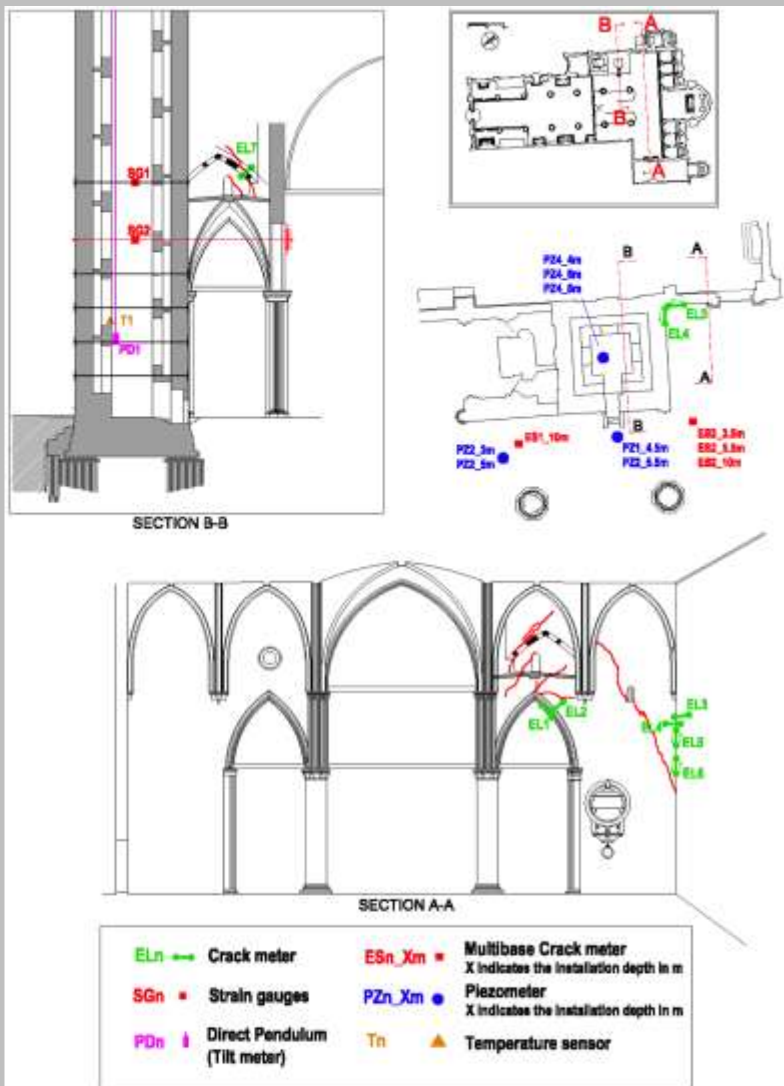
SECTION A-A





SECTION B-B

MONITORING SYSTEM

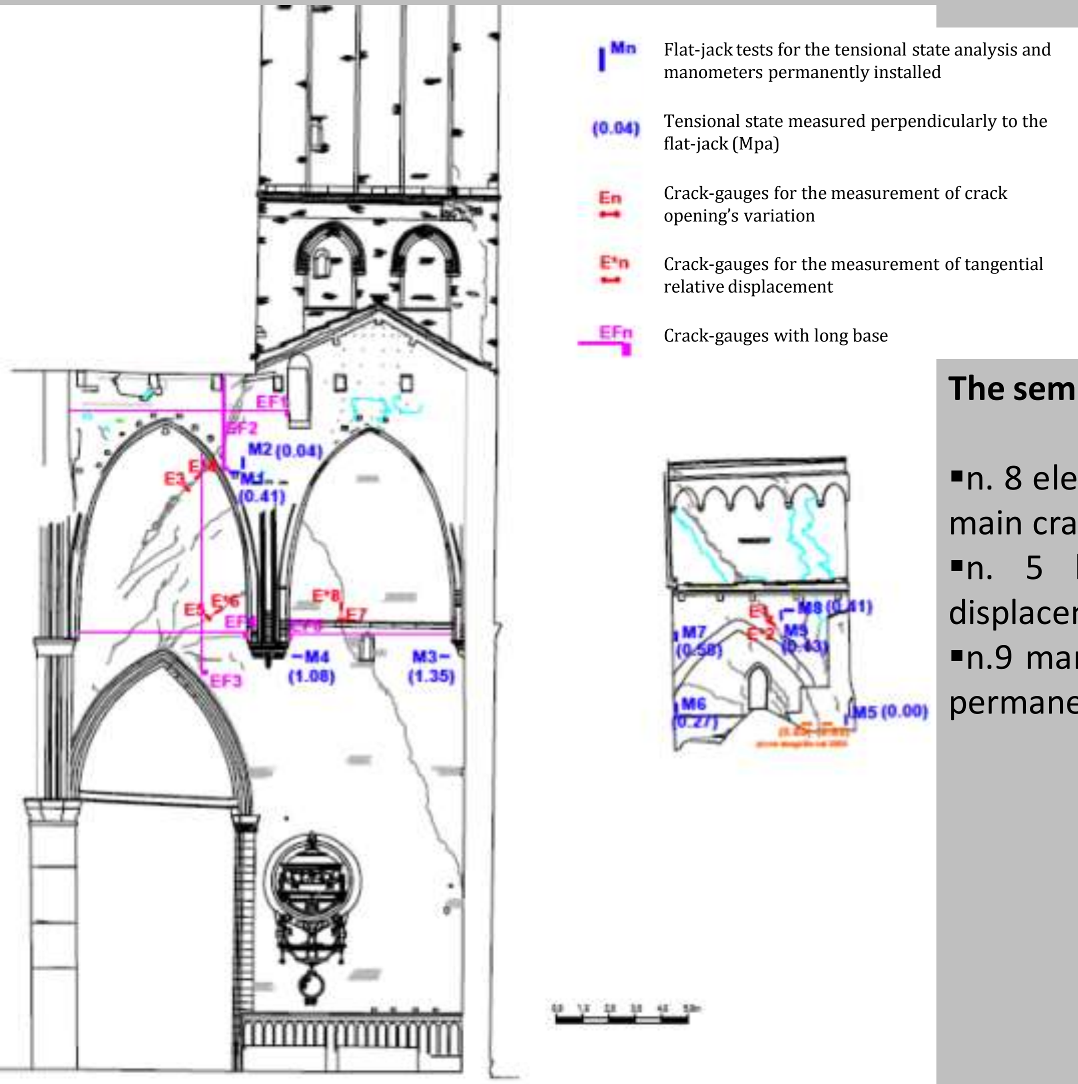


The automatic monitoring system includes:

- n.1 direct pendulum (PDn) equipped with automatic tele-coordinometer, for the measure of the absolute horizontal movement of the top of the tower;
- n.7 electrical crack-gauges (ELn) to check crack pattern's evolution and the opening of principal cracks ;
- n.2 strain gauges on metal tie rods;
- n. 2 multi base crack gauges (ESnXm) for the measurement of relative displacements between ground points on the same vertical line at the tower's base;
- n. 3 piezometers (PZnXm) to control variations of the ground-water level;
- n.2 temperature sensors (Tn) to measure air temperature.

A new automatic acquisition system allowed to transmit data to a remote controller and ensure a constant monitoring of the structure's movement during the interventions phases. Structural monitoring became thus a fundamental design tool that permits to lead all the in-site operations and to develop the necessary corrective actions.

MONITORING SYSTEM

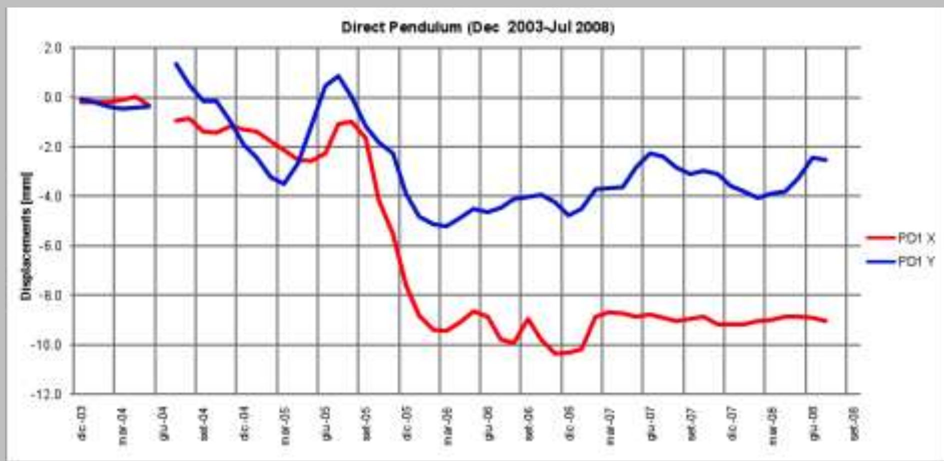


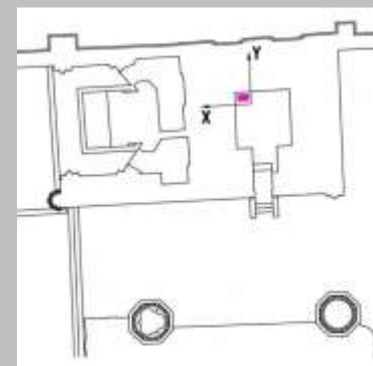
The semiautomatic monitoring system includes:

- n. 8 electrical crack gauges (En) to control the opening of main cracks;
- n. 5 long base crack-gauges to measure relative displacements between vertical structures;
- n.9 manometers to measure pressure's variations of the permanent flat-jacks.

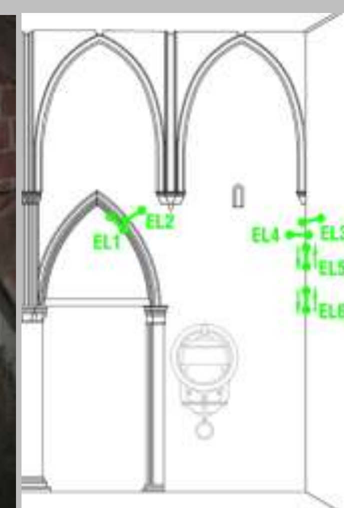
MONITORING SYSTEM

DIRECT PENDULUM



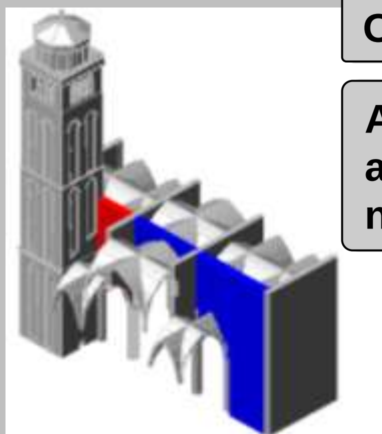


CRACK GAUGES



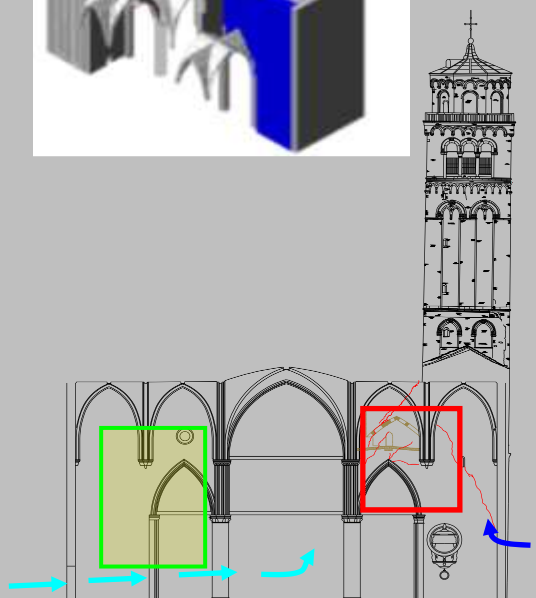
STRUCTURAL DIAGNOSIS

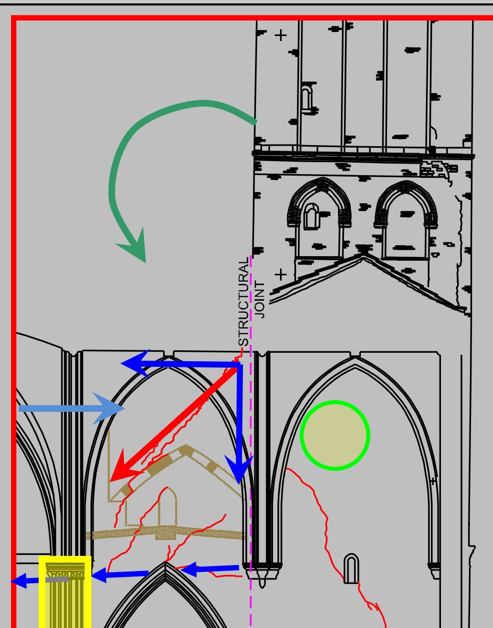
CONSEQUENCES OF THE CHURCH-TOWER MECHANICAL INTERACTION



Out-of-plumb of the tower

A system of skewed cracks on the masonry panel over the stone arch that connects the tower to the column at the corner between nave and transept





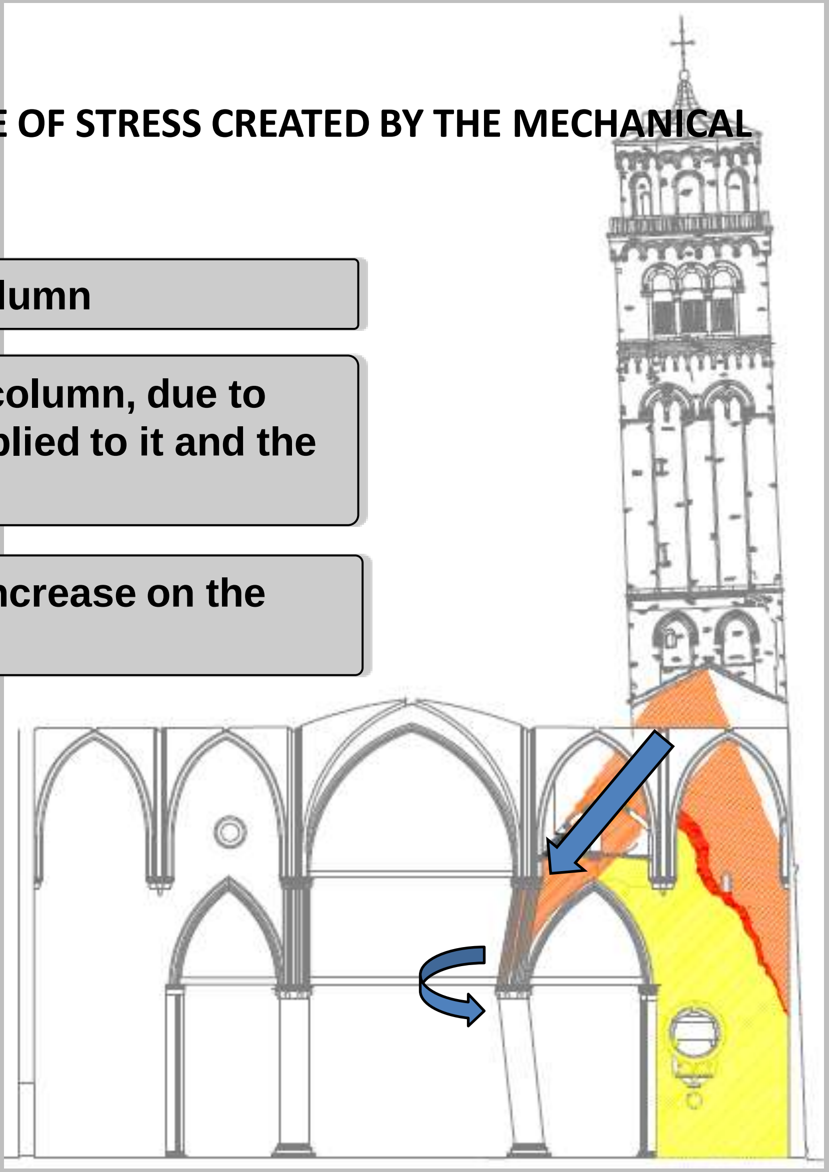
STRUCTURAL DIAGNOSIS

CONSEQUENCES OF THE INTERNAL STATE OF STRESS CREATED BY THE MECHANICAL INTERACTION:

increase of the compression load on the column

a strong transverse bending stress on the column, due to both the eccentricity of the vertical load applied to it and the horizontal component of the thrust

decrease of the vertical load (equal to the increase on the column) on the tower

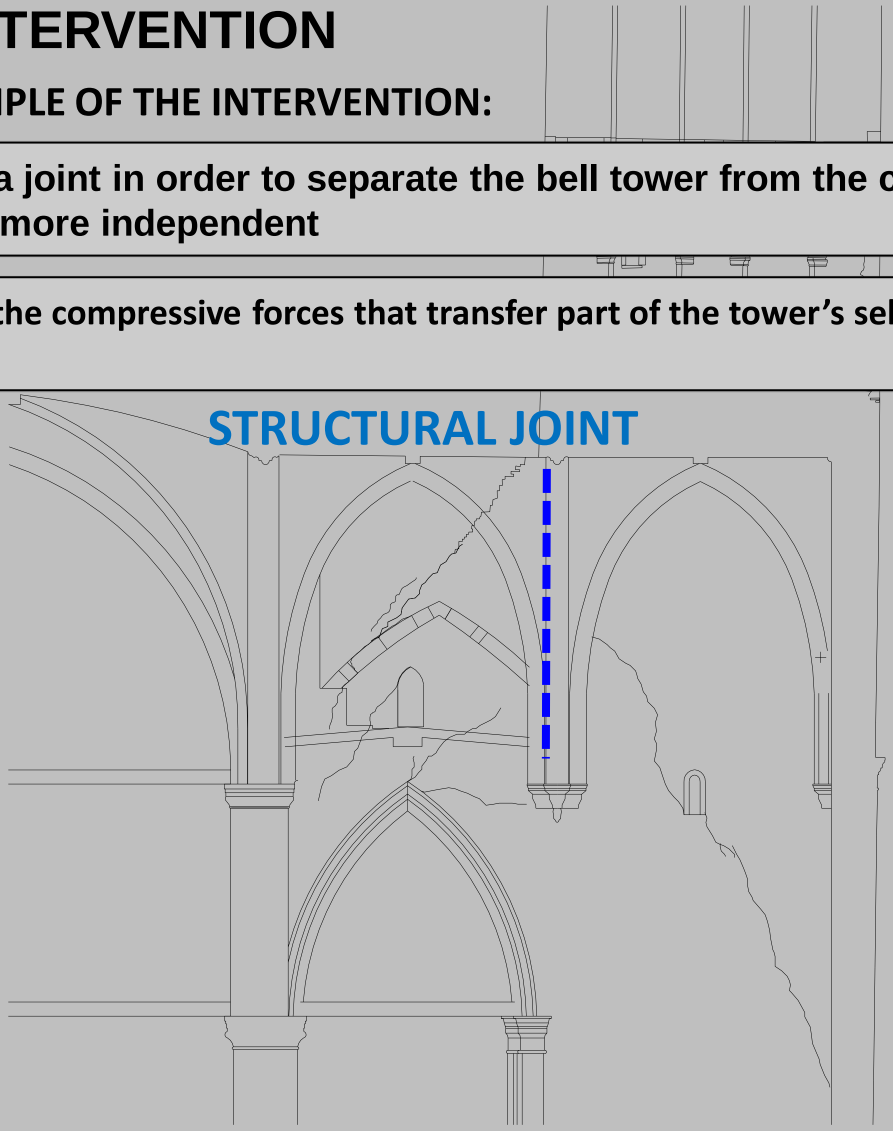


STRUCTURAL INTERVENTION

BASIC PRINCIPLE OF THE INTERVENTION:

Creation of a joint in order to separate the bell tower from the church and make them structurally more independent

Reduction of the compressive forces that transfer part of the tower's self weight to the column



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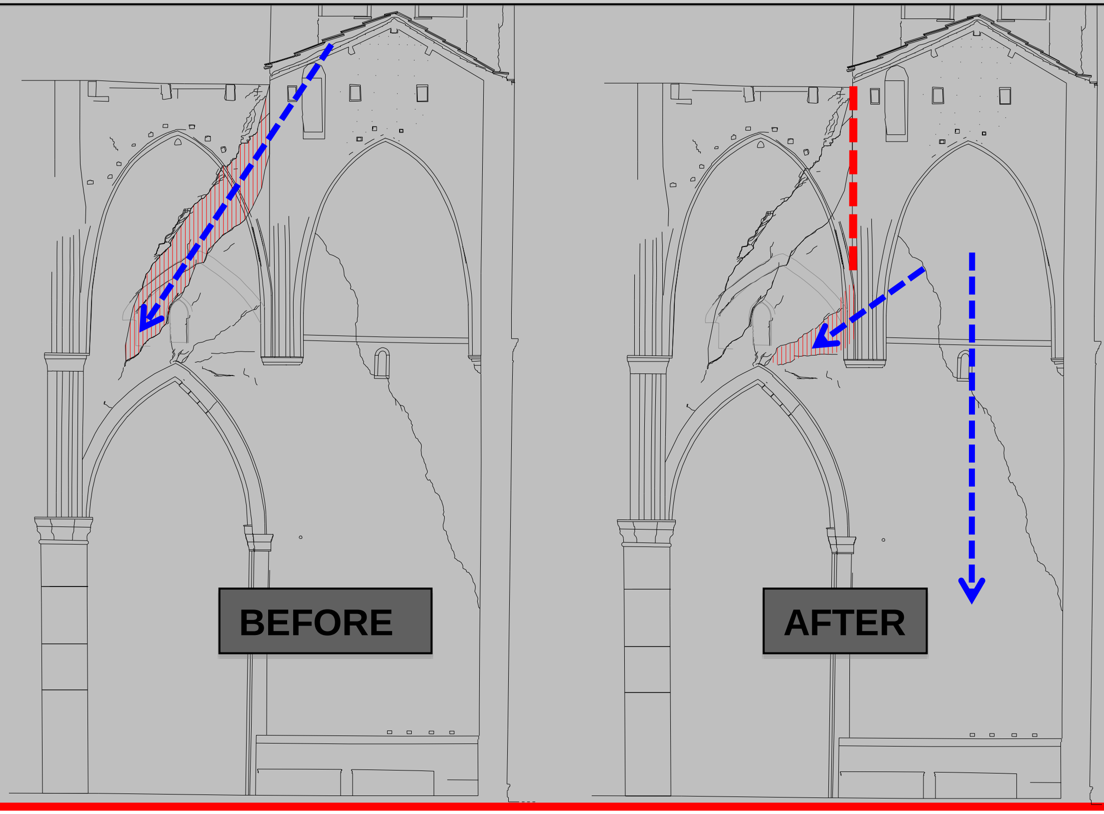


FINITE ELEMENT ANALYSIS

OBJECTIVES:

- Evaluation of the settlement's effects of the soil-foundation system on the masonry structures
- Trace the "settlement history" of the building from its construction to nowadays: the differential movements are assumed as input data for the analyses
- Represent a reliable state of stress of the building in the current structural configuration, calibrating the numerical models by means of the available experimental data
- Design the structural intervention and verify its effectiveness

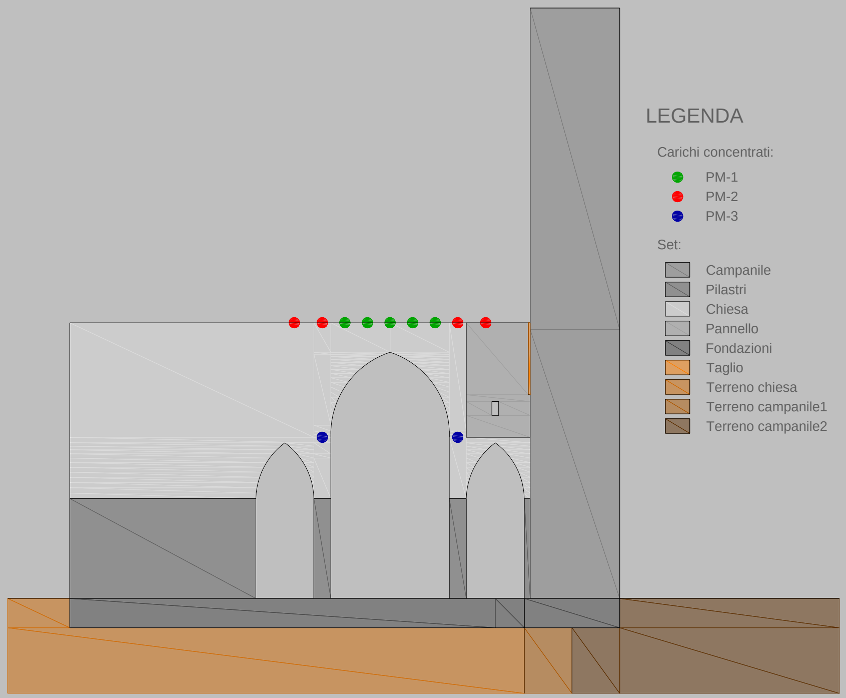
METHODOLOGIES: SIMULATION OF THE FOUR MAIN HISTORICAL STAGES OF THE BUILDING:

1ST PHASE: 1450	Initial state corresponding to the building's construction
2ND PHASE: 1450-1903	Development of church-tower settlements until 1903 when the intervention on foundations was performed
3RD PHASE: 1903-2008	Settlements during the last century – pre-intervention configuration
4TH PHASE: 2008-TODAY	Simulation of the structural intervention, creation of the joint between church and tower – post-intervention configuration

NUMERICAL MODELS

A 2D numerical model is created including the cross section of the church and considering parts of the structure and loading conditions that are relevant in relation to the structural problem.

Simulation of building's settlements during centuries through a non-linear phased analysis, varying the values of stiffness of the underlying soil.



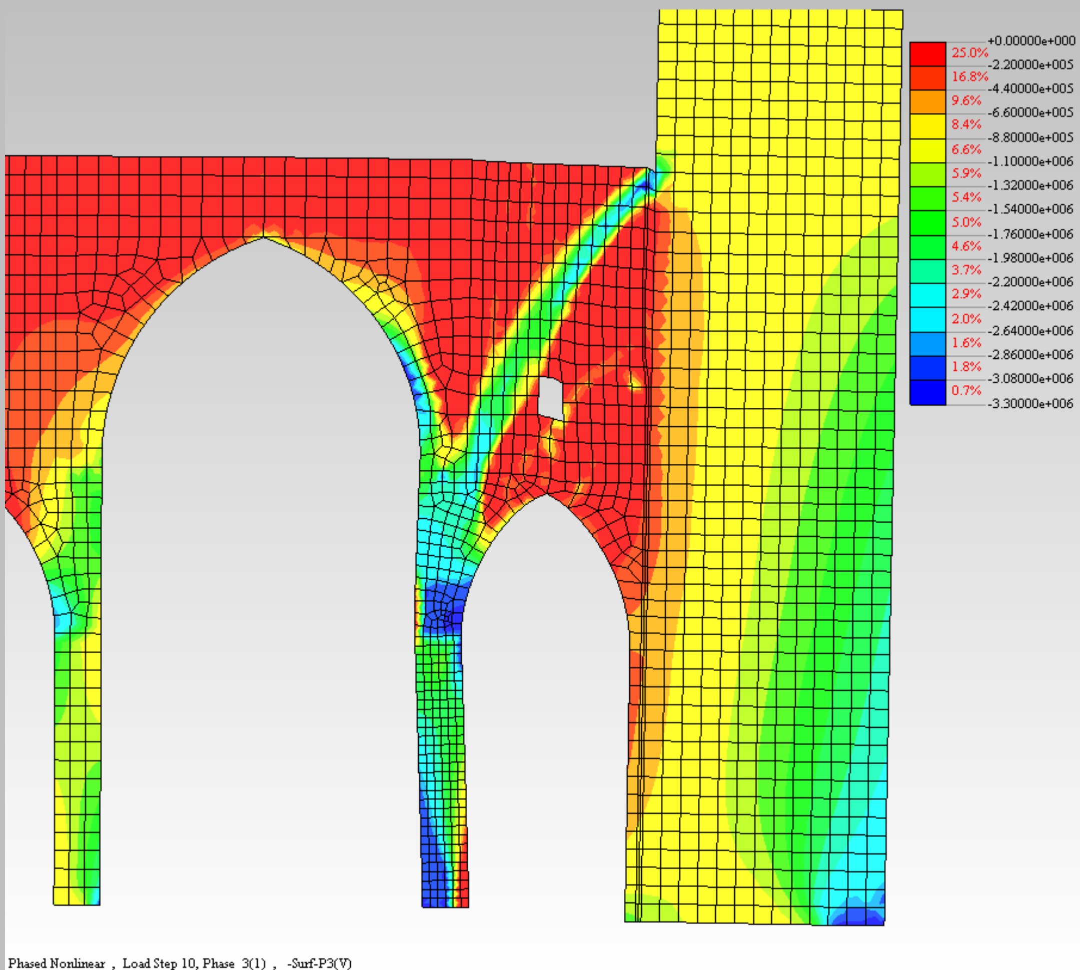
MAIN RESULTS

3RD PHASE: 1903-2008

Settlements during the 20th c.: reversal of tower's rotation toward the church after the intervention on foundations

Pre-intervention configuration

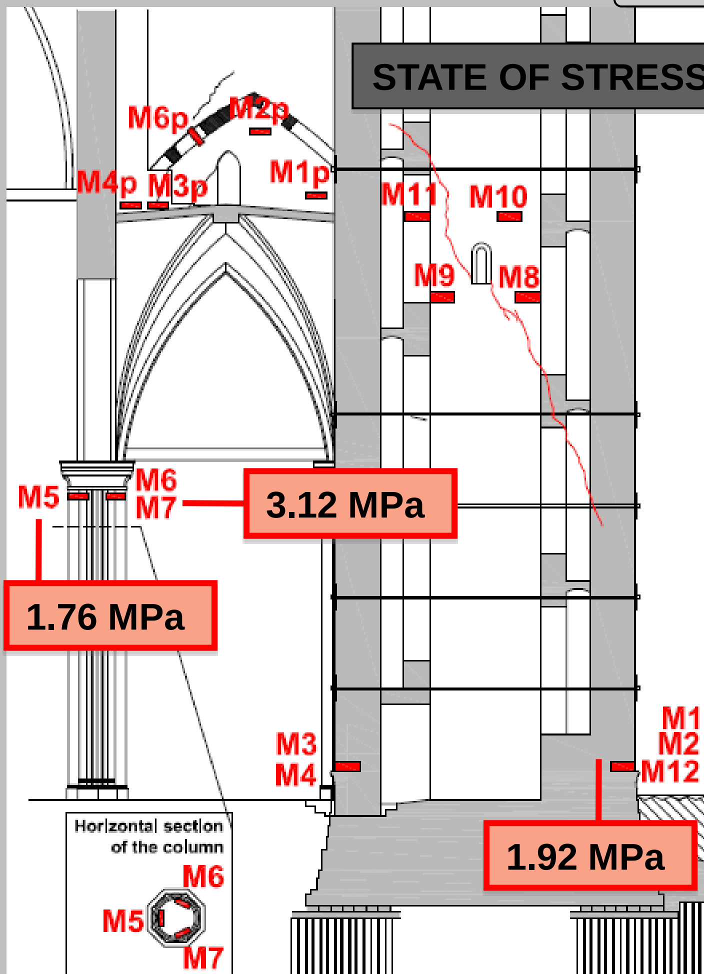
VERTICAL STRESSES DISTRIBUTION

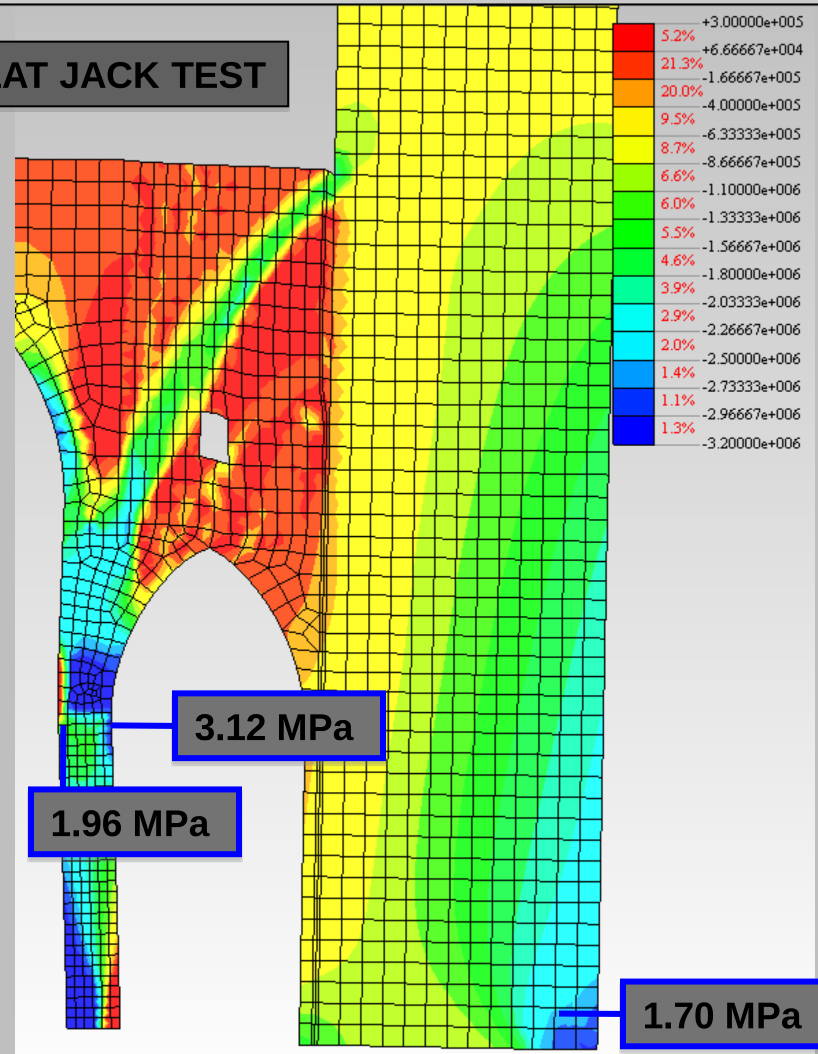


3RD PHASE: 1903-2008

COMPARISON BETWEEN EXPERIMENTAL AND NUMERICAL RESULTS

STATE OF STRESS: FLAT JACK TEST



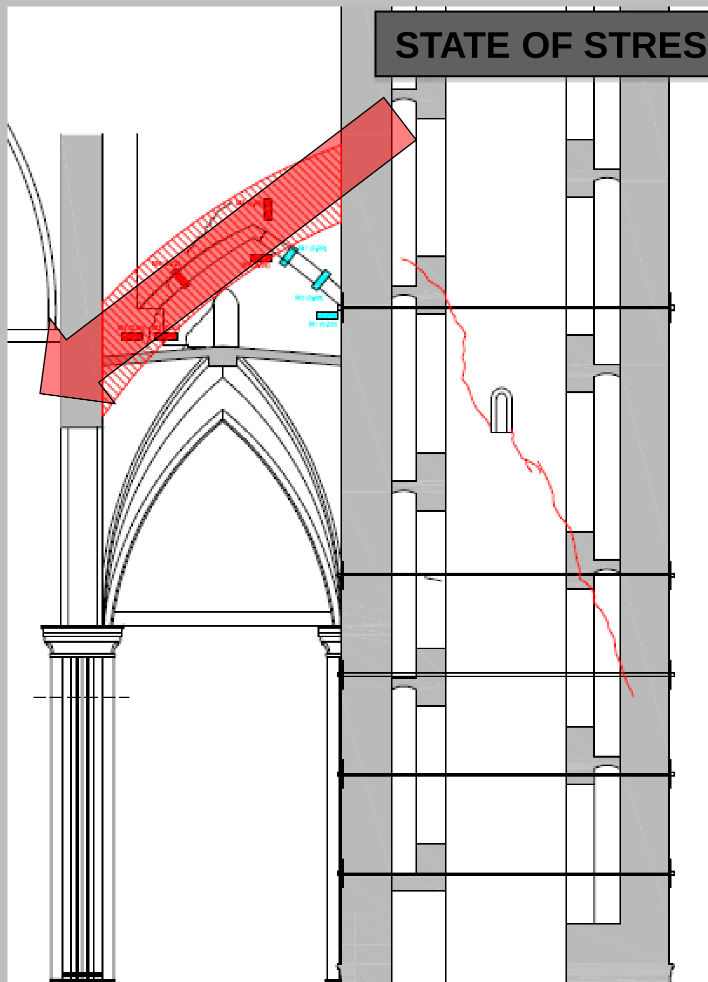


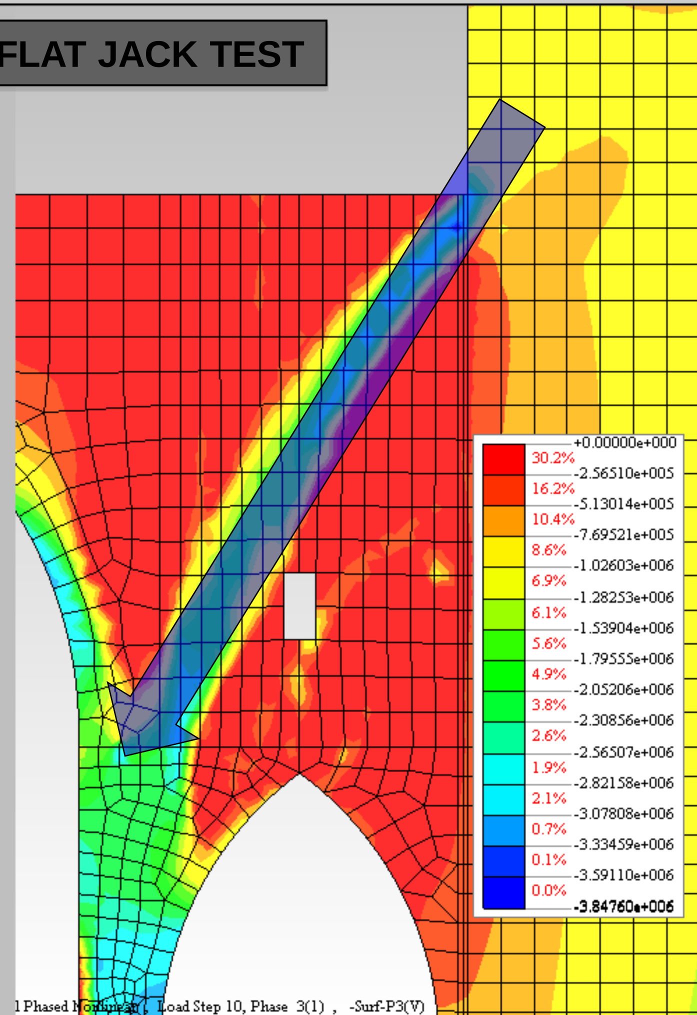
PROF. CLAUDIO MODENA

3RD PHASE: 1903-2008

COMPARISON BETWEEN EXPERIMENTAL AND NUMERICAL RESULTS

STATE OF STRESS: FLAT JACK TEST

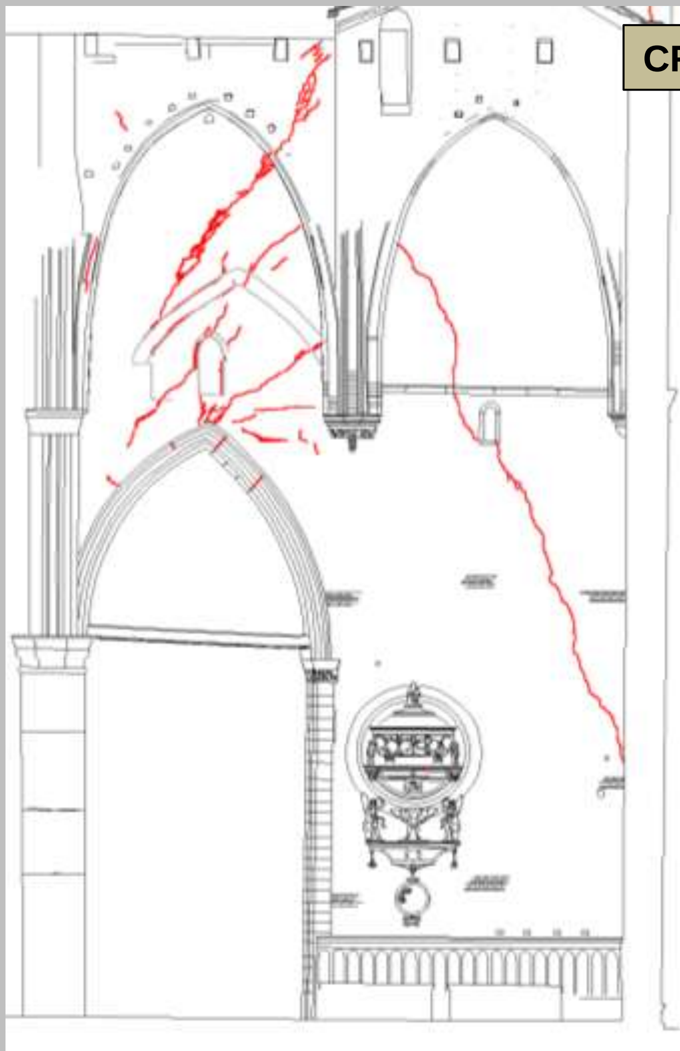


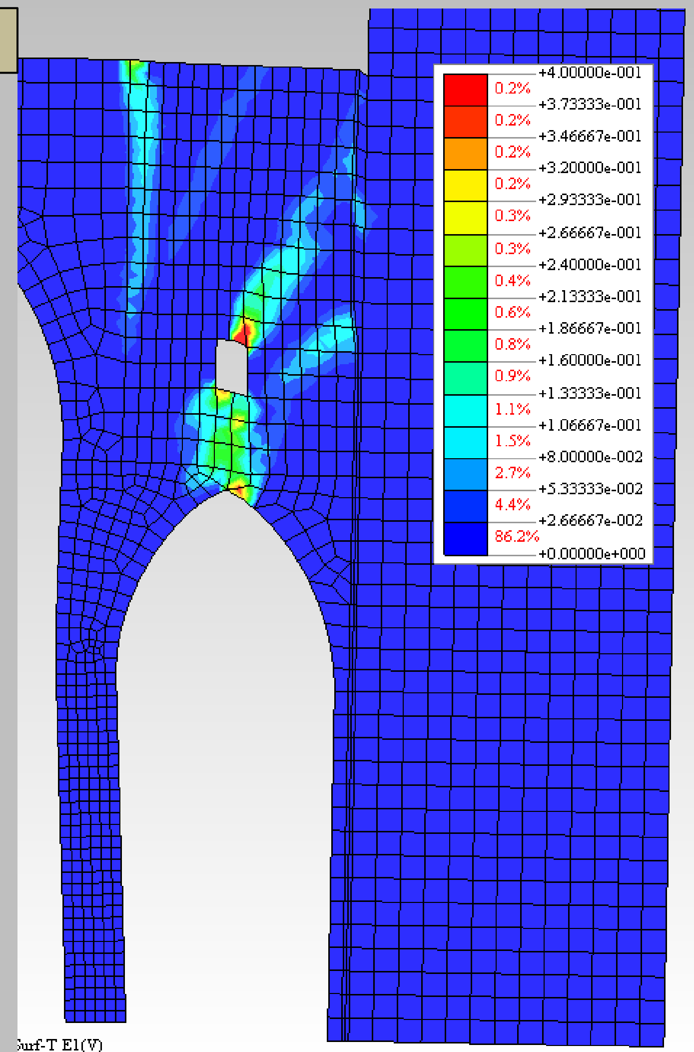


3RD PHASE: 1903-2008

COMPARISON BETWEEN EXPERIMENTAL AND NUMERICAL RESULTS

CRACK PATTERN



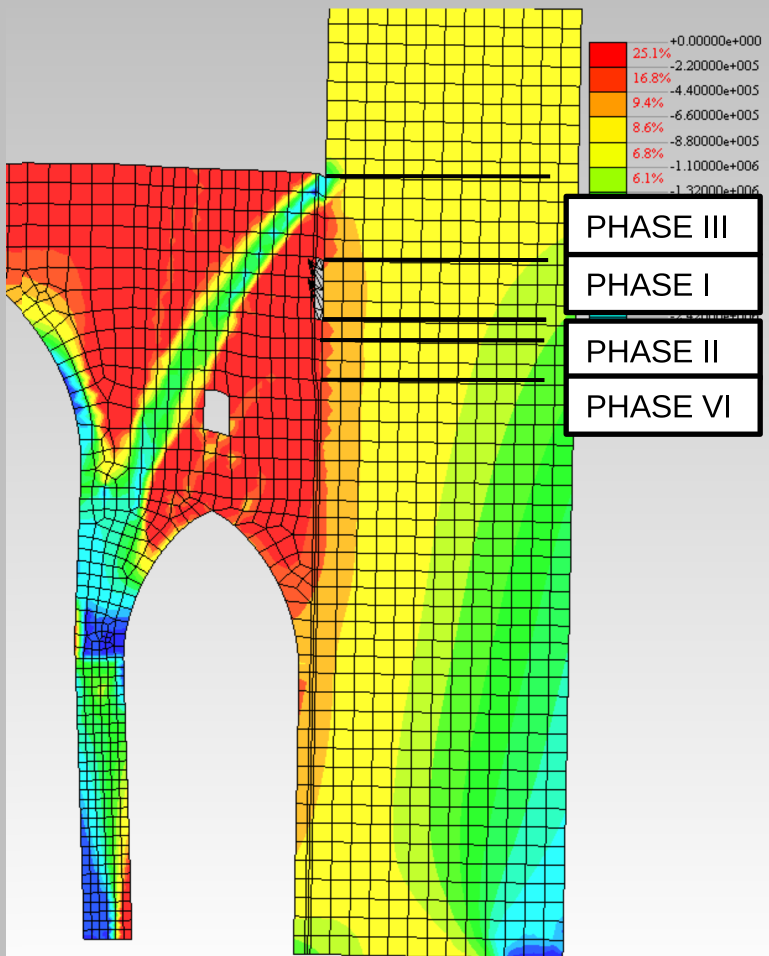


4TH PHASE: 1903-2008

STRUCTURAL INTERVENTION AUGUST-OCTOBER 2008

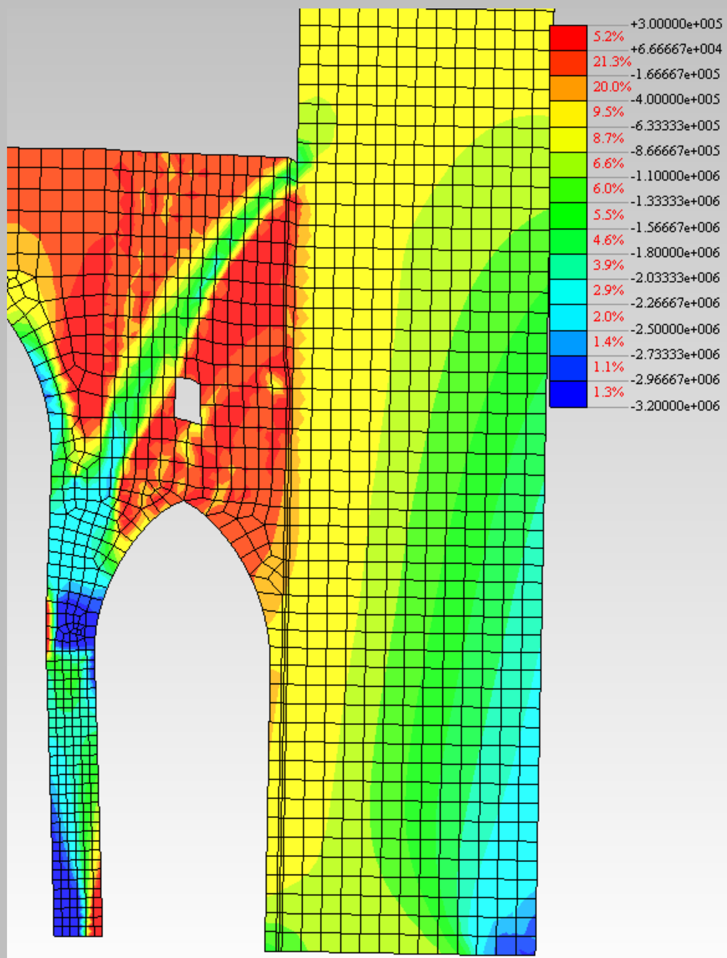
NUMERICAL SIMULATION OF THE INTERVENTION

VARIATION OF THE STRESS PATTERN DURING THE FOUR INTERVENTION'S STAGES

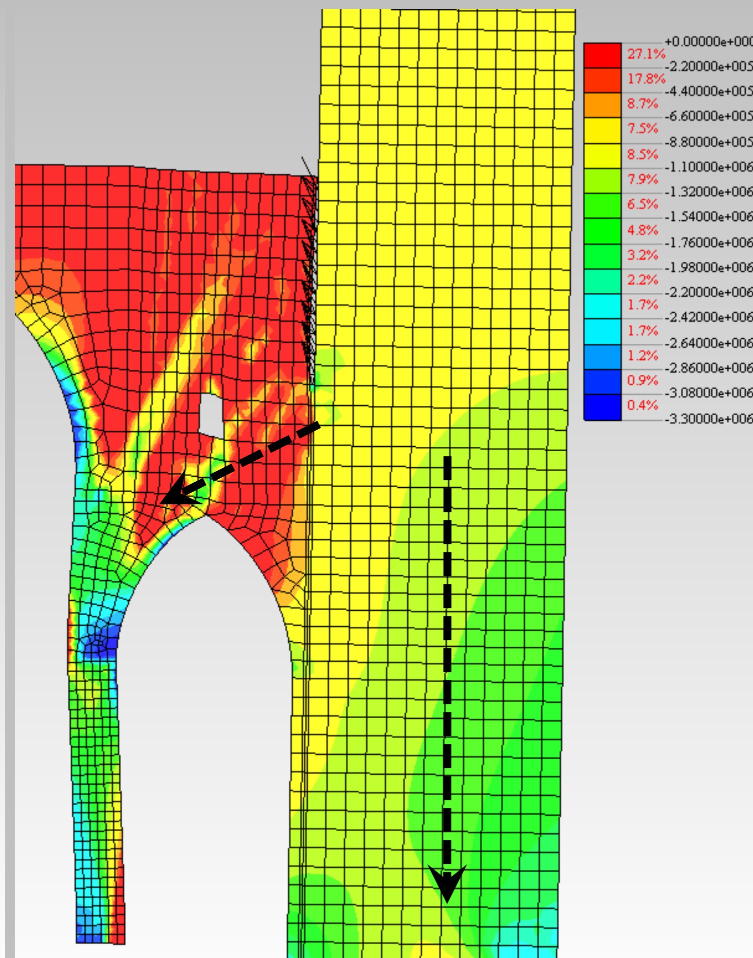


4TH PHASE: 1903-2008 → **STRUCTURAL INTERVENTION AUGUST-OCTOBER 2008**

PRE-INTERVENTION



POST-INTERVENTION



CONCLUSIONS

EFFECTS OF THE INTERVENTION AND EVALUATION OF ITS EFFECTIVENESS

Positive effects on the global structural behavior of the church-tower mechanical system

Improvement of the stability conditions of the column

Considerable reduction of the vertical load on the column (-15%)

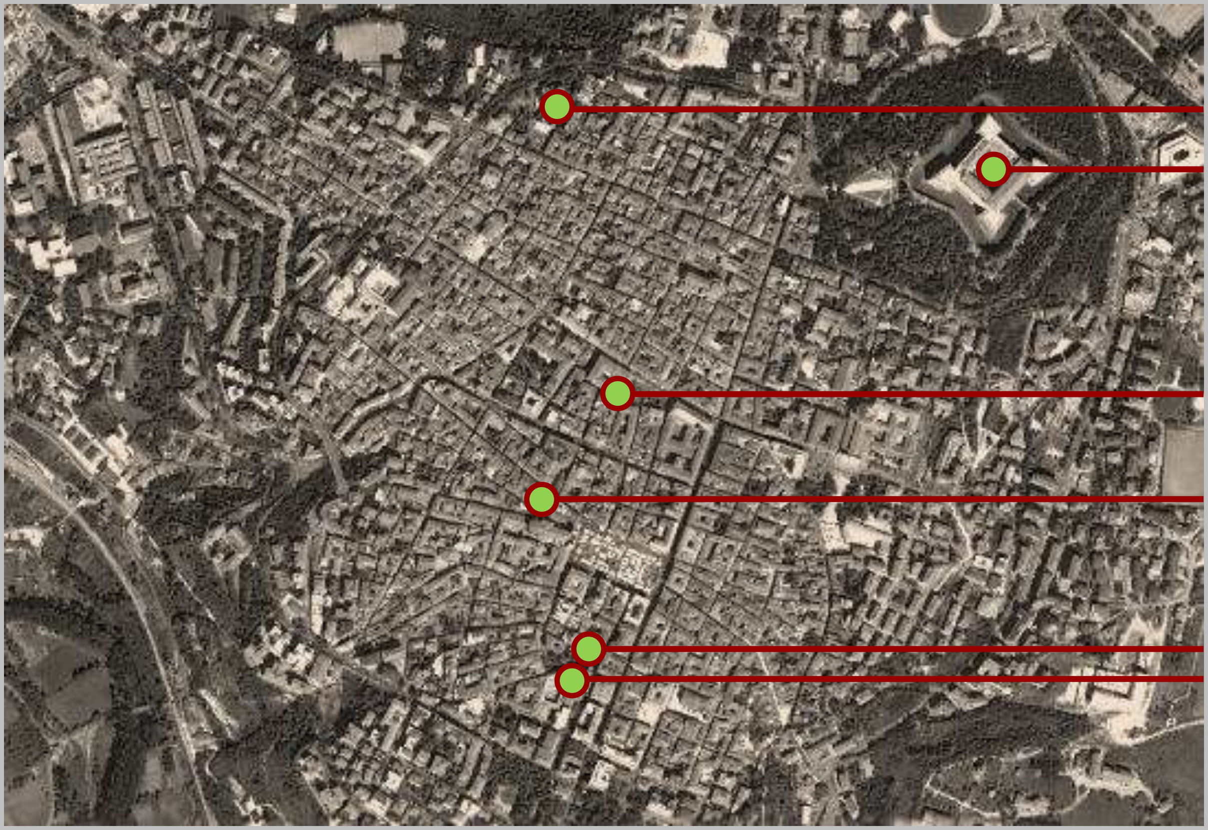
Corresponding increase of loads and stresses at tower's base

High reduction of the load's eccentricity and bending moment at tower's base

The creation of the discontinuity joint between church and tower determined a new static configuration in which they are structurally more independent

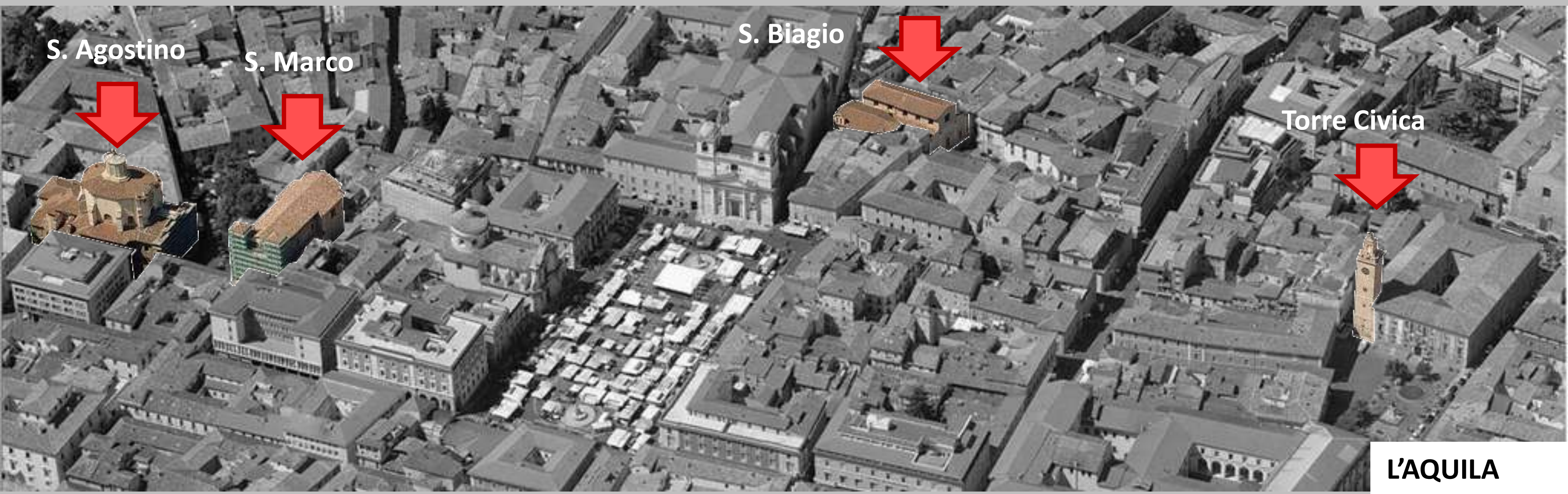
L'AQUILA MONITORING NETWORK

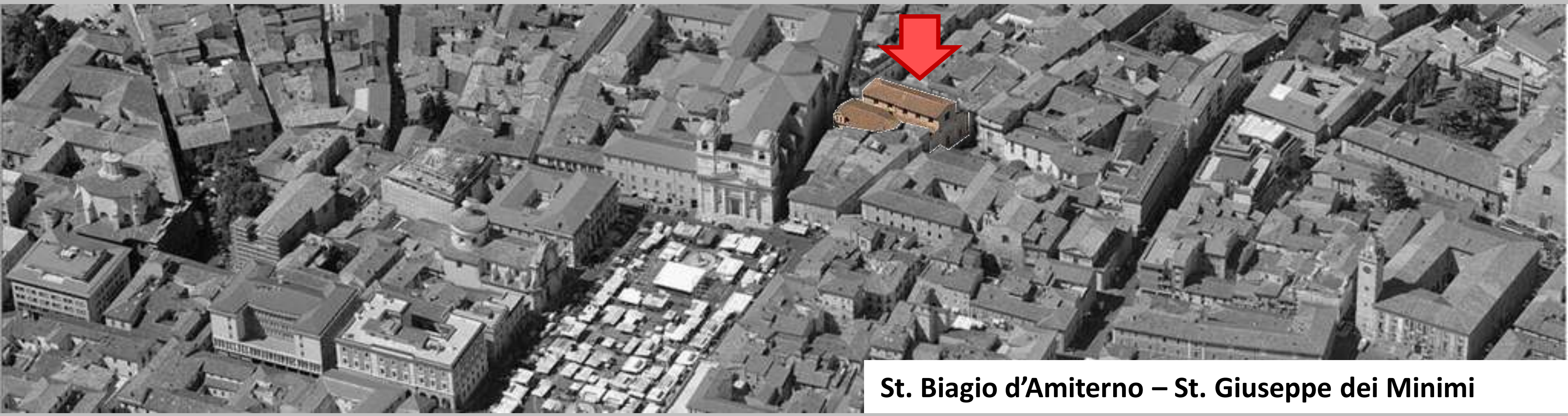
By request of the officer of the Cultural Heritage Authority, and in cooperation with the university of Nagoya (Japan), the National Institute of the Conservation and Restoration (ISCR), the Veneto Region, SHM systems were designed and installed on six representative and emblematic CH buildings in L'Aquila after the devastating earthquake occurred on the 6th of April 2009 in the Abruzzi Region.



Monitoring Systems & Strategies

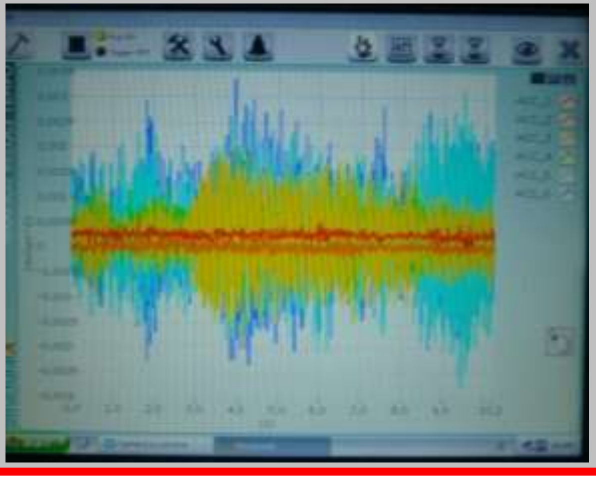
Prof. Claudio Modena





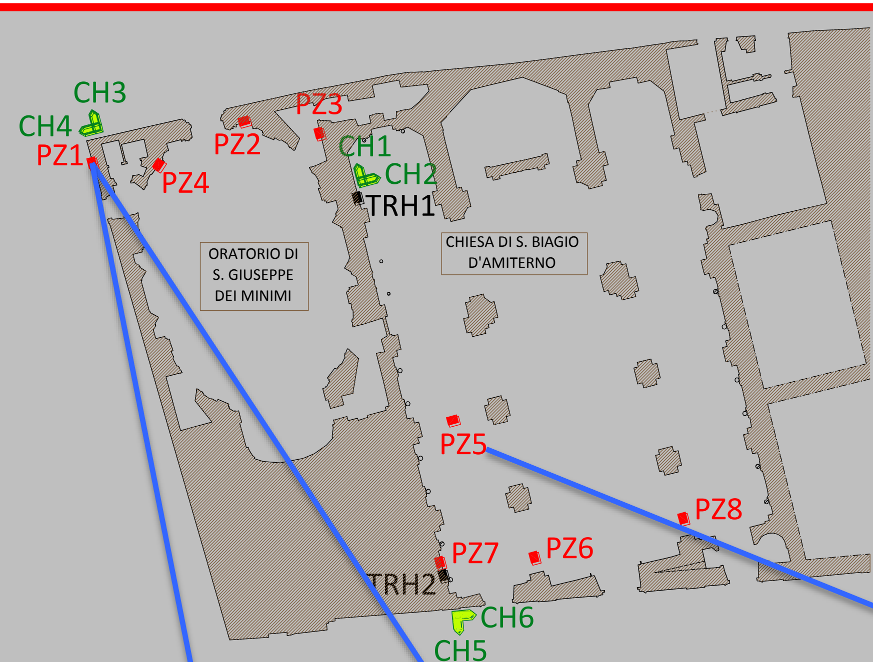
St. Biagio d'Amiterno – St. Giuseppe dei Minimi

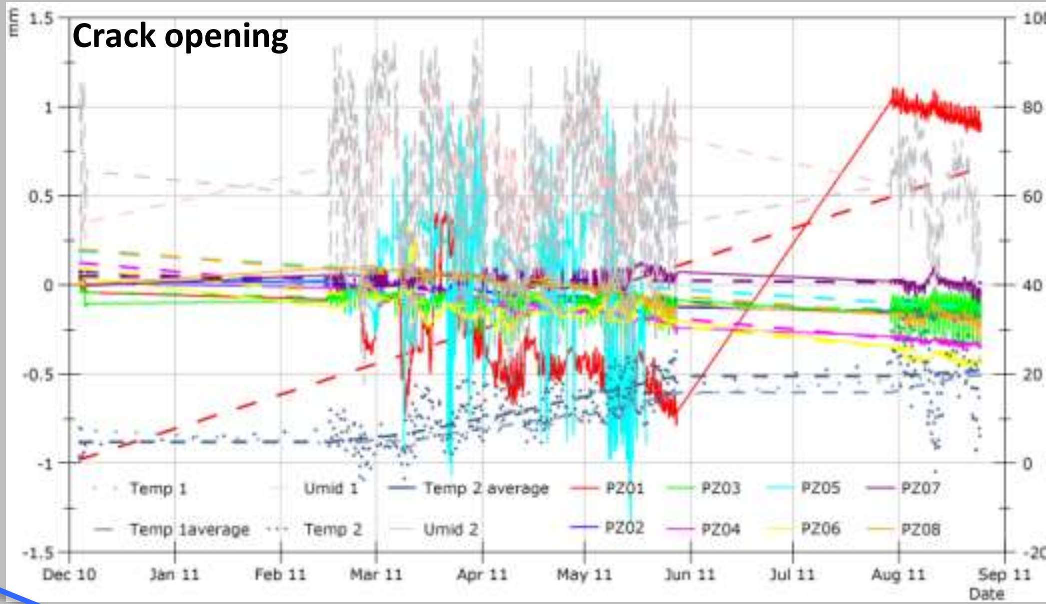
INSTALLED SENSORS (Dec 2010)
2 Temperature + RH sensor
8 LPDT (crack detection)
6 single axis accelerometers



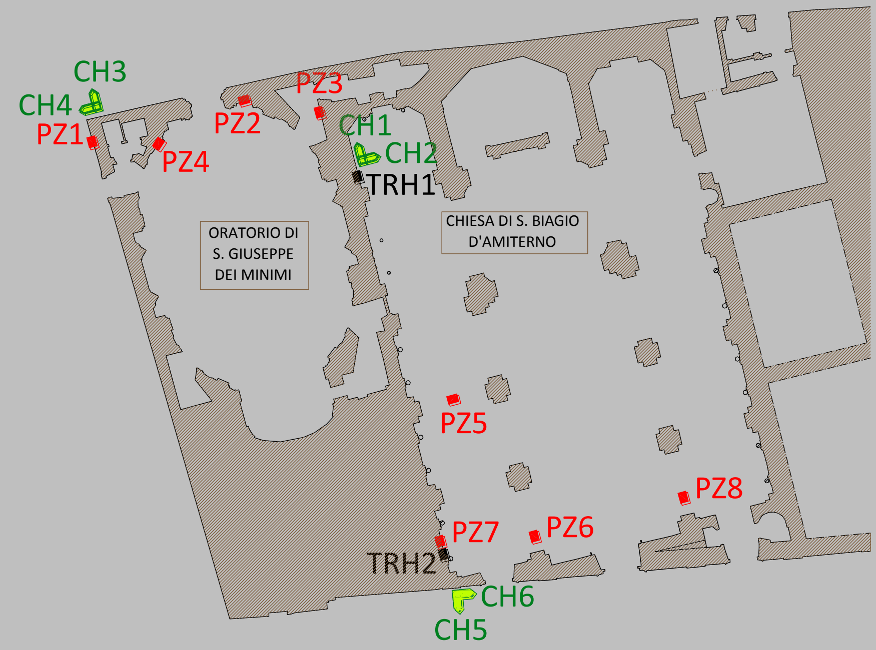
Monitoring Systems & Strategies

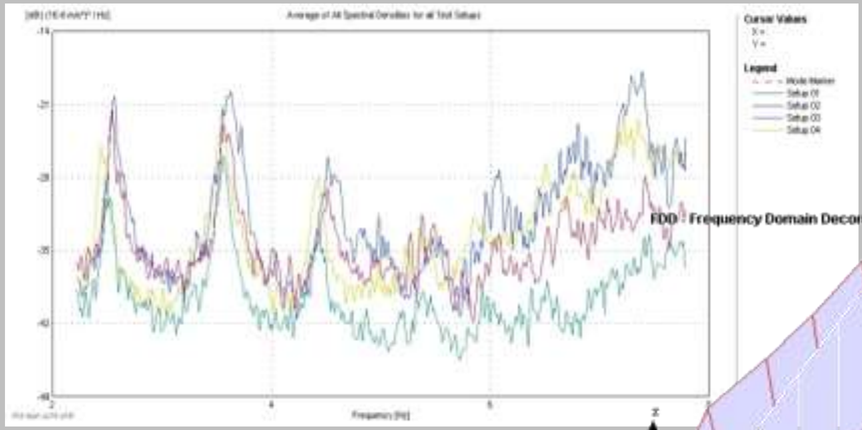
Prof. Claudio Modena



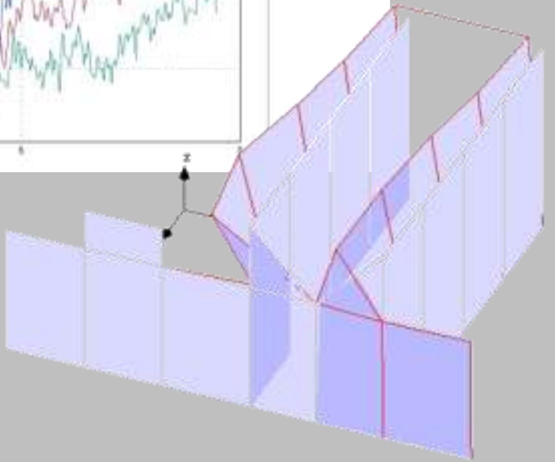


PROF. CLAUDIO MODENA





FDD - Frequency Domain Decomposition



Modal properties

St. Marco

INSTALLED SENSORS (Aug 2009)

1 Temperature + RH sensor

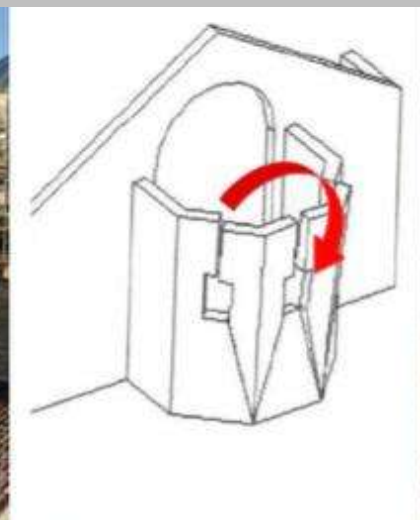
5 LPDT (crack detection)

4 single axis accelerometers

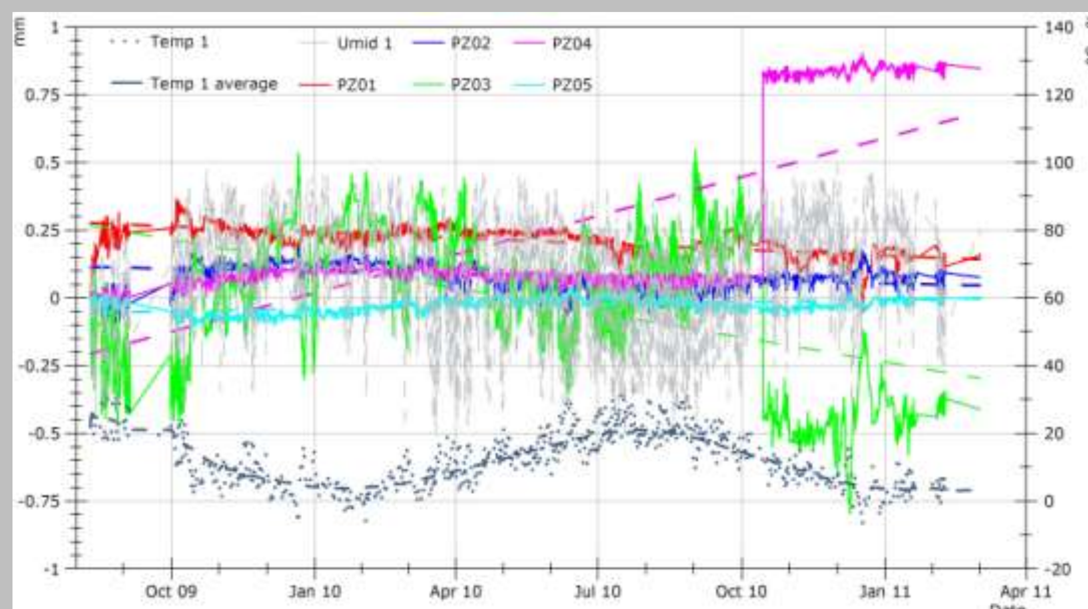
After the earthquake the church reported severe damage in the apsidal and transept area, where a critical crack pattern was noticed in the external walls, which manifested a visible outward overturning, involving the four pillars sustaining the dome. Also the transversal response of the church proved to be inadequate, since the most part of the vaults collapsed, such as a big portion of the external wall, at the clerestory level. Severe damage was finally reported in the vaults of the apse, of the presbytery, in the triumphal arch. The initial provisional strengthening intervention started the 4th of July and were completed in November 2009. This first intervention aimed at counteracting the most critical collapse mechanisms, such as the apsidal and transept walls overturning.

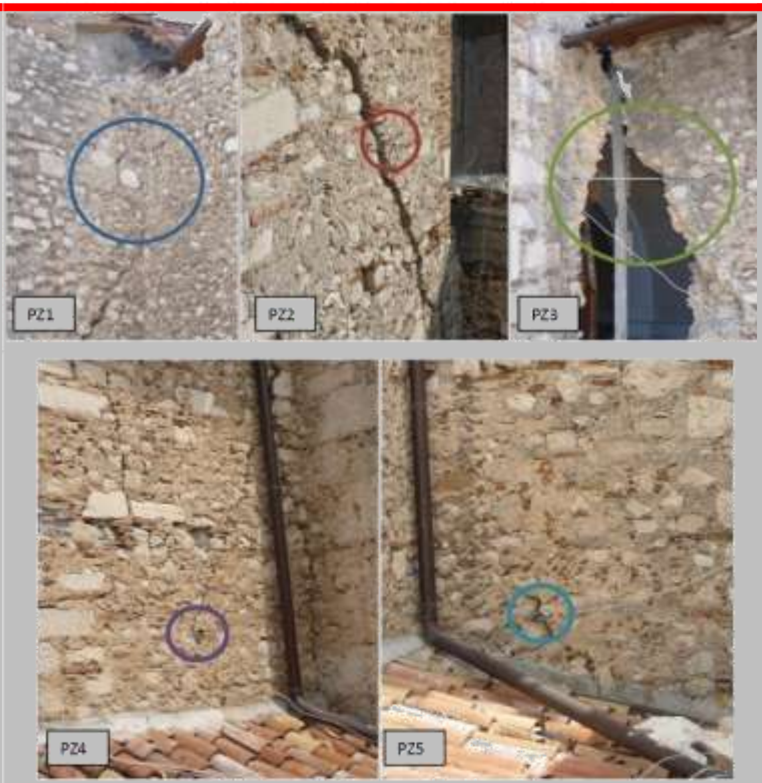
Monitoring Systems & Strategies

Prof. Claudio Modena

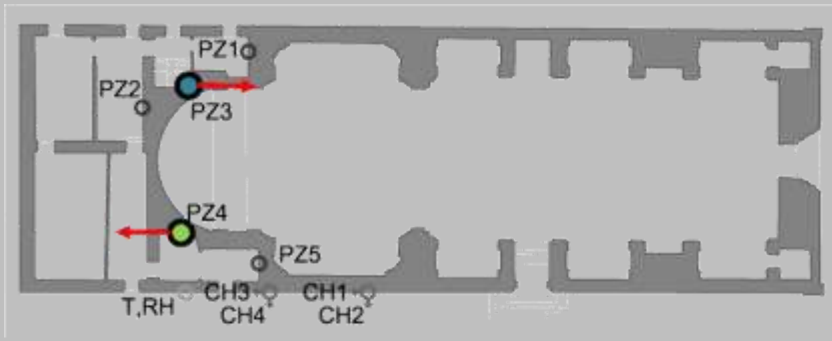


In parallel to the execution of the interventions, the opening of the main cracks was controlled by means of an automated low-cost SHM system which is continuously acquiring data, storing hourly the readouts coming from 5 linear displacement transducers positioned in the external area of both apse and transept, where the worst damage scenario is observed. Data are correlated to the environmental parameters recorded by a temperature – relative humidity sensor positioned at the base of the scaffolding.

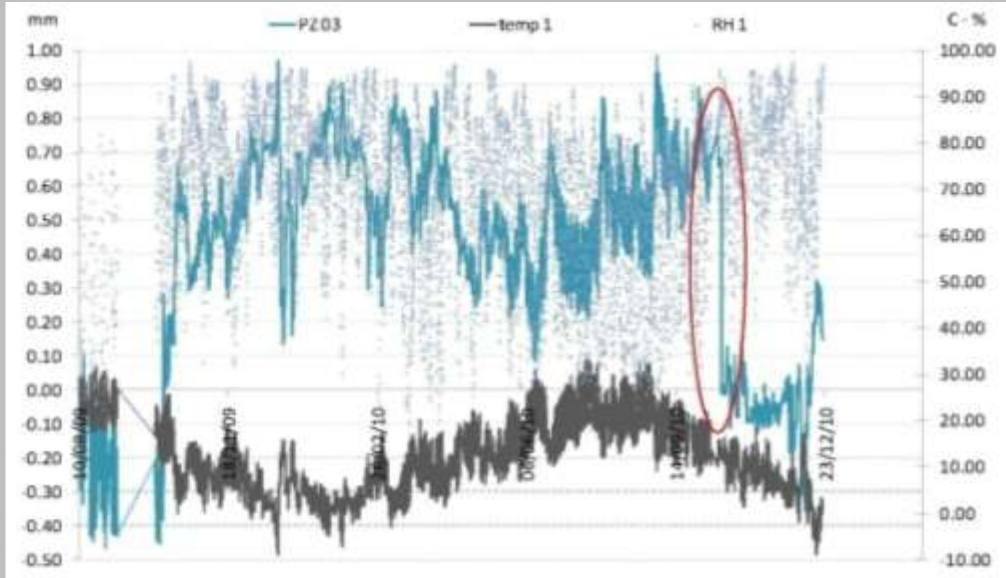




PZ1
PZ2
PZ3
PZ4
PZ5

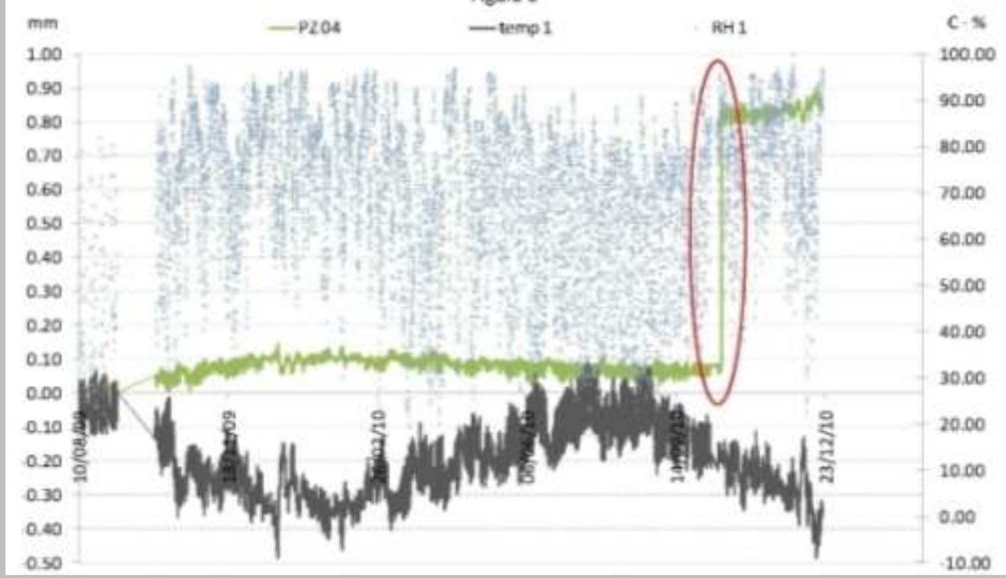


PZ1
PZ2
PZ3
PZ4
PZ5
T,RH
CH3
CH4
CH1
CH2



mm
PZ03
temp 1
RH 1
C - %
10/08/09
18/11/09
26/02/10
06/06/10
14/09/10
23/12/10

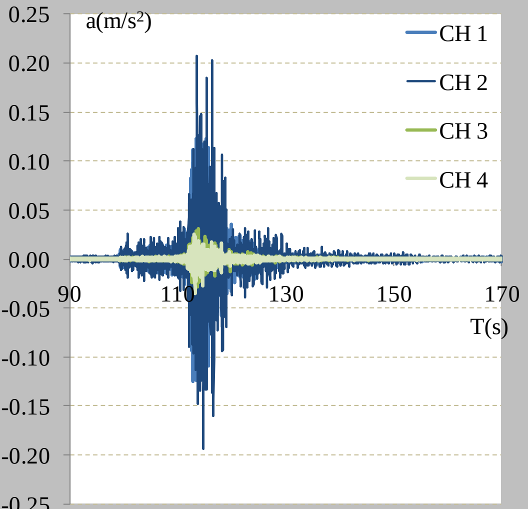
Figura 6

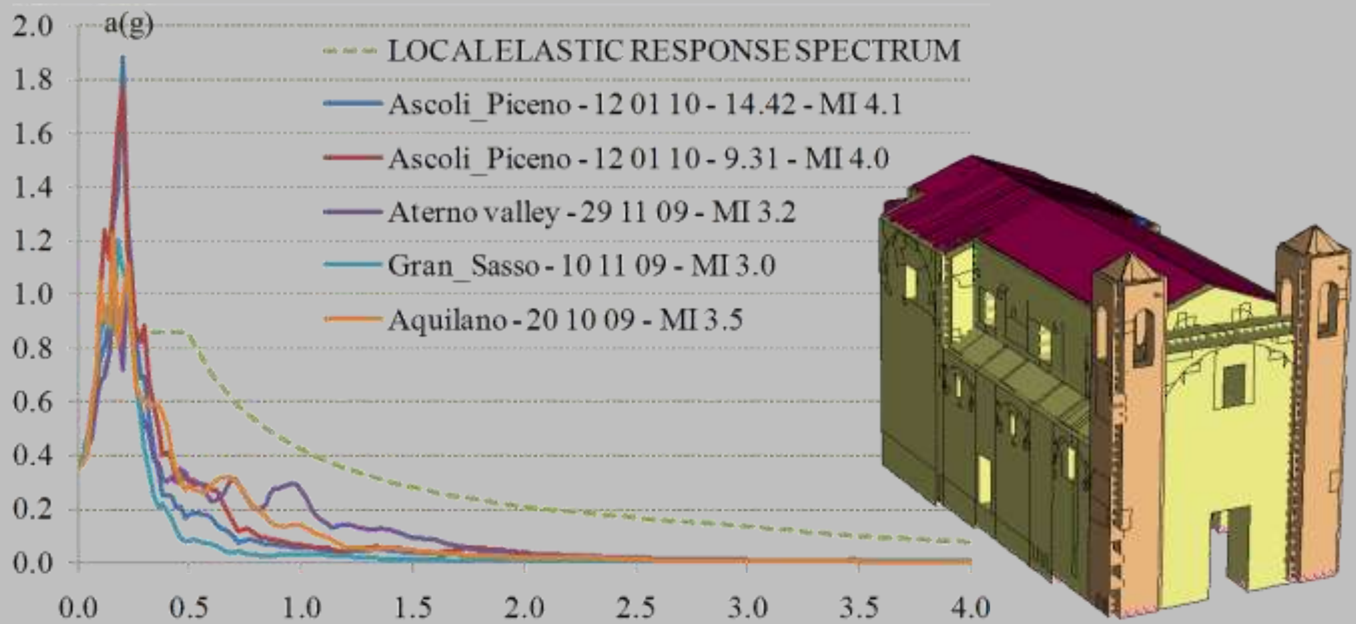


mm
PZ04
temp 1
RH 1
C - %
10/08/09
18/11/09
26/02/10
06/06/10
14/09/10
23/12/10

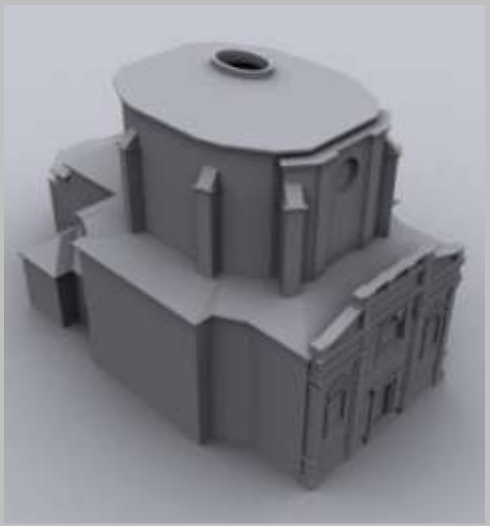
Response spectra scaled to the local peak ground acceleration elaborated from recorded minor seismic events in the L'Aquila area and some higher however moderate magnitude in different seismic districts (Ascoli Piceno, at a distance of 100 km from L'Aquila).

Such plots indicate a local resonance with very high peaks around the frequency of 5 Hz, in a frequency band where several structural eigenvalues are noted.





St. Agostino



INSTALLED SENSORS (Sept 2010)

2 Temperature sensors

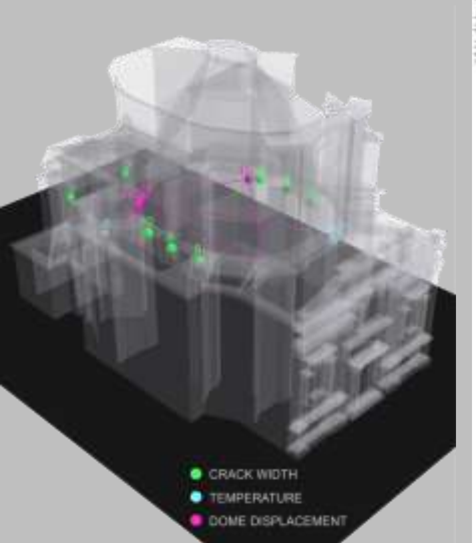
4 PDT (crack detection)

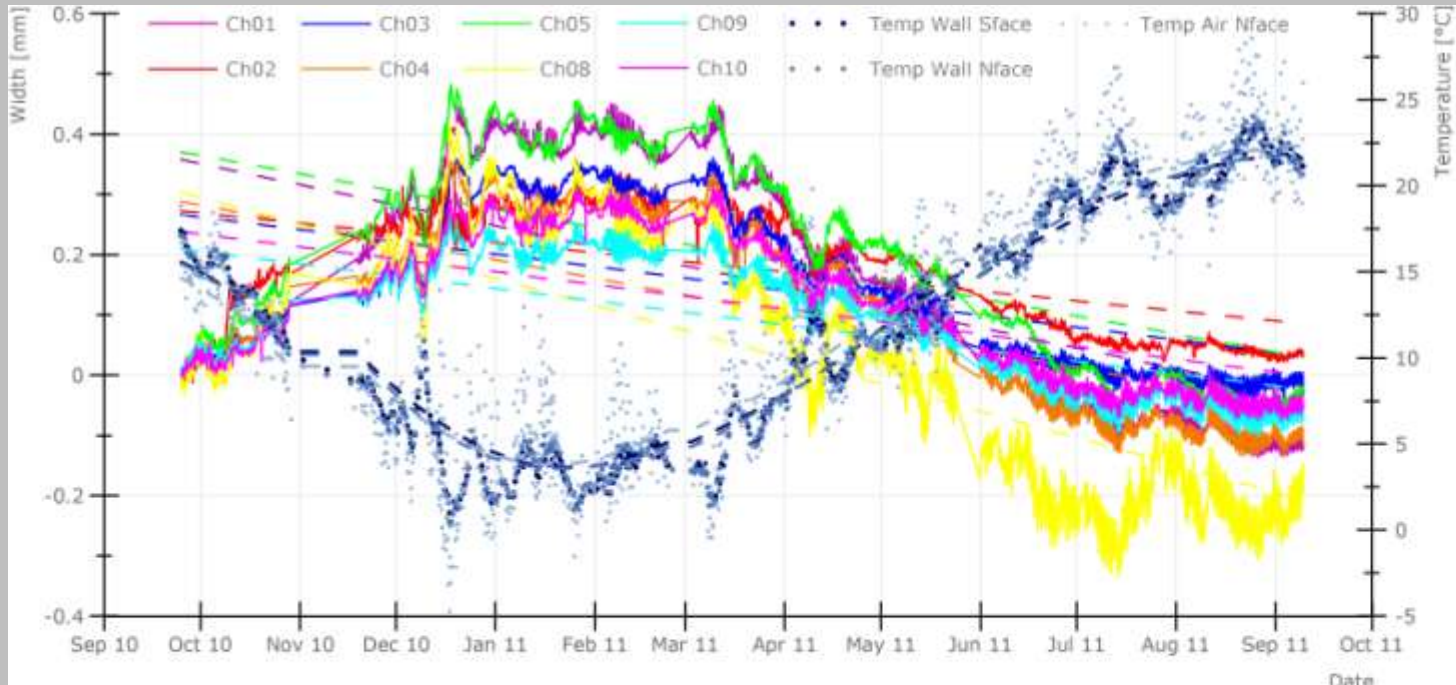
4 String pot

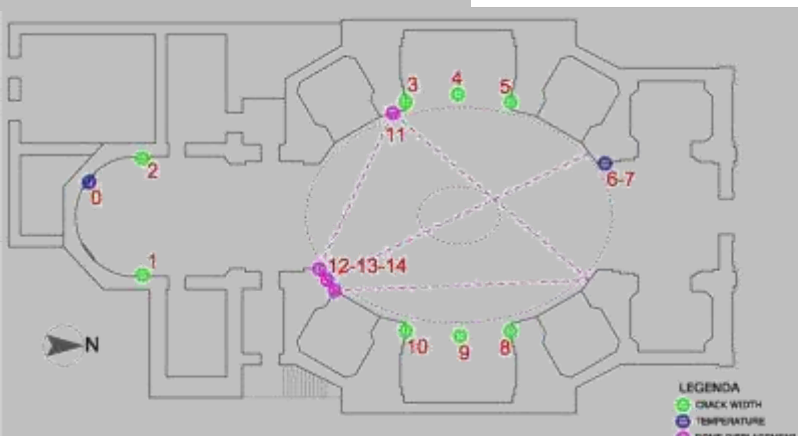
16 single axis accelerometers

Nagoya University, Japan

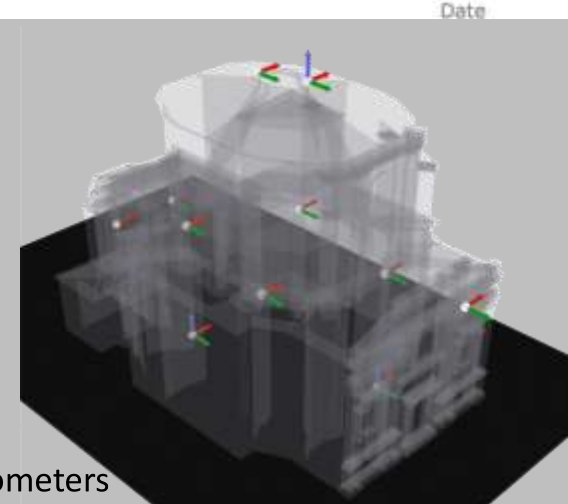
Static sensors







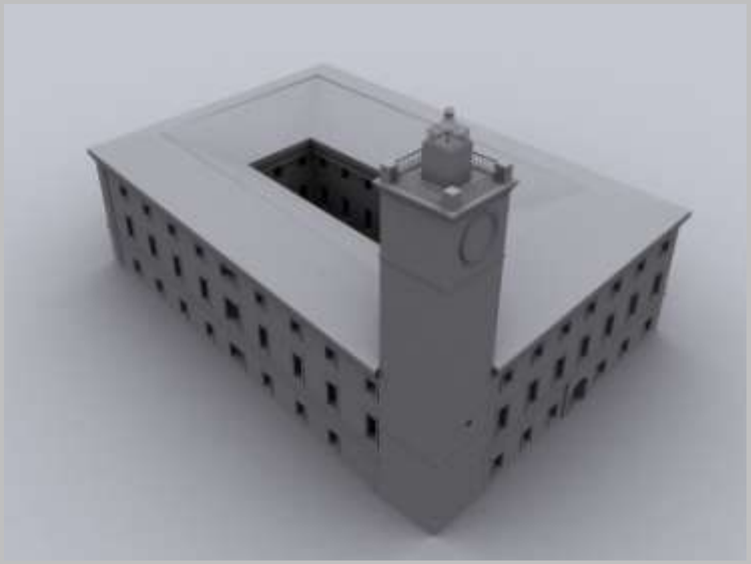
INSTALLED SENSORS (Sept 2010)
2 Temperature sensors
4 PDT (crack detection)
4 String pot
16 single axis accelerometers



accelerometers

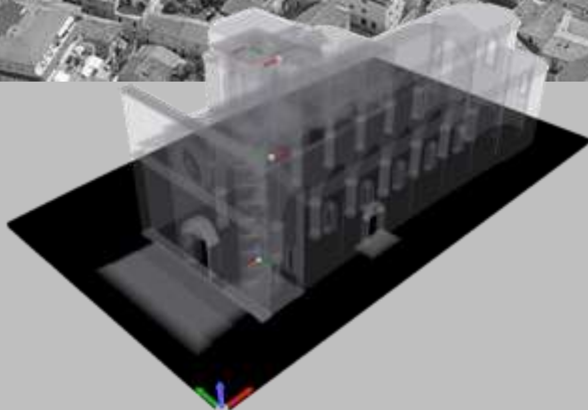
TORRE CIVICA

Nagoya City University, Japan
DCT Università degli Studi di Padova



Installed sensors (July 2010)

8 accelerometri monoassiali
2 termometri
4 estensimetri
4 fessurimetri
inclinometri

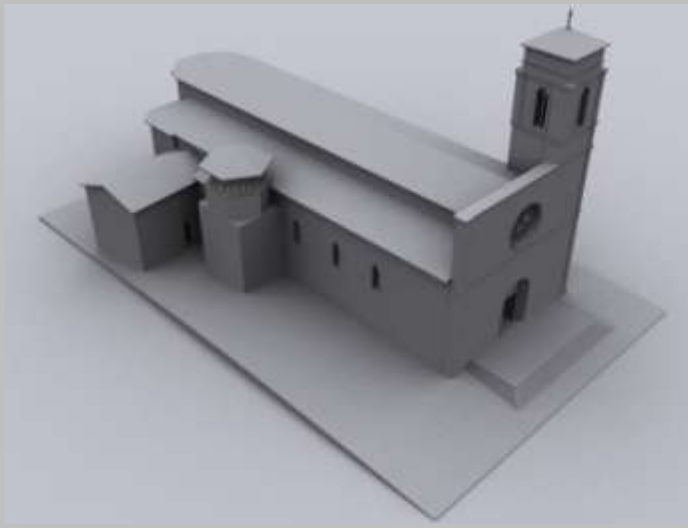


CHIESA DI SAN SILVESTRO

Nagoya City University, Japan
DCT Università degli Studi di Padova

Installed sensors (July - Sept 2010)

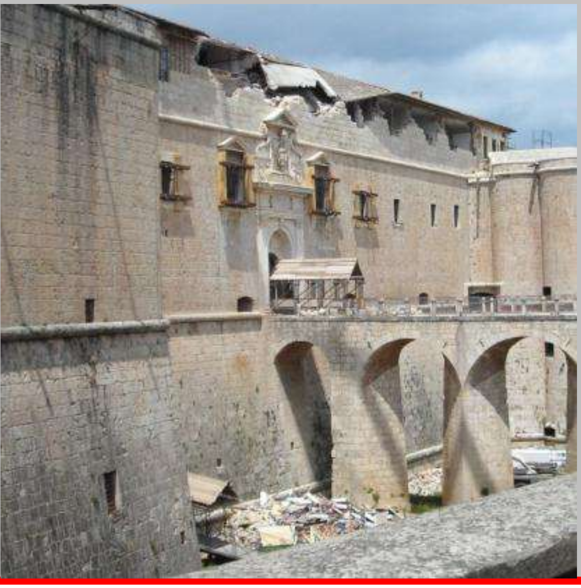
8 accelerometri monoassiali
2 termometri
4 estensimetri
4 fessurimetri
inclinometri



Monitoring Systems & Strategies

Prof. Claudio Modena

Spanish Fortress



INSTALLED SENSORS (Dec 2009)
8 single axis accelerometers
1 weather station
6 LPDT (crack opening)
2 tiltmeters

Following the 6th of April 2009 earthquake, the fortress was seriously damaged, especially in the upper floors, where several collapses were noticed. Between the recorded damage, overturning and flexural mechanisms on the external walls, shear damage in the external and internal walls, damage to vaults and arches, local collapses of floors and vaults, corresponded to the most worrying observations.

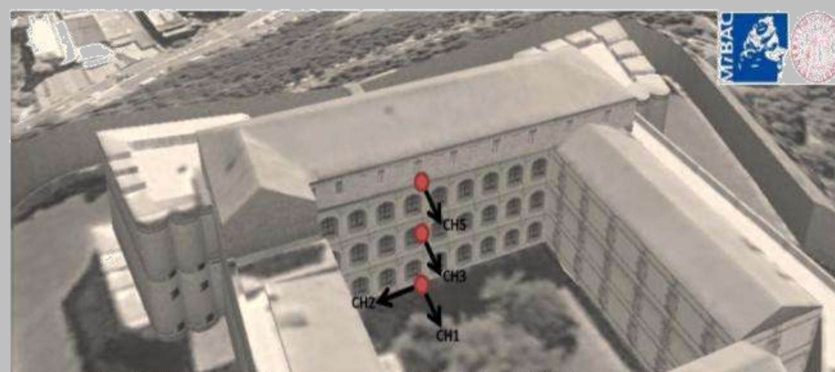
Damage manifested by the building were remarkable both for intensity and distribution, and were considered so serious to likely prejudice the overall stability of the building.

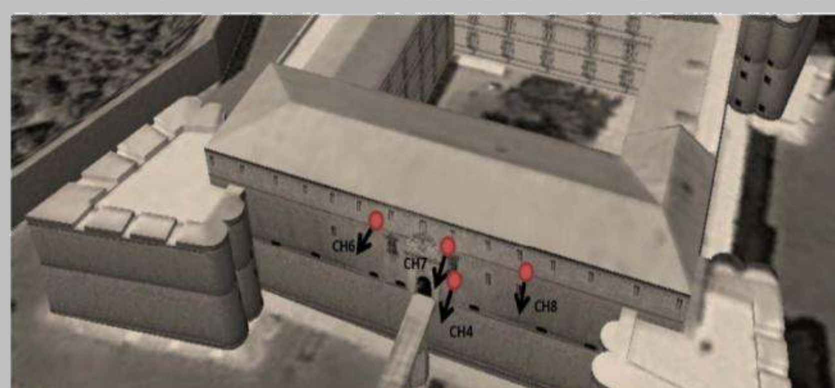
MONITORING SYSTEMS & STRATEGIES

PROF. CLAUDIO MODENA

In December 2009 a dynamic monitoring system was installed in the Spanish fortress of L'Aquila, following a first investigation campaign carried out in September, including dynamic identification tests. The system complements a static monitoring system installed in the first months after the earthquake by the ISCR - National Conservation and Restoration Institute) of Rome, devoted to the control of the crack pattern evolution and the environmental parameters.

The dynamic system is composed by an acquisition unit connected to eight high sensitivity piezoelectric accelerometers. The central unit, located at the second floor of the fortress, in the S-East wing, is provided with a WiFi router for remote data transmission.





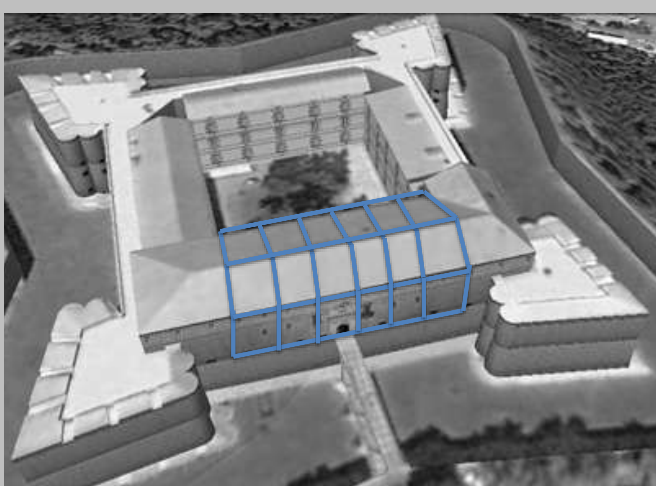
Monitoring Systems & Strategies

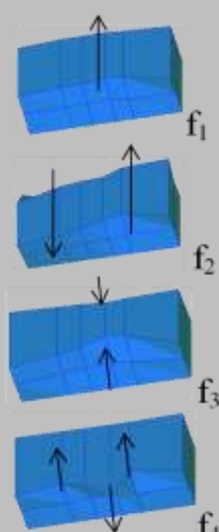
Prof. Claudio Modena

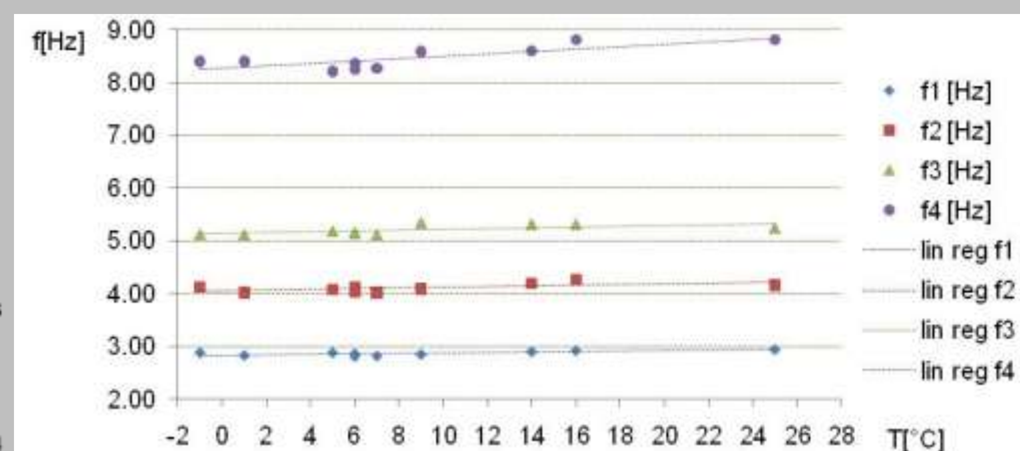
The dynamic system is composed by a central acquisition unit connected to the internet for the remote data transmission connected to 8 piezoelectric acceleration sensors.
A couple of reference sensors is positioned at the ground floor, to record the base acceleration in occurrence of an aftershockt, and the remaining sensors are fixed at the structure at the upper levels, according to the identified mode shapes.

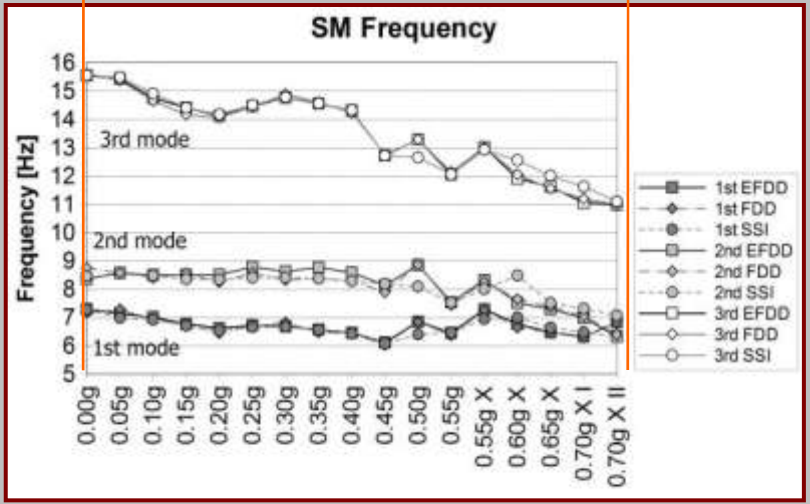
Displacement sensors are located on the pillars to assess the progression or stationariness of the overturning of the inner facade of the bulding, towards the courtyard.

Up to now, monitoring results indicate a general correlation between the environmental parameters and the dynamic properties





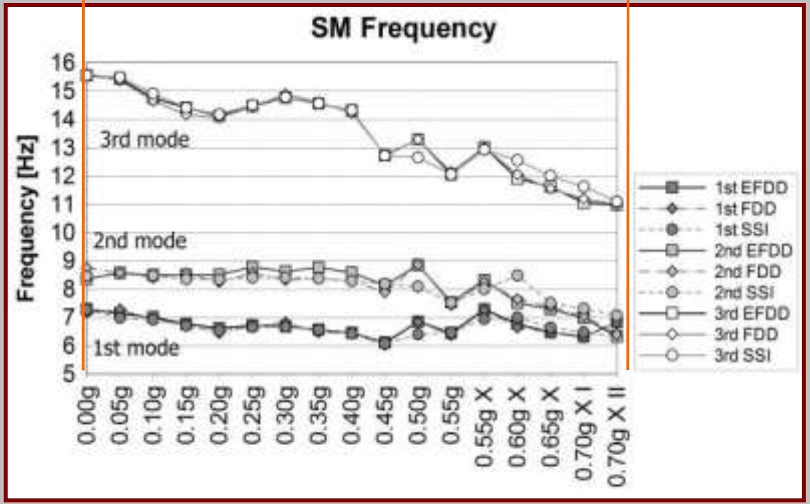




CONCLUSIONS (I)

Monitoring is being more and more considered, in the field of cultural heritage buildings, as a key activity in order to increase the knowledge on the structural functioning of monuments and therefore to have a deeper insight on their conditions.

In case of a seismic event, monitoring can furthermore prove its usefulness in quantitatively evaluating the progression or stationariness of the damage pattern of selected buildings, in order to keep controlled their structural behavior and to allow to intervene in an effective way and more urgently if an unsafe displacement patterns is noticed, also as an early warning procedure for the safety of the workers employed in the strengthening interventions.



CONCLUSIONS (II)

Between the available techniques that may be profitably used to control the response of a historic masonry building, dynamic identification proves to be a very effective tool, since it allows to experimentally measure parameters related to the global structural behavior.

The combined use of dynamic identification procedures and "local" controls (besides the monitoring of the environmental parameters), providing quantitative information on local conditions of structural elements (e.g. cracks opening), can be an important asset in the effort of attaining a deeper degree of awareness on the "real" structural functioning of the monuments.

THANK YOU!

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