2012 EERI ANNUAL & EARTHQUAKE MEETING



# **Learning from the Past to Protect the Future**

April 10-13, 2012 - The Peabody Hotel, Memphis, TN

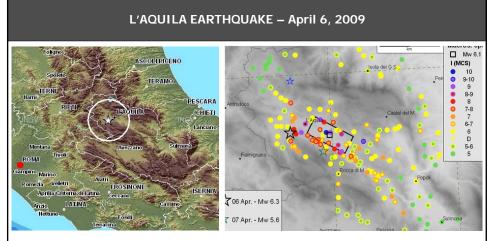
# Seismic Performance of Masonry Buildings after the 2009 L'Aquila Earthquake

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#### SAFETY AND CONSERVATION OF MASONRY BUILDINGS IN ITALY

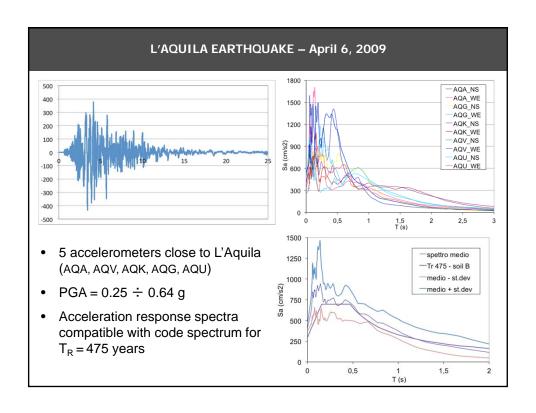
- Italy has a high percentage of ancient masonry structures
- The seismic risk in Italy is very high. Earthquakes are quite frequent but rarely of large magnitude (from 6 to 7  $M_W$ )
- Masonry buildings always suffered serious damage due to earthquakes, but specific constructive details were adopted in the areas at higher seismic risk
- Need of conservation of ancient buildings, with strengthening interventions which are compatible with the original structure
- Recent codes and guidelines in Italy adopt the performance based assessment procedure for the design of interventions and propose nonlinear models for in-plane and out-of-plane response of masonry buildings



Magnitude  $M_w = 6.3$  - Intensity (max)  $I_{MCS} = 10$ Shallow focal depth (10 km) - Short duration (less than 10 s)

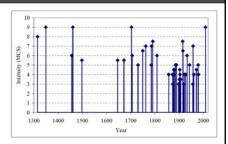
L'Aquila: ≈70.000 inhabitants - 48 small villages: ≈60.000 inhabitants Victims: 308 (203 in L'Aquila, most in pre-code r.c. buildings)

Injured: 1,500 - Homeless: >24.000 - Damaged buildings: 15.000



#### HISTORICAL SEISMICITY AND MASONRY BUILDINGS

- One big earthquake every 300 years
- → in most cases, buildings were reconstructed by using the ruins
- Many earthquakes of small to medium intensity
- → vulnerability induced by damage and aging of materials



### L'AQUILA AND THE SURROUNDING AREA

- L'Aquila, the capital of Abruzzo Region, is an historical town
- In the surrounding area (Aterno Valley) there are a lot of small villages, many of them with ancient historical centres.

#### TYPES OF MASONRY BUILDINGS

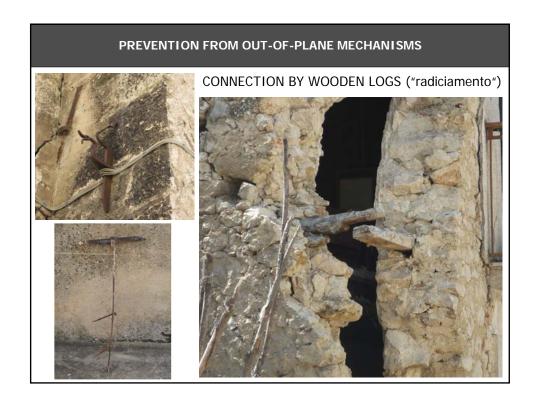
- Residential buildings in historical centres, strictly connected in complex aggregates
- Monumental palaces in the centre of L'Aquila (most of them were built after 1703 earthquake, by using the ruins of smaller buildings)
- Churches: high concentration of this vulnerable type of structures

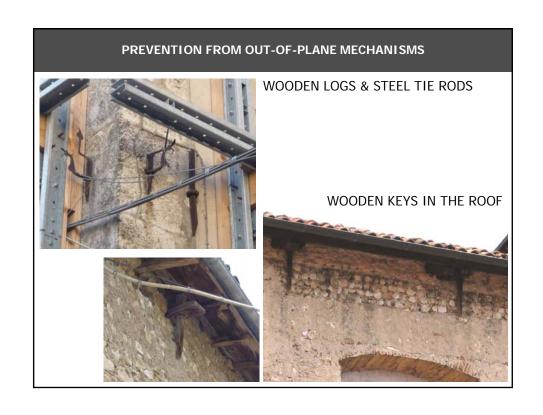
## **COLLAPSE MECHANISMS**

- OUT-OF-PLANE overturning
- IN-PLANE failure of walls
- Collapse of thin-walled vaults
- Local mechanisms in aggregates













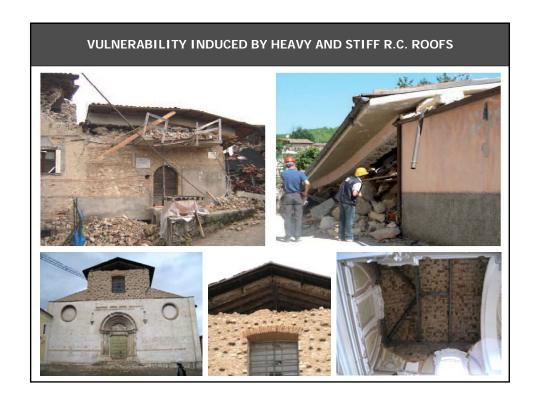


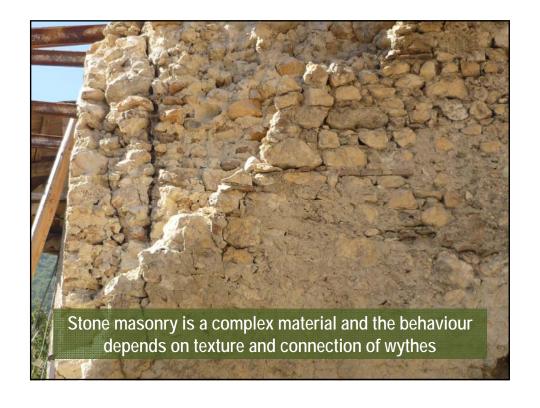
# SPECIFIC VULNERABILITIES IN PALACES

Shear strength of masonry panels is strongly reduced due to:

- alterations occured in the past (closed windows, additions, ....)
- flue of chimneys, cuts due to equipments, ....







## **OUTER WYTHES TEXTURE**

- Small irregular limestone blocks (20÷25 cm)
- Lime mortar, that surrounds very well the blocks, giving an almost isotropic behaviour





## TRANSVERSAL SECTIONS OF MASONRY

- Outer wythes are thin, compared to the wall thickness
- In most cases, masonry is almost homogeneous through thickness
- Absence of transversal stone shear keys









