Integrated Fire Engineering and Response
COST action network number TU0904 in domain Transport and Urban Development

Training School on 11-14 April 2012
Fire Engineering Research - Key Issues for the Future

UNIVERSITY OF MALTA
L-Università ta' Malta

The Marquees Vernasse of Akaia Palace, in Naples

Protection of historical buildings against catastrophic actions: case studies

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Protection of historical buildings against catastrophic actions: case studies – 3 actions analyzed

1. *Earthquake*

Case studies:

1. The gothic cathedral of Fossanova, *Lazio*

2. The old Palace in Saint Peter square in L'Aquila, *Abruzzo*

2. *Impact*

Case study

1. The Royal Palace in Naples, *Campania*

3. *Fire*

Case study

1. The Marquees Vernasse of Akaia palace, Naples - *Campania*

Italy

OLD Masonry: Stone works

- Different typologies

- Different structural problems

1. Cathedral and singular panels

Case studies: MATERIALS

1. The gothic cathedral of Fossanova**,**

STONE BLOCK WORK – LIME STONE

2. The old Palace in Saint Peter square in L'Aquila,

STONE WORK – STONES settled WITH NO REGULAR SHAPE with and alternation of BRIKS LAYERS

2. Pavilion Vault

Case study: MATERIALS

1. The Royal Palace in Naples,

STONE WORK – STONES settled WITH NO REGULAR SHAPE

3. Corner house

Case study: MATERIALS

1. The Marquees Vernasse of Akaia palace, Naples

STONE BLOCK WORK – TUFF STONE

Case study: The gothic cathedral of Fossanova

Fossanova Full scale Model – shaking table test

PROHITECH Project activities ("Earthquake Protection of Historical Buildings by Reversible Mixed Technologies" FP6- INCO-CT-2004-509119). It's a European project coordinated by *Prof. Federico Mazzolani*, devoted to the protection and conservation of the cultural heritage in the Euro-Mediterranean area. The project stopped in 2008; all tests and full scale models produced were built up and checked in Skopje – IZIIS Laboratory.

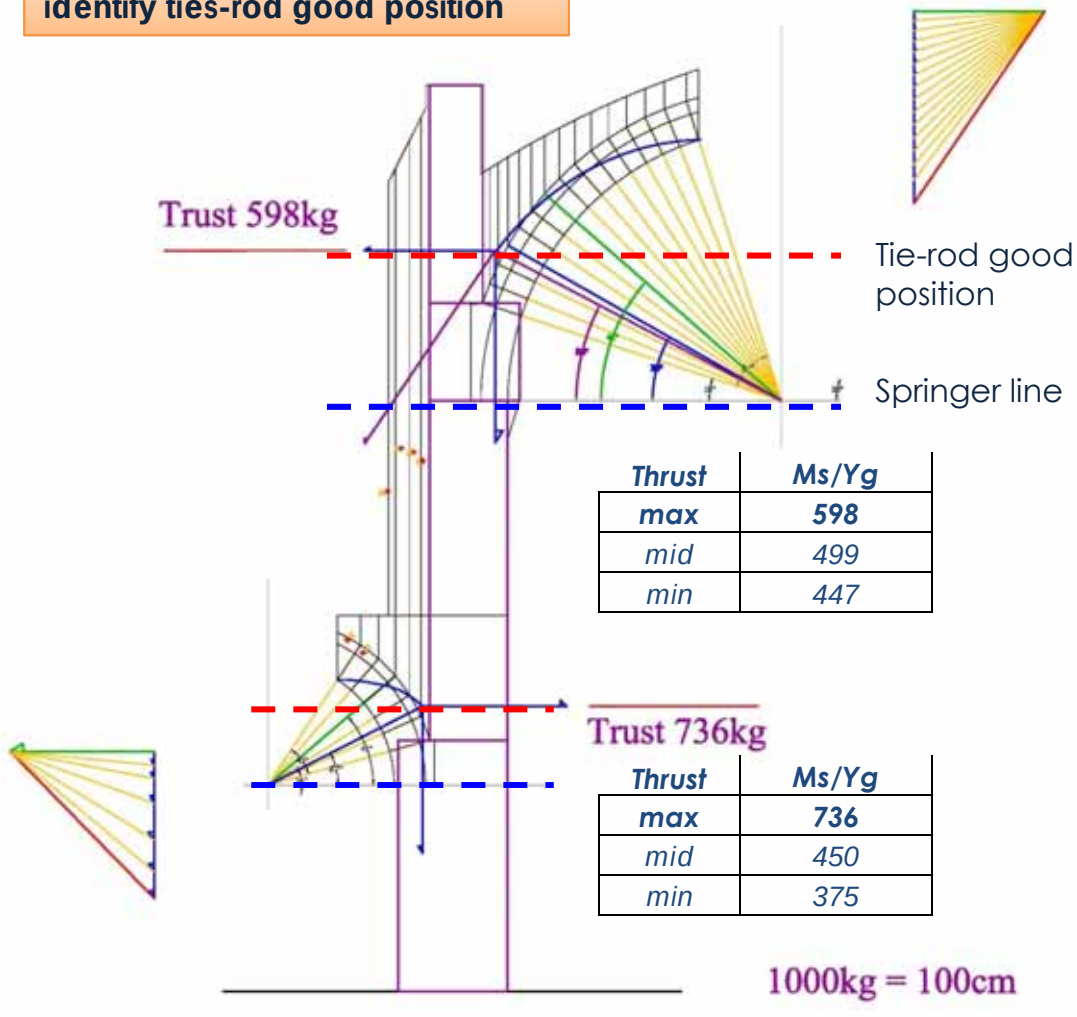
Additional test

The additional test was conducted on the Fossanova cathedral's large scale model (scale 1:5.5), in collaboration with the University of Reggio Calabria (in the framework of Reluis activities.) and with the contibution of Lazio's Supervision on the architectonical heritage

The Strengthening of the model tested

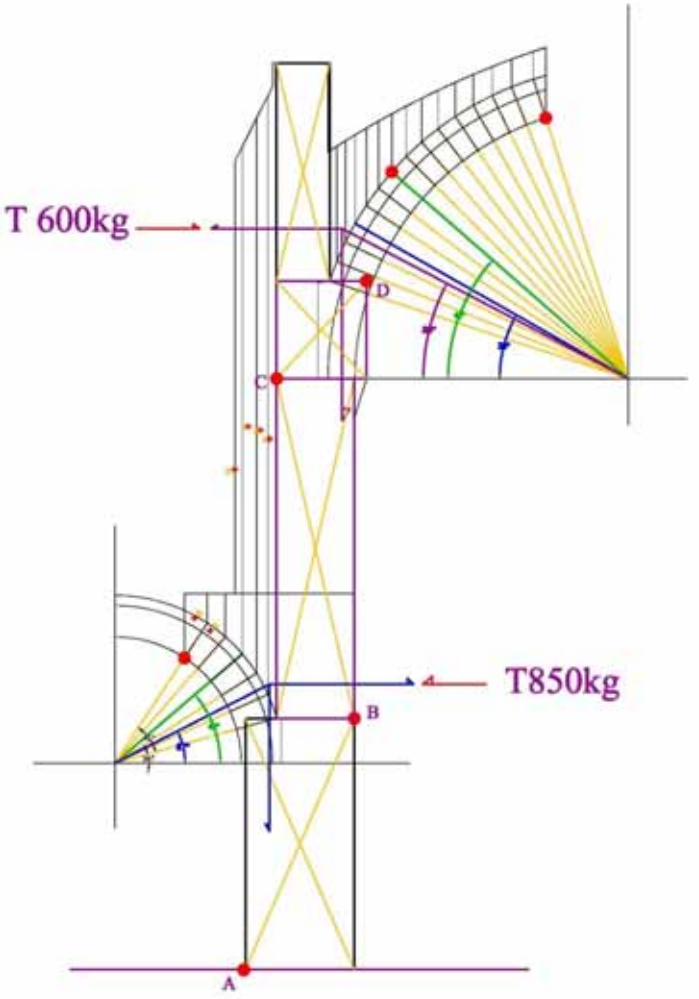
Traditional techniques of intervention

Graphic analysis for easily identify ties-rod good position



Thrust	*Ms/Yg*
max	***598***
mid	*499*
min	*447*

Thrust	*Ms/Yg*
max	***736***
mid	*450*
min	*375*



Equilibrium Condition
Ms - λ*Mr = 0
λ = Ms/Mr

Without tie-rod

λ A	**λ B**	**λ C**	**λ D**
0,21	0,09	0,70	0,58

With tie-rod

λ A	**λ B**
1	0,36

Case study: The old Palace in Saint Peter square in L'Aquila

L'AQUILA Earthquake

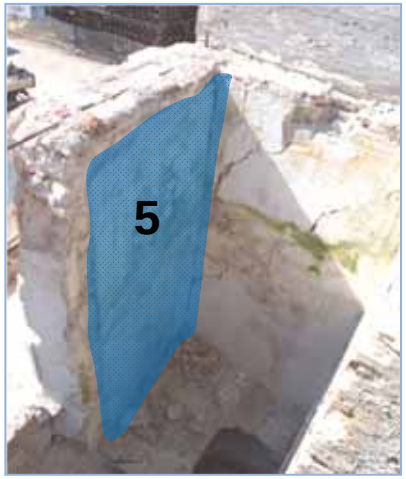
06 April 2009

Before seismic action

Historical centre of L'Aquila city, San Peter Square – Old Palace signed up -

OLD Palace after seismic event – corner failure -

Old Palace façade



Panel selected

Old Palace façade on S. Peter square before testing program

TESTING PROGRAM

2 façade occupied
(only the masonry elements of the first floor)

6 panels tested out-of-plane

1 panel tested in-plane

University involved:
Michele Candela, Reggio Calabria

Sergio Lagomarsino, Genoa

Antonio Borri, Perugia

Façade on Pretatti street – Panels selected -

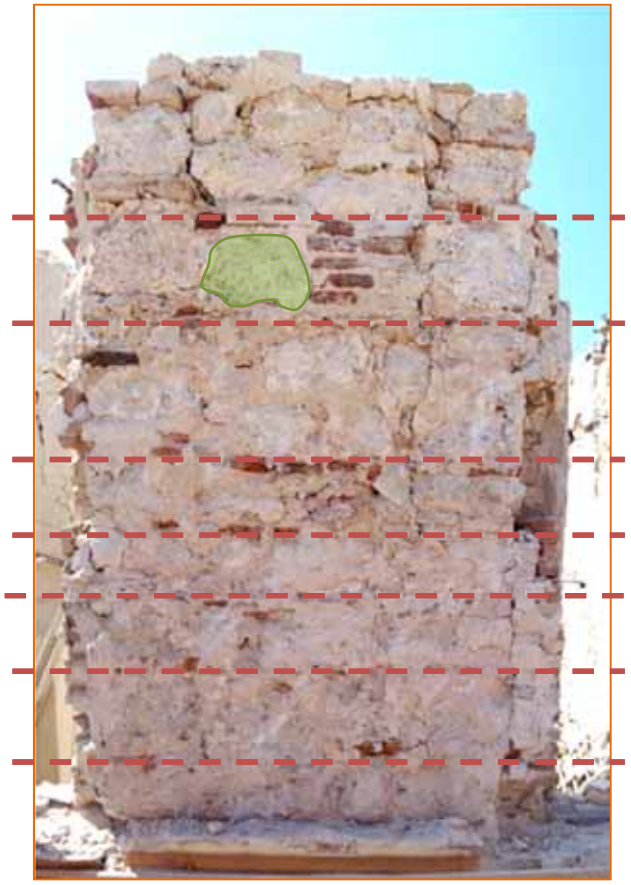
Building site during controlled demolish program of the damaged parts

Analysis and evaluation of the masonry characteristics

Defects detected

1) **NO transversal connections**

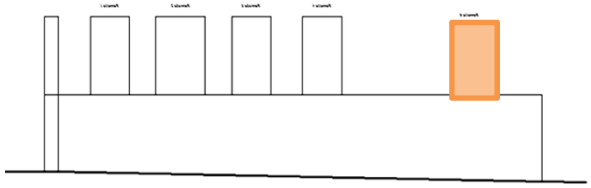
2) **NO contact between stones – mortar joints too bigger**



ASSESSMENT of the stonework TYPE

- no ordinary setting;
- small size of the stones;
- regular flatten made in bricks;
- no transversal section links totally absence of headers;
- thick mortar joints;
- no contact between stones

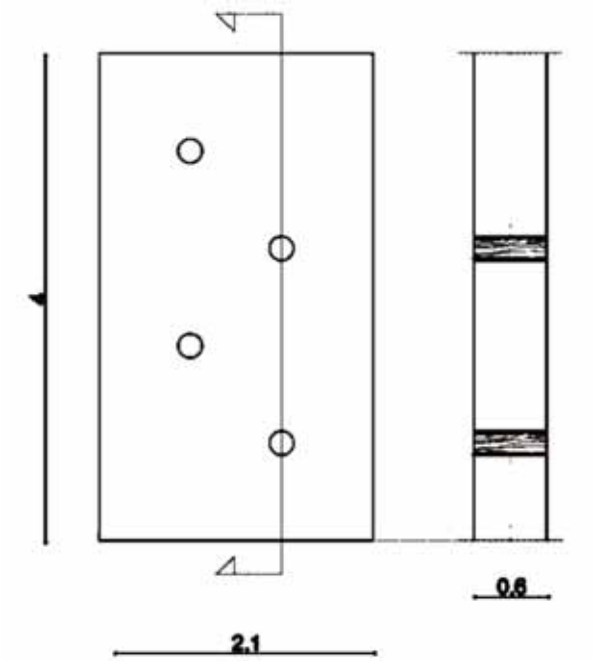
"TAL QUALE"



Pretatti street - façade

PANEL 5 REINFORCEMENT STRATEGY

Problem
no transversal section links
Solution
Headers in wooden pushed in load condition by wedges
Problem
thick mortar joints and consequently no contact between stones
Solution
Replacement of the mortar joints with small bricks elements formed like wedges.



THE STRENGTHENING

Executive phases
1) Study of the masonry setting

2) Drill the panel with 4 hole full in wideness, diameter of ø 200.

3) Replacement of the mortar joints with wedge elements;

4) Setting of the wooden headers and the pushing of the elements in loading condition by wedges elements.

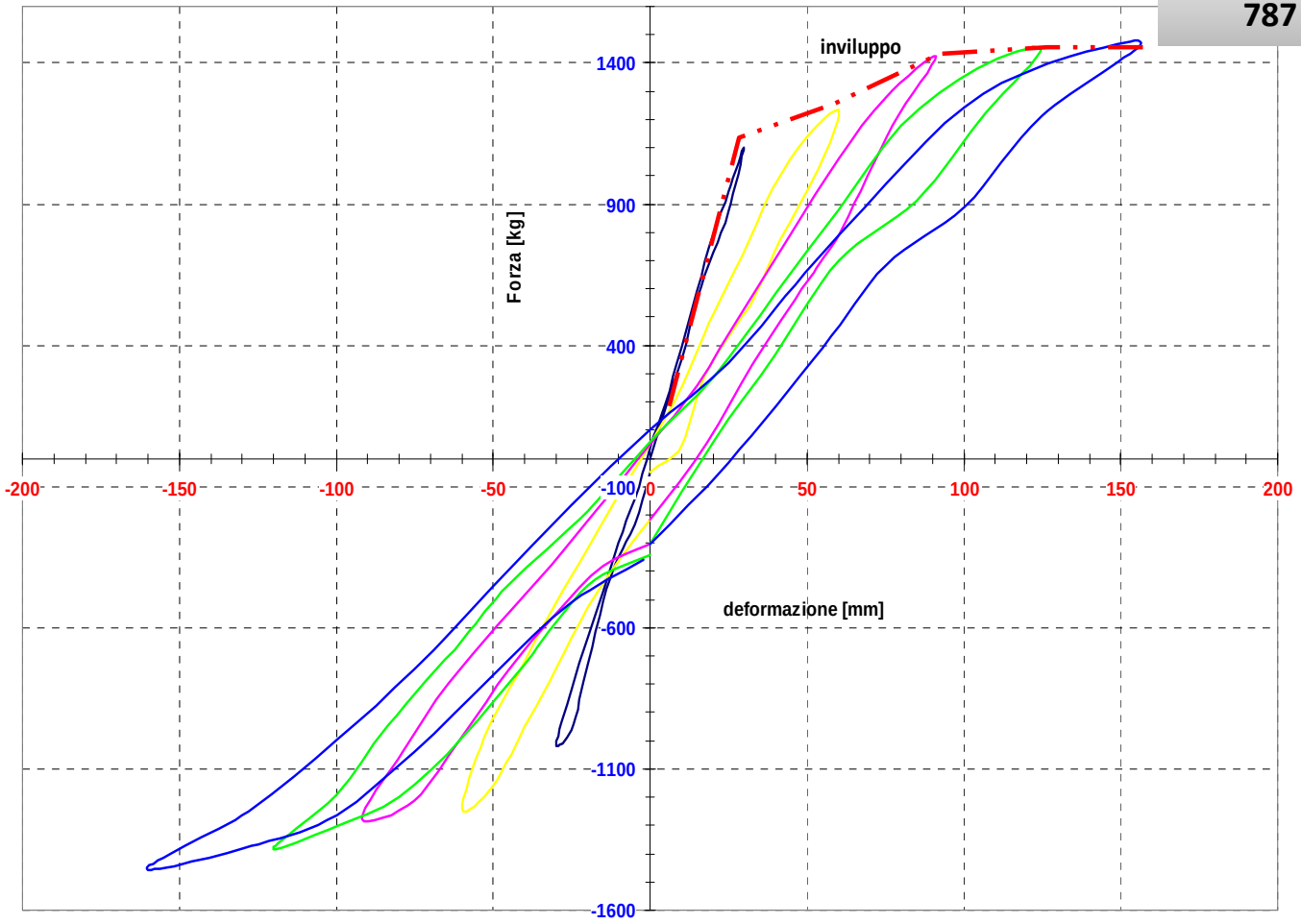
PHASE 1

PHASE 2

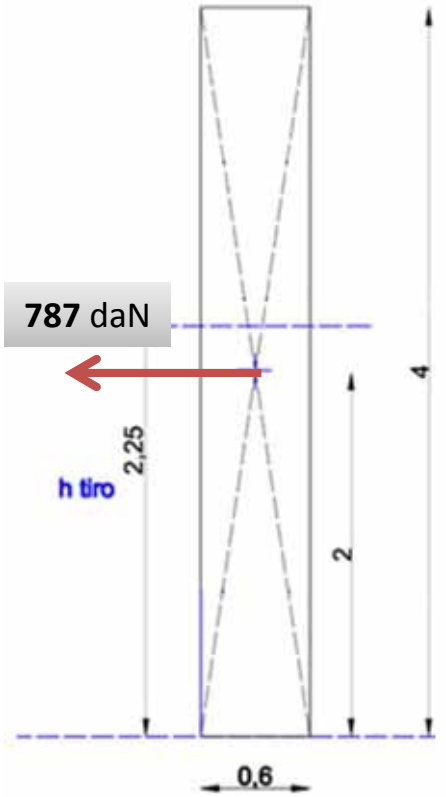
PHASE 3

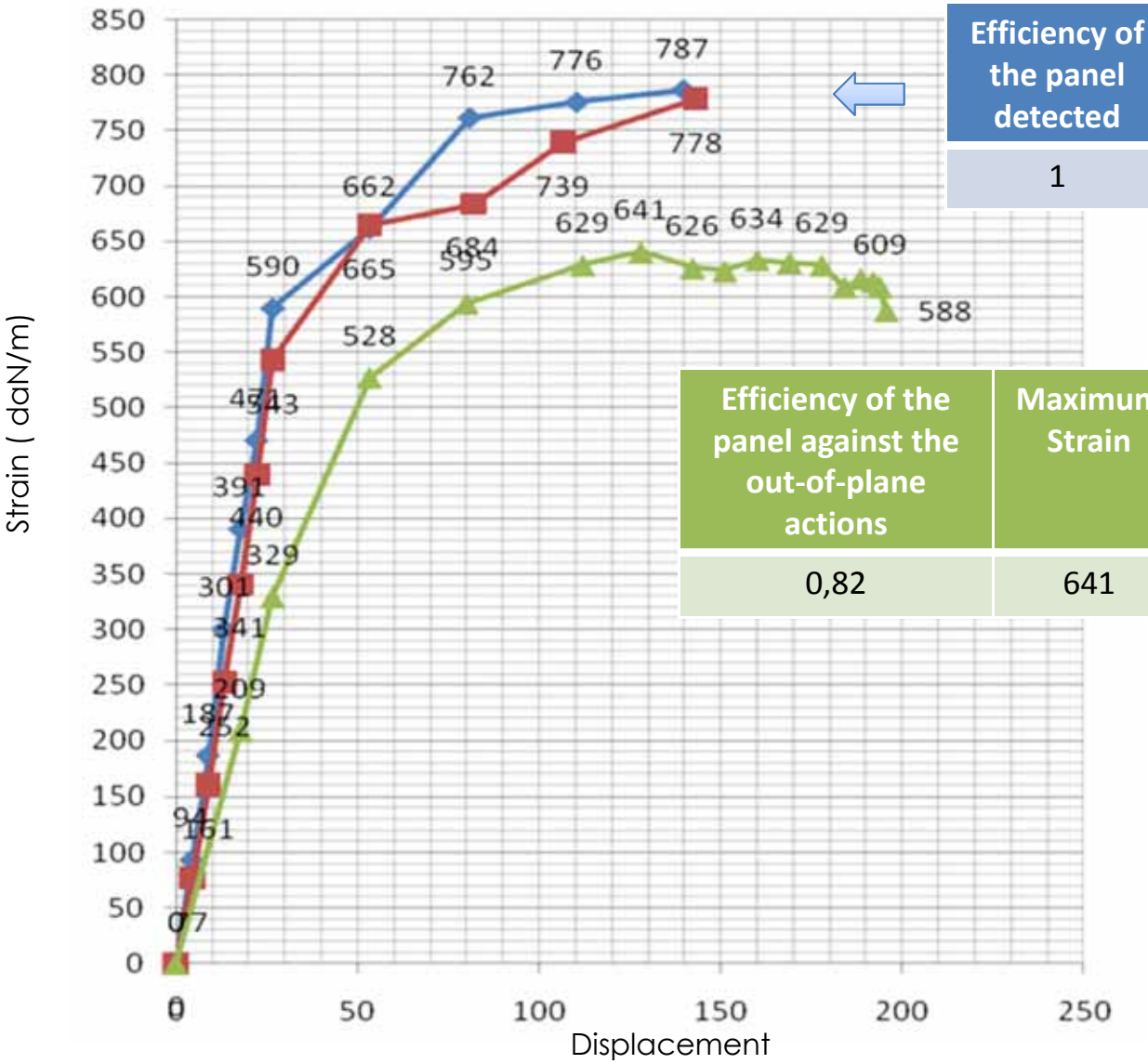
PHASE 4

Maximum strain
787 daN



787 daN





Efficiency of the panel detected	Maximum Strain
1	787

DEGRADATION OCCURRED 18%

Efficiency of the panel against the out-of-plane actions	Maximum Strain
0,82	641

Capacity curve comparison:

In **blu** Maximums Envelope - positive phases data

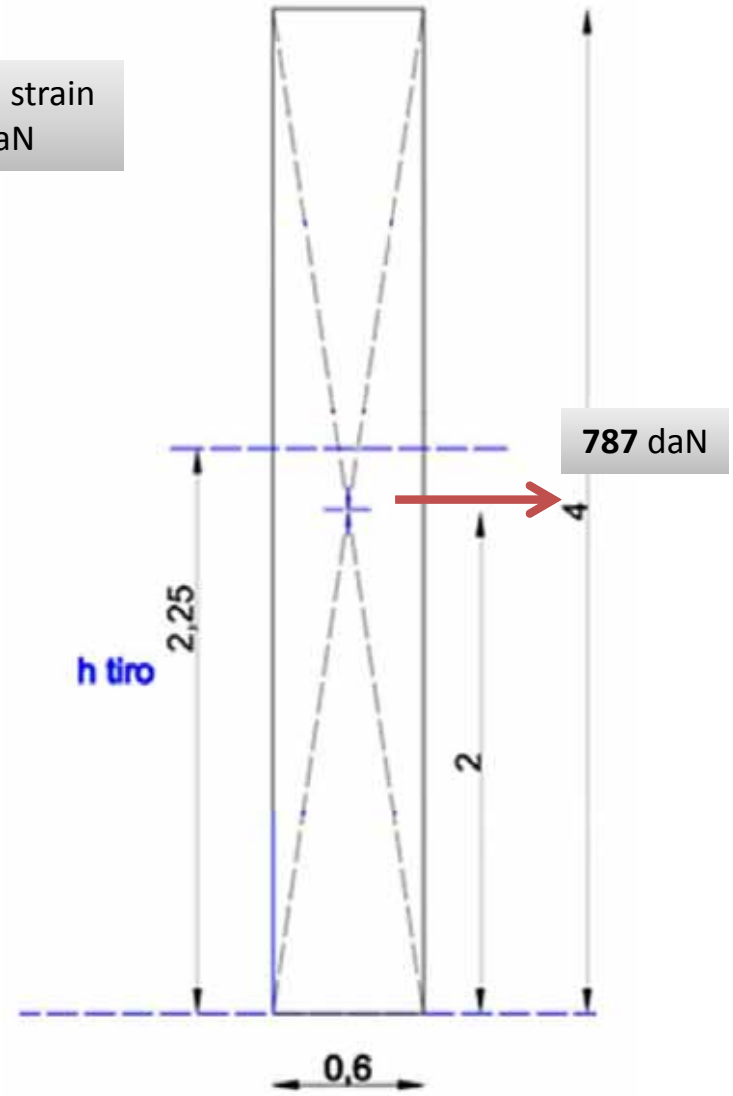
In **red** Maximums Envelope - negative phases data

In **green** PUSH OVER curve

Fmax (daN)	Fomol. (daN)	Trust (daN)	Mr (daN*m)	Ms=Mr Teoric Model(daN *m)	Efficiency compared to a Rigid block
1469	1653	787	1574	1570	**1**

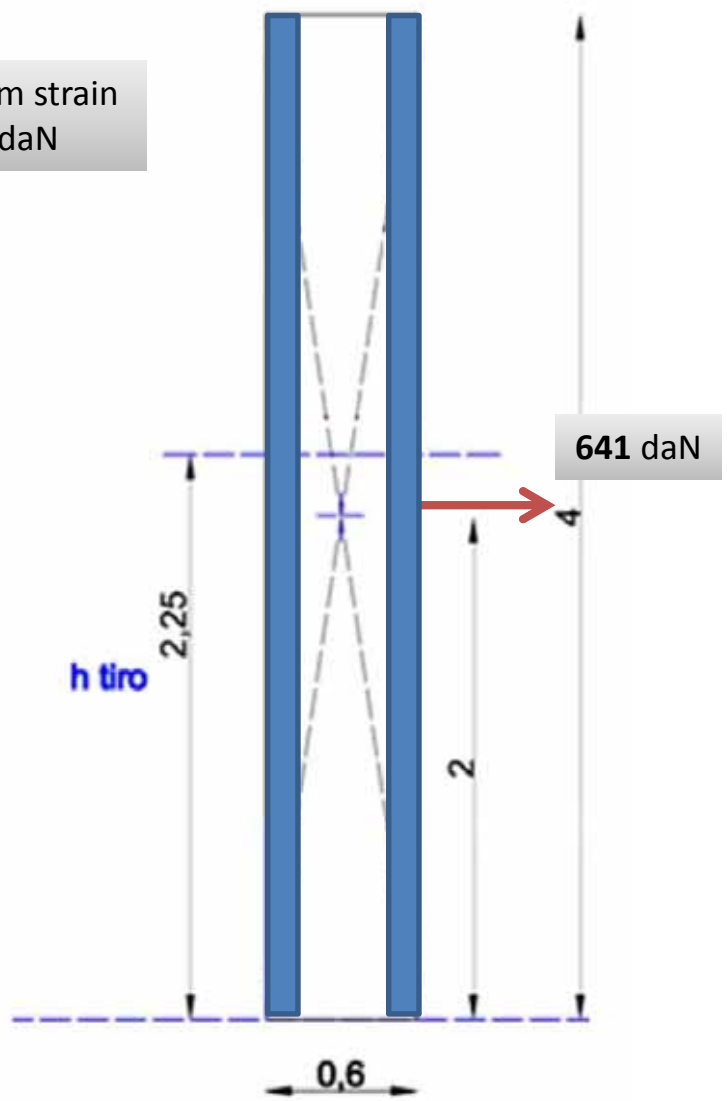
Before cyclic action

Maximum strain
787 daN



After cyclic action

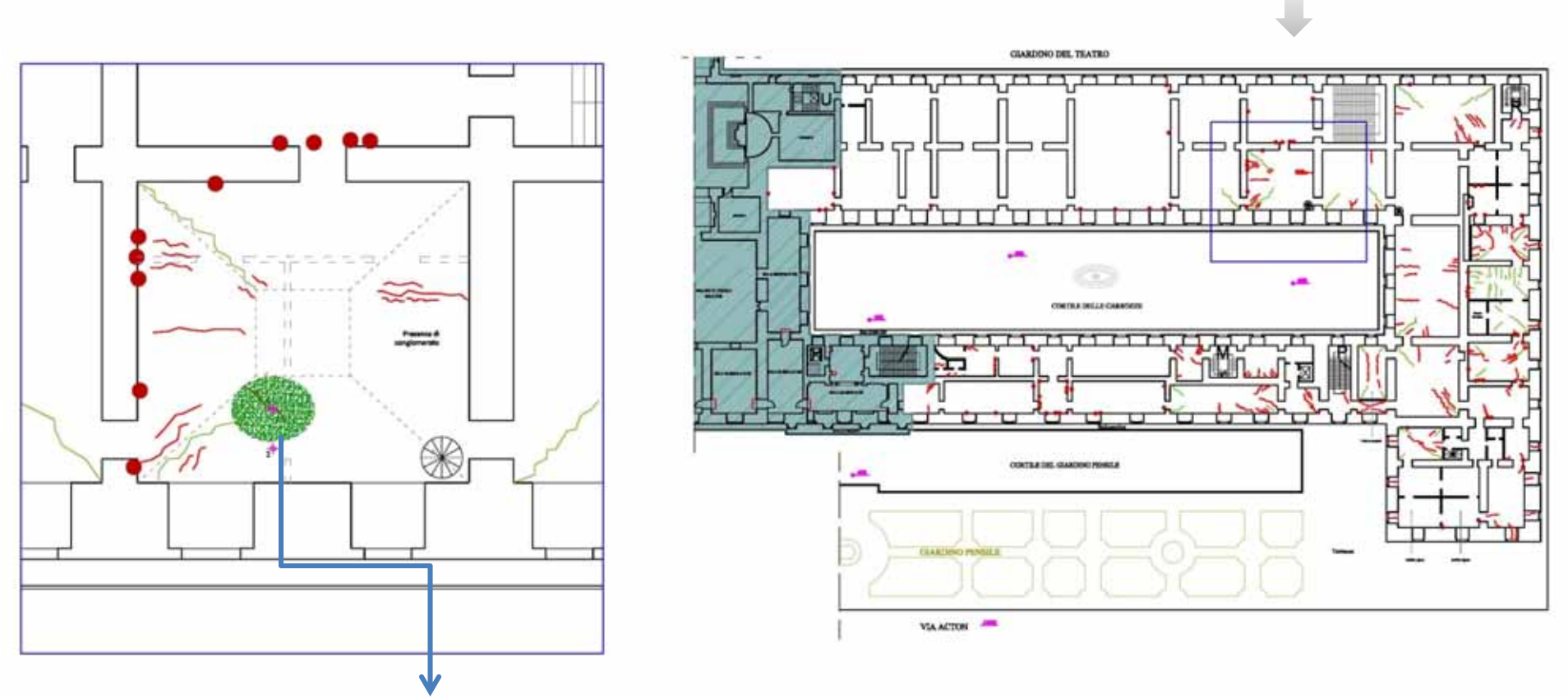
Maximum strain
641 daN



Case study: The Royal Palace in Naples

The Royal Palace in Naples IMPACT ACTION – NATIONAL LIBRARY HALL

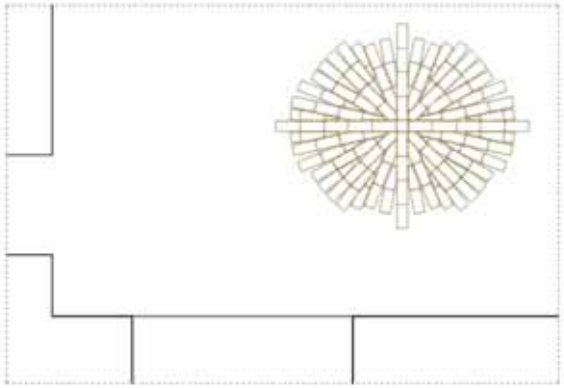
Area bombed during World War Two



break due to the bomb impact

The Royal Palace in Naples IMPACT ACTION – NATIONAL LIBRARY HALL

Damage occurred in 2009. it was due to wrong reinforcement intervention



Strategy approved and checked by loading tests

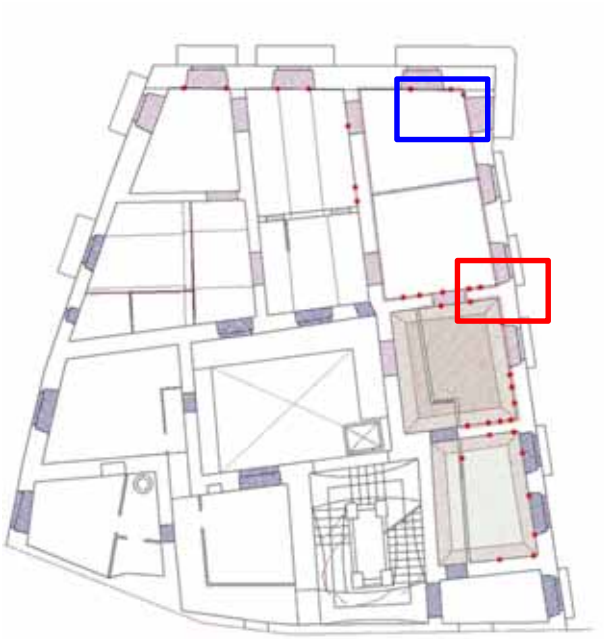
Case study: The Marquees Vernasse of Akaia palace, Naples

The Marquees Vernasse of Akaia palace, Naples

FIRE ACTION – OCTOBER 2009

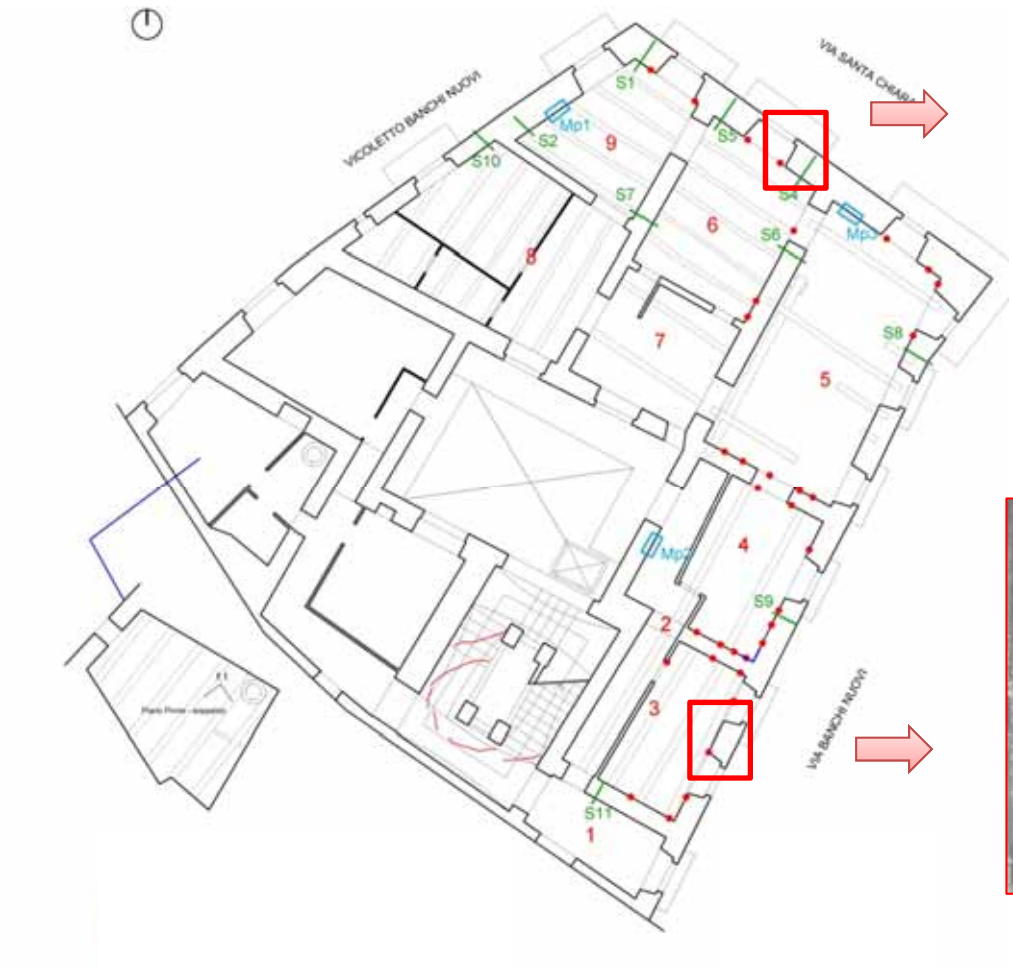
The Marquees Vernasse of Akaia palace, Naples

FIRST FLOOR DAMAGE OCCURRED



The Marquees Vernasse of Akaia palace, Naples

TESTS



Test campaign

Specimens – under fire action

Specimens – no hit by fire action

The Marquees Vernasse of Akaia palace, Naples

TESTS

DATA RESUTS – NO FIRE ACTION

Specimens	Dimensions [cm]	Volume g/c³	compression resistance [MPa]	Elastic modulo [MPa]
n.1	6.9x6.8x7.0	1.51	4.62	1488
n.2	6.8x6.8x6.9	1.54	4.58	1665
n.3	7.1x7.2x6.9	1.50	4.51	1823
n.4	6.7x6.8x6.8	1.50	4.22	1778

MINIMUM	4,06[MPa]
MAXIMUM	4,62[MPa]
	4,39[MPa]

DATA RESUTS - FIRE ACTION

Specimens	Dimensions [cm]	Volume g/c³	compression resistance [MPa]	Elastic modulo [MPa]
n.1	7.1x7.2x6.8	1.55	3.41	1636
n.2	7.3x7.1x7.2	1.50	3.24	1431
n.3	6.8x6.9x7.2	1.49	3.19	1474
n.4	6.8x6.7x6.9	1.52	3.04	1574

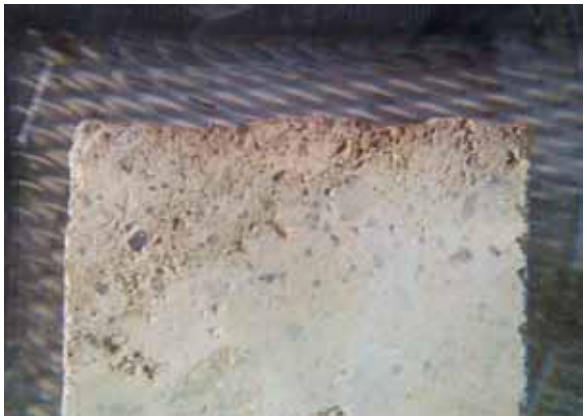
MINIMUM	3,04 MPa
MAXIMUM	3,41 Mpa
	3,22 Mpa

Specimens – under fire action notes

Thickness degraded – 2,70cm

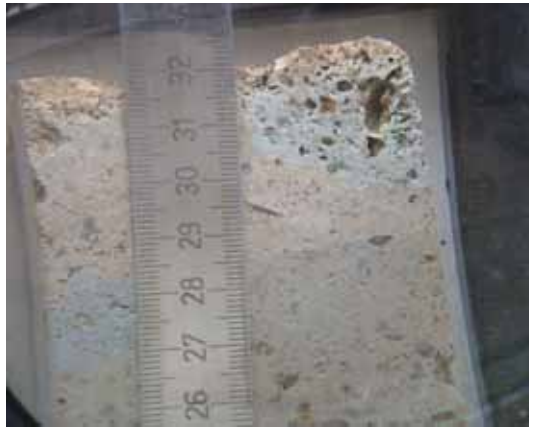
Thickness degraded – 2,95cm

Thickness degraded – 2,66cm



Thickness degraded – 3,56cm

Thickness degraded – 4,11cm



Thickness degraded – 3,60cm

Thank you very much for your attention