



ועדת הרייטי הבין-מסדרית להערכות והעידות אדמה  
National Steering Committee for  
Earthquake Preparedness



UNIVERSITA  
DEGLI STUDI  
DI PADOVA



## International Seminar

**Assessment and improvement of structural safety under seismic actions of existing constructions: Reinforced Concrete Structures and Historical buildings**

SCE - Shamoon College of Engineering, Beer Sheva - 29 November 2015

International Conservation Center, Citta' di Roma, Old Acre - 1 December 2015

**Lessons learned from the past earthquakes:  
damages catalogues and interpretation**

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# EFFECTS OF EARTHQUAKES ON CULTURAL HERITAGE



*L'Aquila earthquake – 2009*

Historical buildings are particularly threatened by earthquake events

Specific approaches are needed to evaluate and reduce their vulnerability while safeguarding their artistic and historical values

→ Knowledge is the first step



# SAFETY STANDARDS FOR HISTORICAL STRUCTURES

**ISO 13822** (bases for design of structures – assessment of existing structures - 2001)

**Assessment of safety:** Structures designed and based on earlier codes, or designed and constructed in accordance with good construction practice when no codes applies, may be considered safe to resist actions others than accidental actions (including earthquake) provided that:

- Careful inspection does not reveal any evidence of significant damage, distress or deterioration
  - The structural system is reviewed, including investigation of critical details and checking them for stress transfer
- The structure has demonstrated satisfactory performance for a sufficiently long period of time for extreme actions due to use and environmental effects to have occurred
  - Predicted deterioration taking into account the present condition and planned maintenance ensures sufficient durability
  - There have been no changes for a sufficiently long period of time that could significantly increase the actions on the structure or affect its durability, and no such changes are anticipated

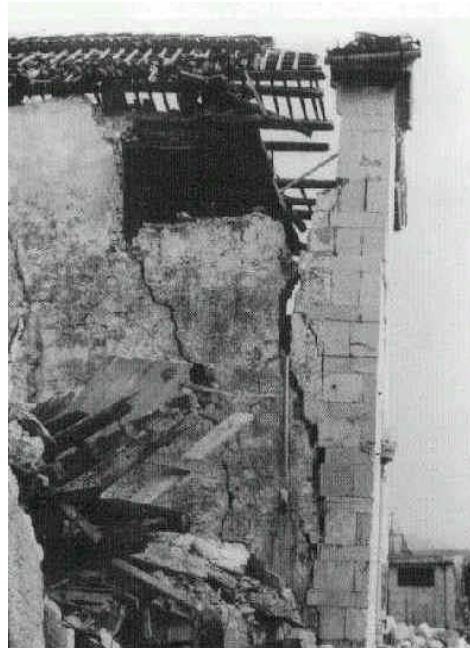
# EARTHQUAKES EXPERIENCE (ITALY)

The experience of earthquake that struck Italy (Umbria-Marche 1997, Abruzzo 2009, Emilia 2012) showed that existing masonry buildings fail due to mechanisms related to low masonry quality or lack of connections among structural components.

→ rigid-body mechanisms (mainly out-of-plane) causing the loss of equilibrium of walls, portions or assemblages

Some strengthening techniques which became very popular and even compulsory according the previous seismic code (injections, jacketing, replacement of flexible floors with stiff floors) showed their limits.

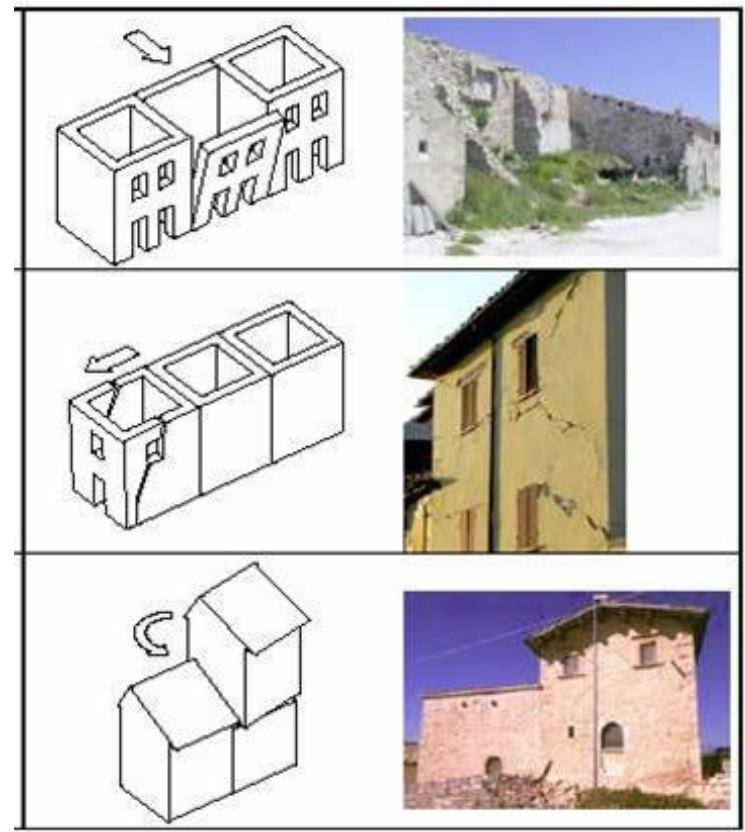
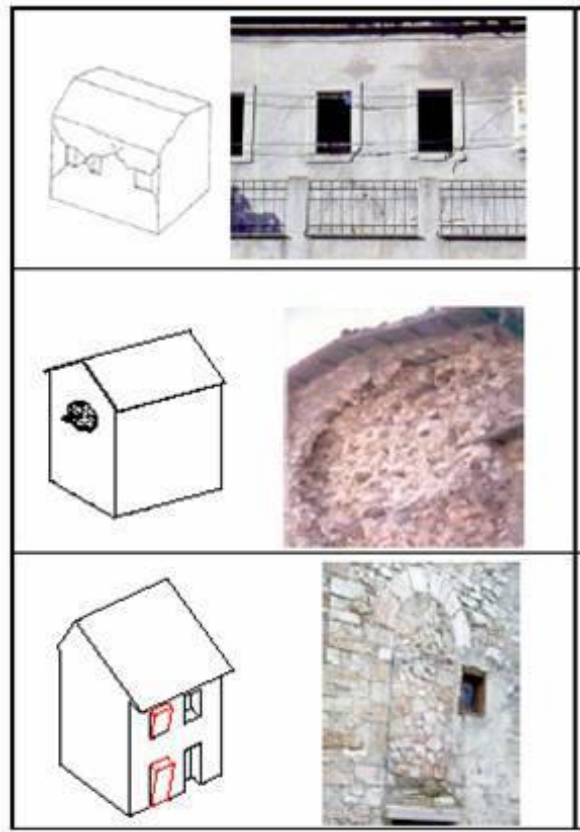
→ low performances or the structural behaviour of existing masonry buildings even worsened



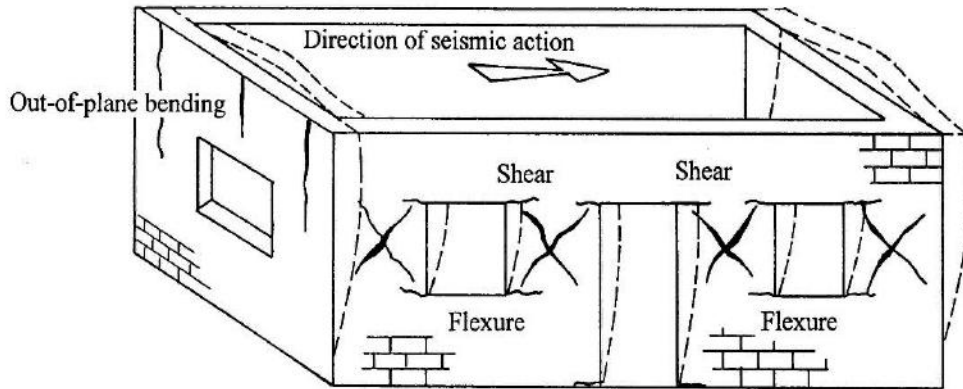
# EARTHQUAKES EXPERIENCE (ITALY)

Since the experience of the Umbria-Marche earthquake, the damage observation, together with experimental and theoretical studies, also underlined that the seismic response is influenced by the interaction with close buildings

→ local effects occurring earlier than a global behaviour can be developed



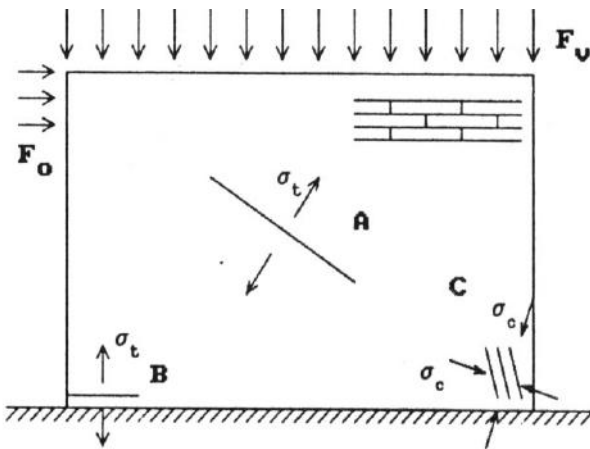
# MASONRY BUILDING BEHAVIOUR UNDER SEISM



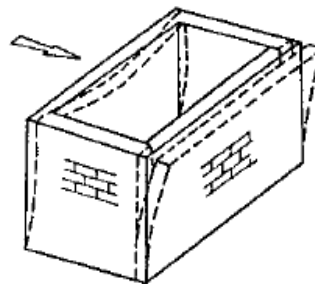
Building deformation and typical damage of the bearing masonry structural elements under seismic action

(Tomazevic, 1999)

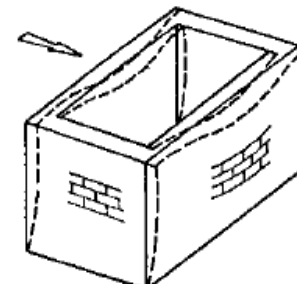
Wall damage for in-plane actions



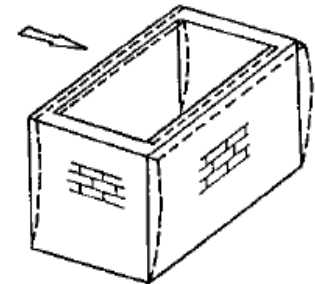
Effect of connections (wall-to-wall; wall-to floor/roof)  
Effect of type of floors



Flexible floor and walls without connections



Flexible floor and connected walls



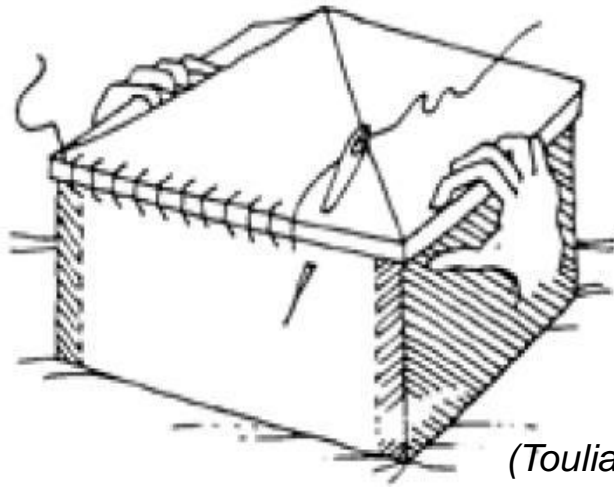
Rigid floor and connected walls

# EARLY EXPERIMENTAL STUDY ON SHAKING TABLE

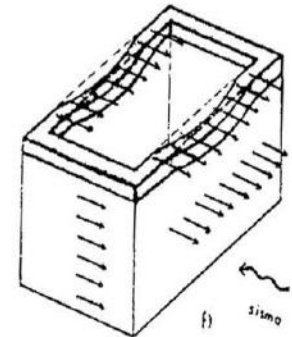
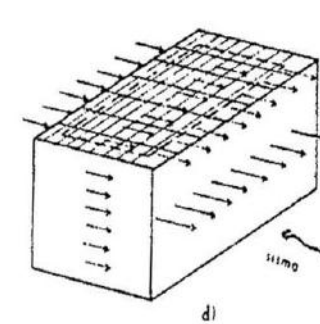
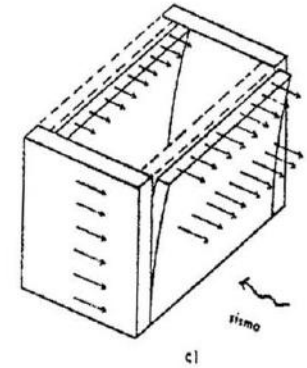
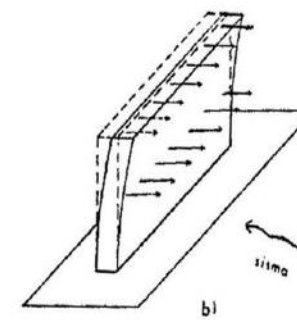


(ZAG Slovenia, Tomazevic )

# RESPONSE TO EARTHQUAKE: STRUCTURAL CONFIGURATION



- a) isolated wall (non connected)
- b) high-stiffness floor
- c) no connections among elements
- d) wall-to-wall and wall-to-floor connection by ring-beam



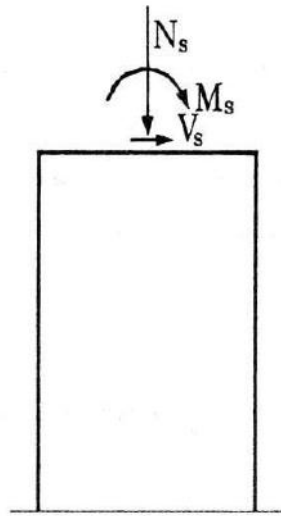
## BOX-LIKE BEHAVIOR

Horizontal forces absorbed by the walls in their plane

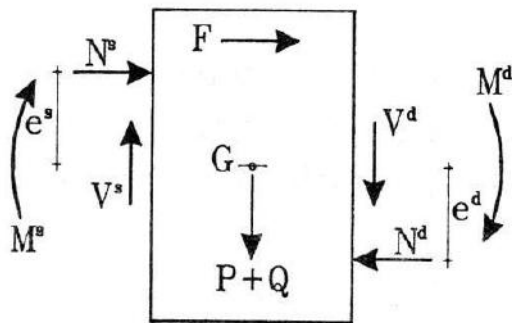
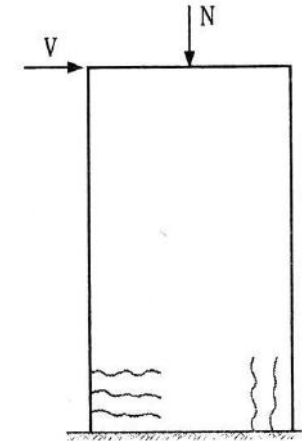
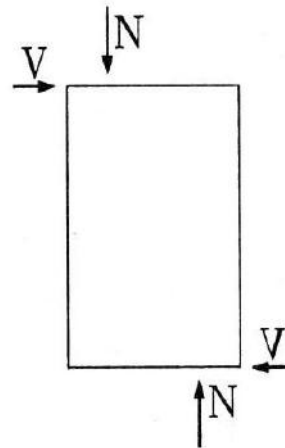
- Floors/roof with “sufficient” in-plane stiffness
- Adequate connection between walls
- Adequate wall-to-floor and wall-to-roof connections



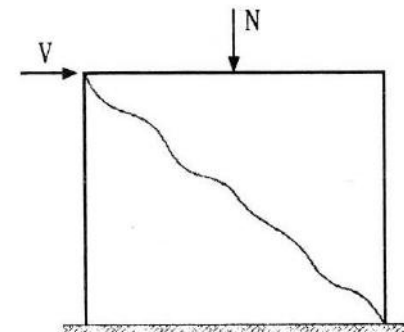
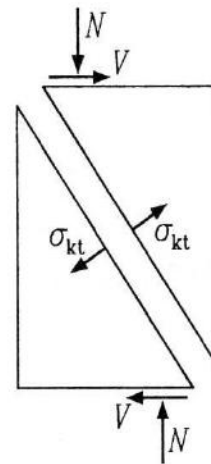
# IN-PLANE FAILURE MECHANISMS



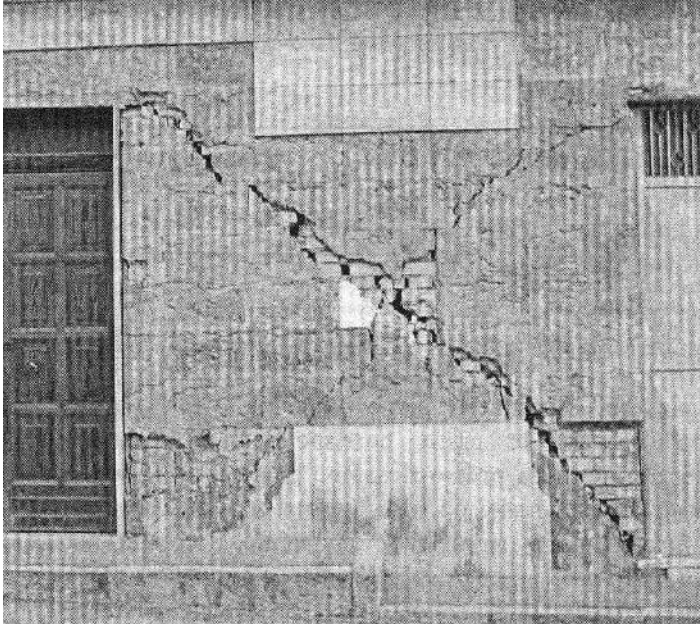
Flexure



Shear



# IN-PLANE FAILURE MECHANISMS

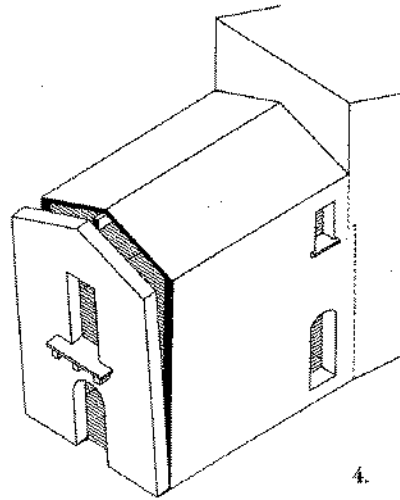
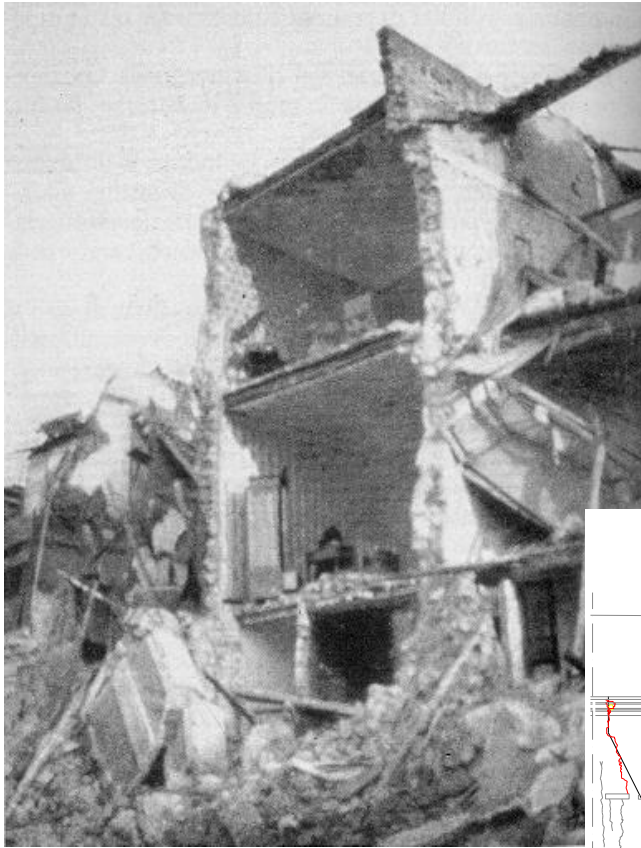


Shear in a squat wall

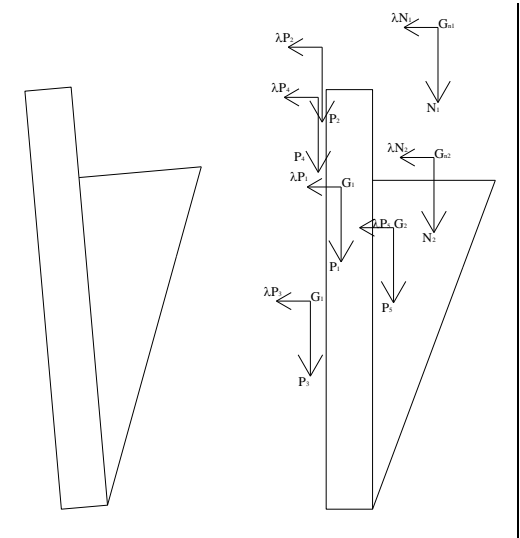
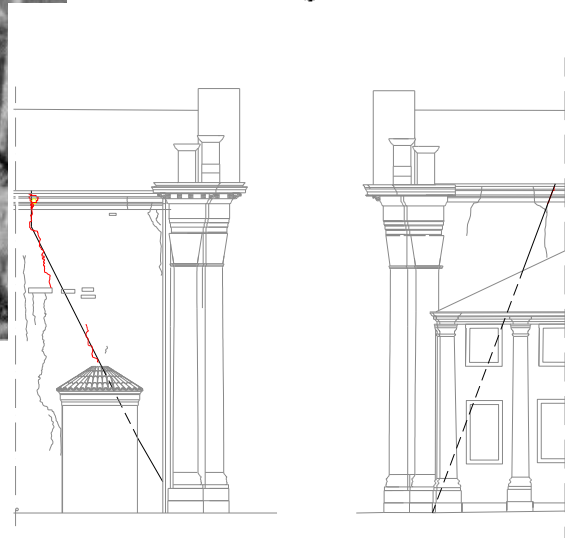


Flexure (and shear) in a slender wall

# OUT-OF-PLANE COLLAPSE MECHANISMS



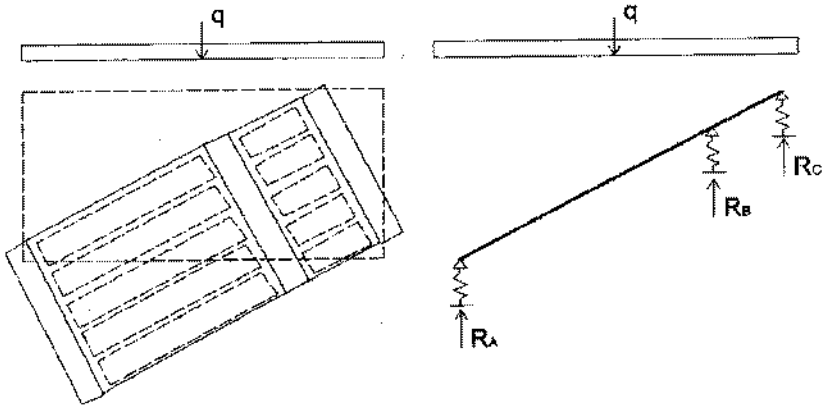
$$\lambda = \frac{P_1 \times \frac{b_1}{2} + N_1 \times d_1}{(P_1 + P_2) \times \frac{h}{2} + (N_1 + N_2) \times h} \dots$$



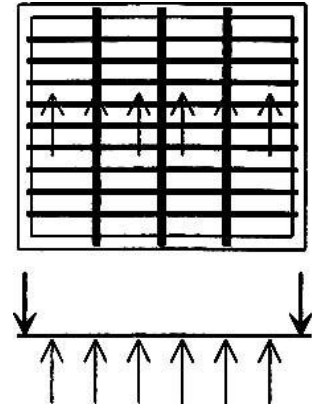
- Brittle mechanism
- Occur early respect to in-plane failures

# ROLE OF FLOORS

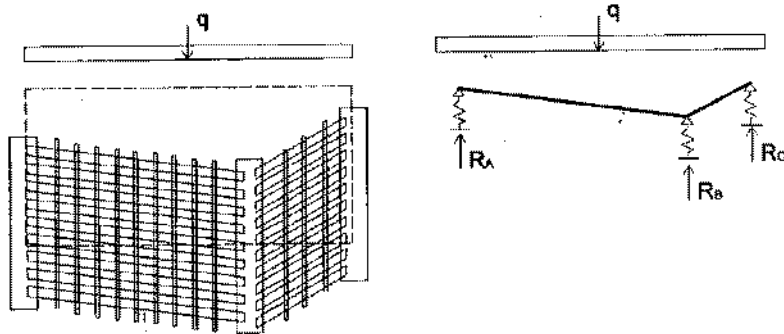
## Rigid floor behaviour



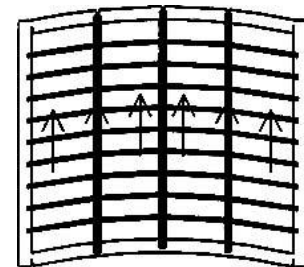
Rigid floors allow an iperstatic redistribution of horizontal forces among shear walls



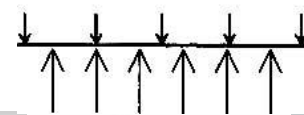
## Flexible floor behaviour



Flexible floors allow an isostatic redistribution of horizontal forces among shear walls

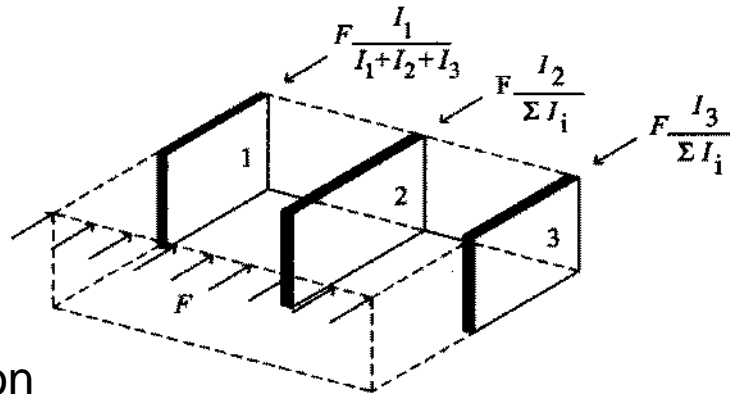


(Ceravolo et Demarie 2004)



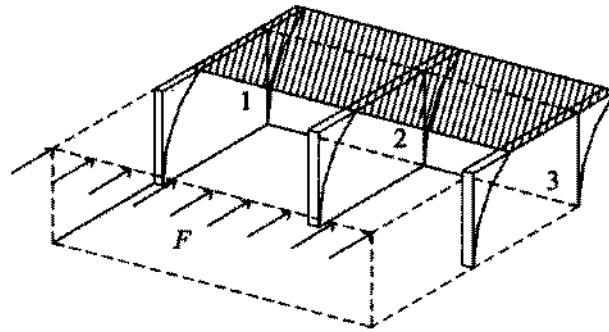
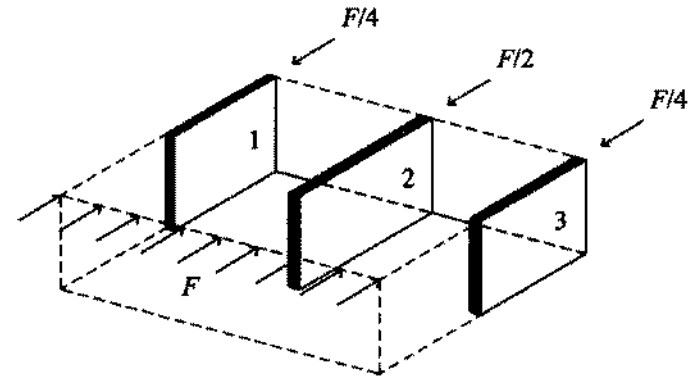
# ROLE OF FLOORS

## Rigid floor

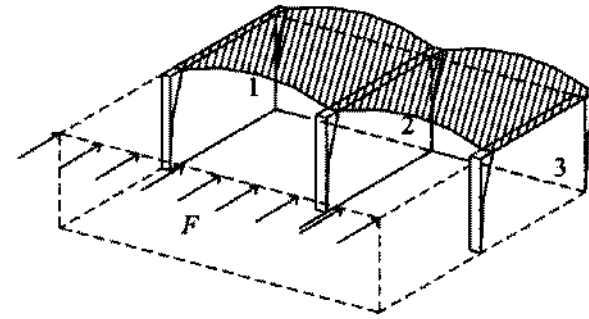


Shear  
distribution

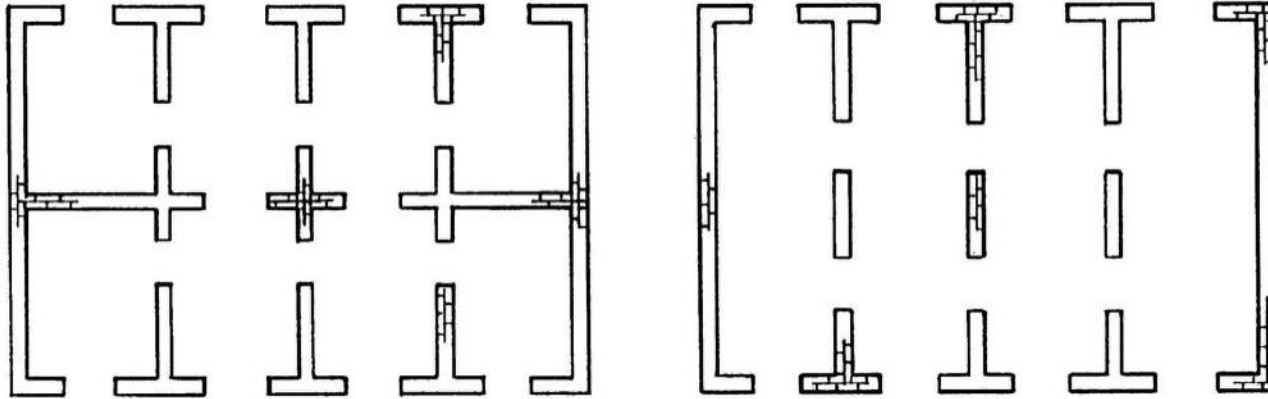
## Flexible floor



Lateral  
deflections

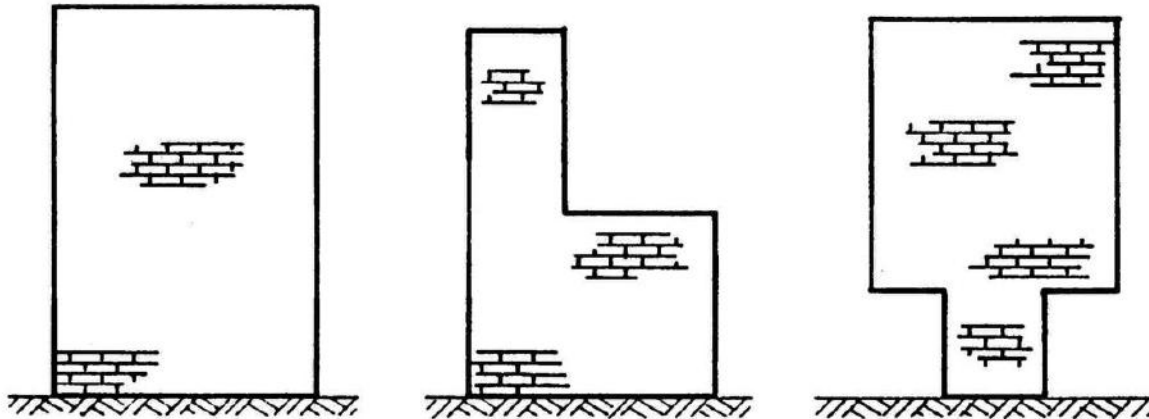


# GEOMETRIC UNIFORMITY



Adequate

Not adequate



Adequate

Not adequate

Bad

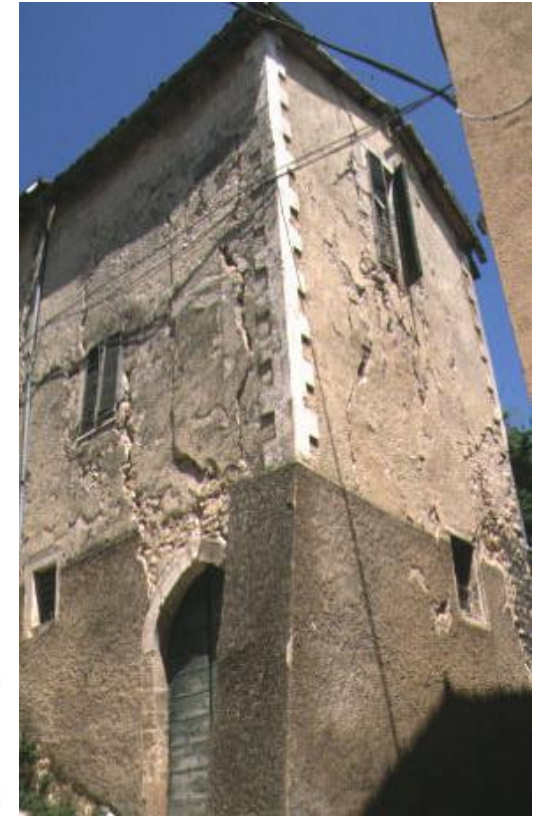
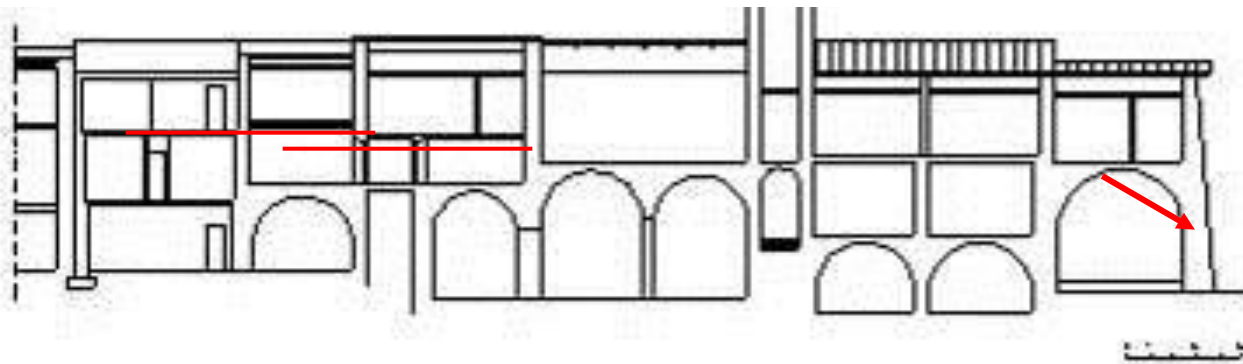
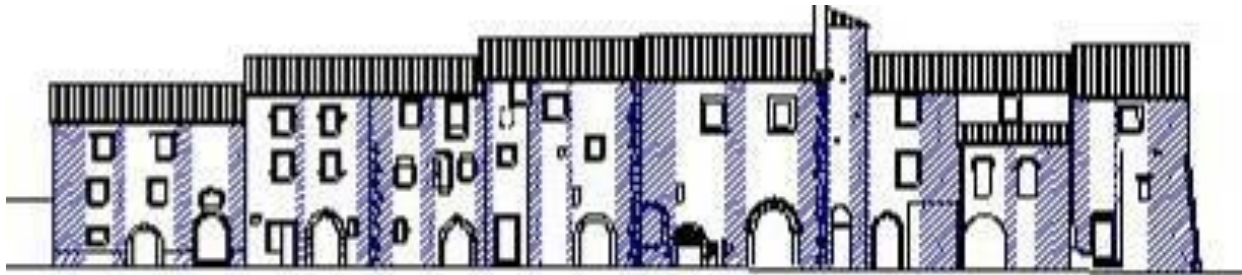
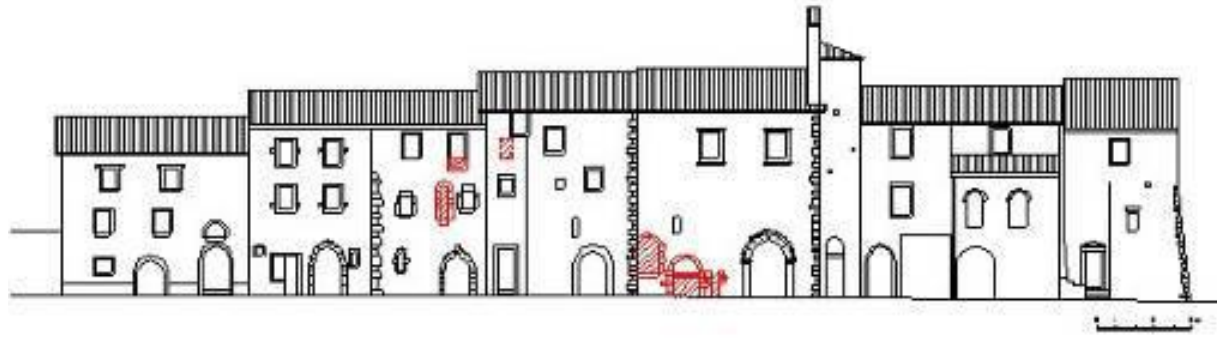
(Tomazevic 1999)

# GEOMETRIC UNIFORMITY



*Neftegorsk, 1995 (Tomazevic)*

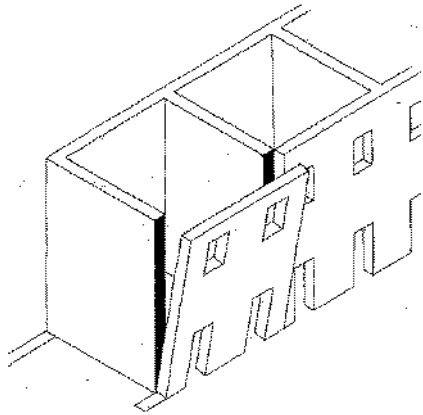
# OTHER VULNERABILITY ASPECTS: OPENINGS AND FLOORS ALIGNMENT, VAULTS THRUST





# RESPONSE TO EARTHQUAKE OF EXISTING BUILDINGS

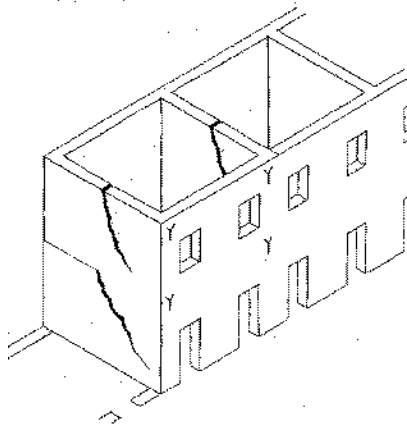
An extensive work of classification was developed for several case studies (buildings and centers), and an “abacus” of mechanisms of collapse was defined. It includes the various “local” modes of loss of equilibrium of portions (macro-elements) which develop instead of a “overall” response.



## Local behaviour

### OUT-OF-PLANE MECHANISMS

Out-of-plane brittle collapse of walls or their portions or assemblages even for low seismic actions



## Overall behaviour

### IN-PLANE MECHANISMS

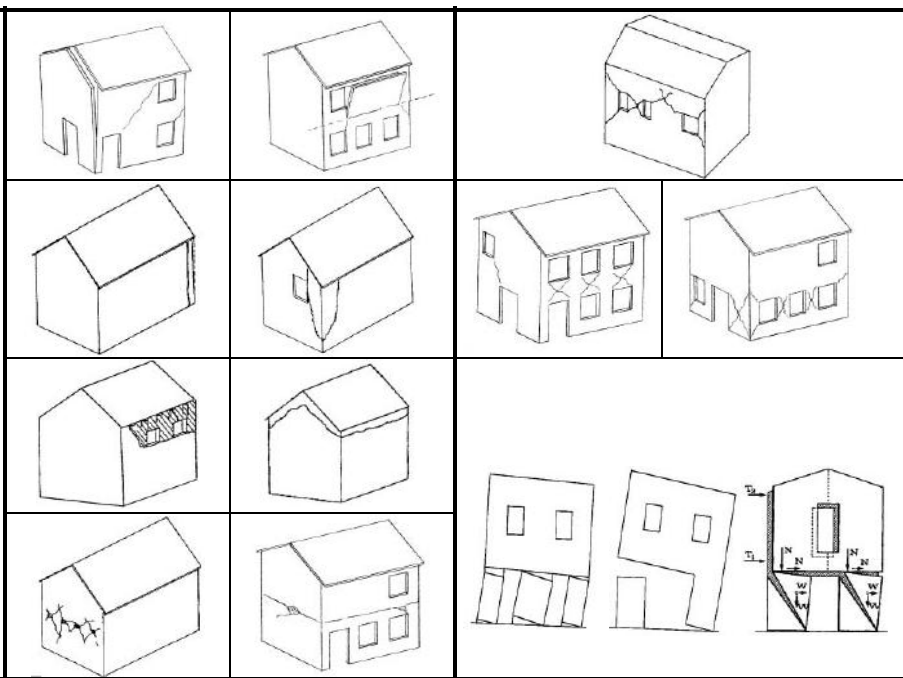
In-plane failure, no out-of-plane collapses for seismic action higher than for the previous case

# CLASSIFICATION OF DAMAGE MECHANISMS FOR BUILDINGS

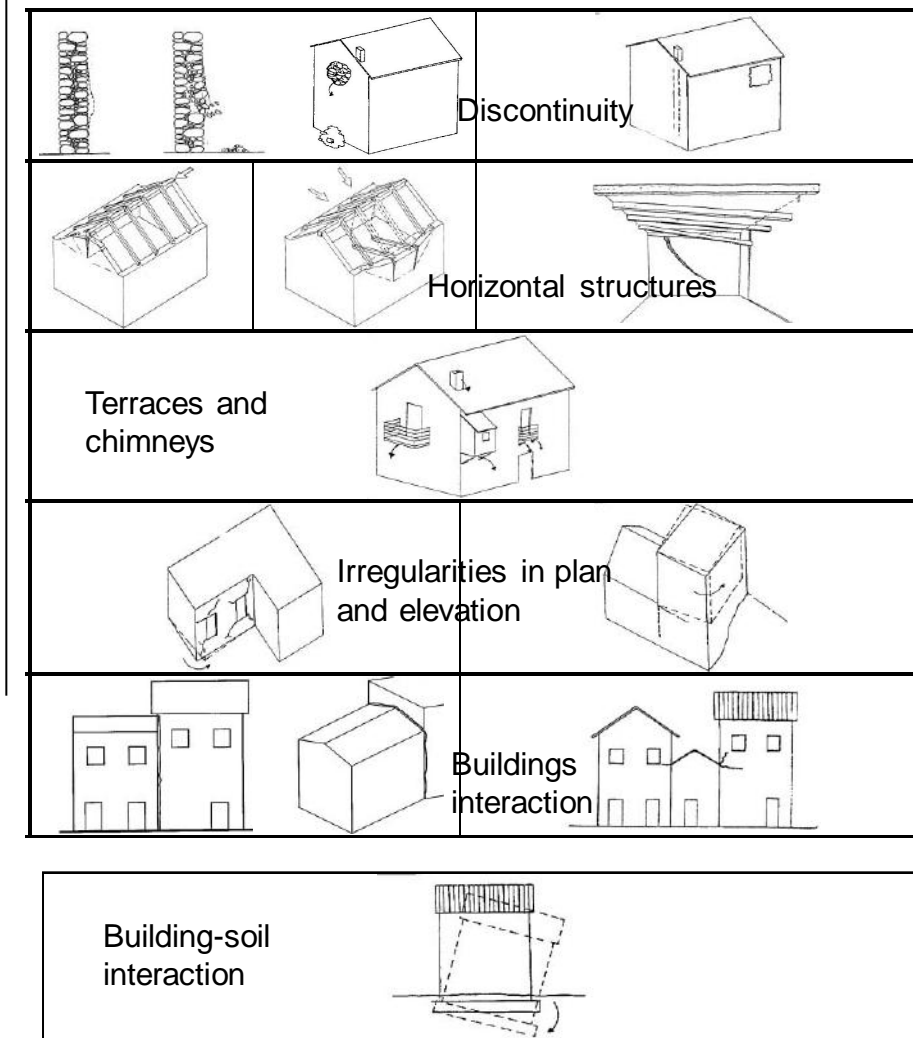
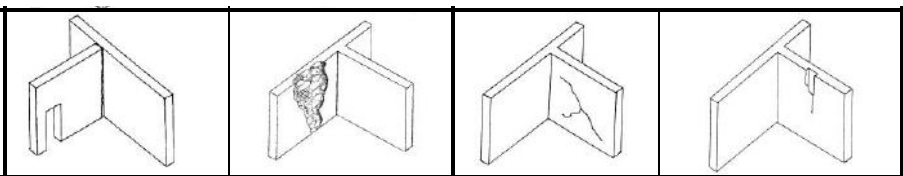
## OUT OF PLANE

## IN-PLANE

### Perimetral walls



### Internal walls



# PERIMETRAL WALLS: OUT OF PLANE MECHANISMS

- Damage:

Total façade collapse

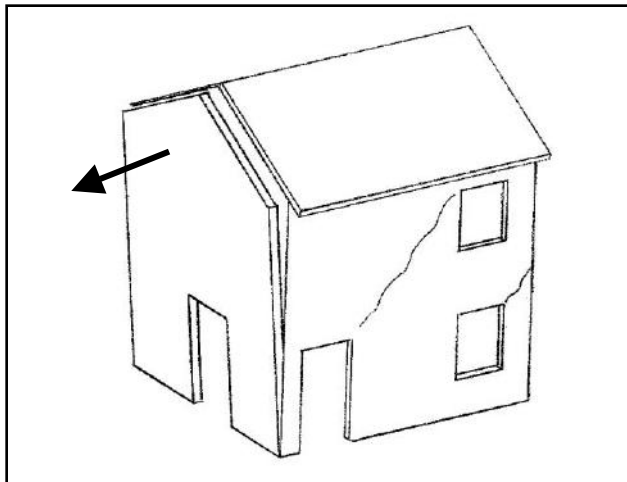
- Mechanism:

Out of plane rotation of the façade with formation of a cylindrical horizontal hinge at the base of the wall

- Structural causes:

Scarce connection between orthogonal walls

Absence of ties and tie beams



# PERIMETRAL WALLS: OUT OF PLANE MECHANISMS

- Damage:

Collapse of the corner

- Mechanism:

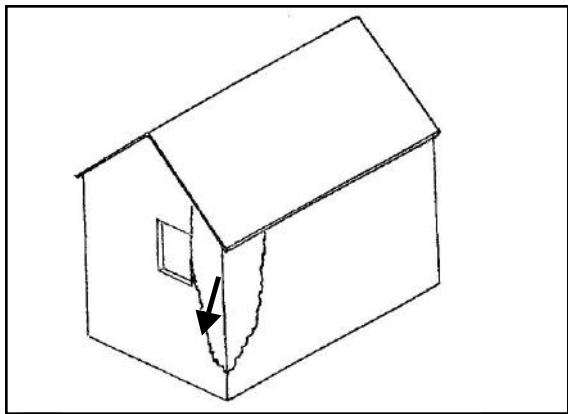
Out of plane rotation of the masonry corner

- Structural causes:

Scarce connection between orthogonal walls

Scarce connection between floors and walls

Presence of openings close by the corner



# PERIMETRAL WALLS: DAMAGE DUE TO FLOORS AND ROOFS SUBSTITUTION



Expulsion of the façade

- Stiffening of horizontal diaphragms with non adequate strengthening of masonry walls



Rigid sliding of roof

# PERIMETRAL WALLS: MECHANISMS INFLUENCED BY THE ROOF

- Damage:

Local collapse of the tympanum

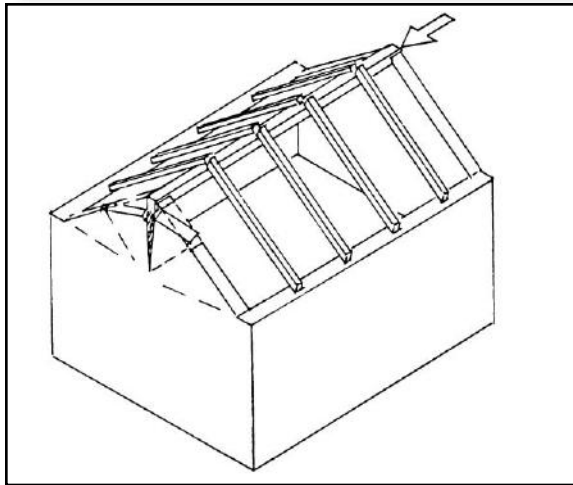
Local collapse of the cornice

- Mechanism:

Out of plane rotation of portion of the façade due to the pounding of the top roof beam

- Structural causes:

Scarce connection between roof and orthogonal walls



# PERIMETRAL WALLS: LOW QUALITY OF MASONRY

- Damage:

Detachment of masonry leaves

Local collapse and material expulsion

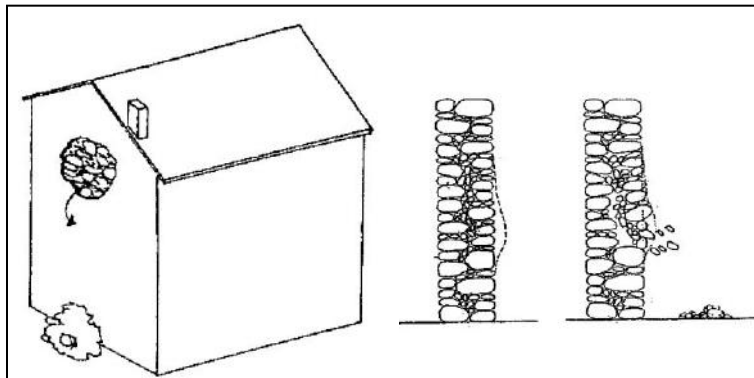
- Mechanism:

Out of plane rotation of portion of the external masonry leaf

- Structural causes:

Scarce quality of masonry walls

Deterioration of masonry walls



# PERIMETRAL WALLS, IN PLANE MECHANISMS: SHEAR CRACKING IN THE LINTELS

- Damage:

Crossed or diffused diagonal cracks above the lintels

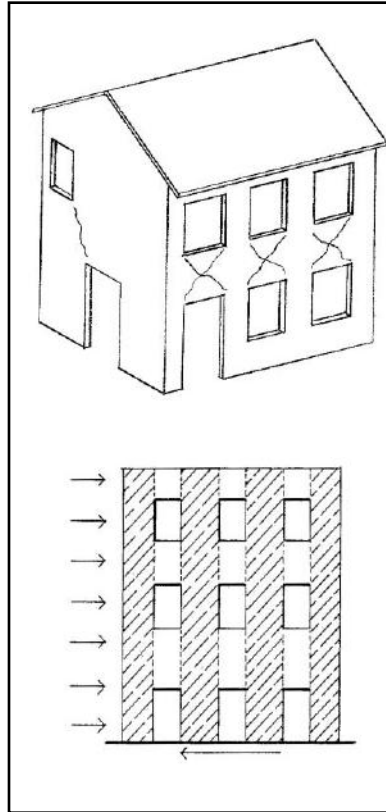
- Mechanism:

Shear cracking of the spandrel walls due to in-plane flexural behaviour

- Structural causes:

Presence of weak lintels??  
architravi?

Masonry piers between openings  
with small height and thickness





# PERIMETRAL WALLS, IN PLANE M.: SHEAR CRACKING IN THE MASONRY PIERS

- Damage:

Crossed (in the central masonry piers) or inclined diagonal cracks in the squat masonry piers

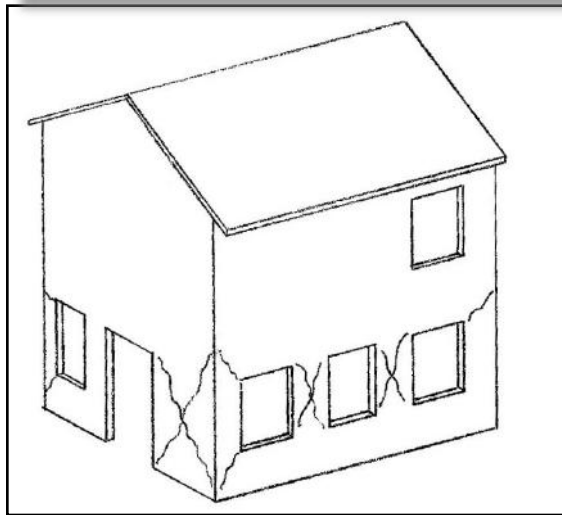
- Mechanism:

Shear cracking of the wall under in-plane actions

- Structural causes:

Presence of many openings

Scarce quality of the masonry or presence of discontinuities



# PERIMETRAL WALLS, IN PLANE M.: OVERTURNING OF THE MASONRY PIERS

- Damage:

Horizontal cracks (tensioned corner) localized mainly at the base of the building

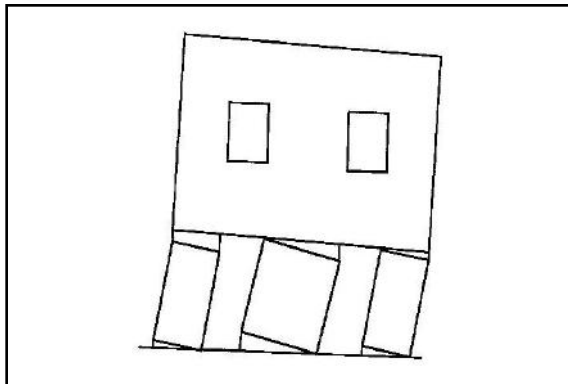
Eventual crushing of the compressed toe, due to attainment of maximum compressive strength

- Mechanism:

Overturning of the masonry piers due to in-plane rotation

- Structural causes:

Excessive slenderness of the masonry piers due to the presence of many openings or large openings



# IRREGULARITIES (SHAPE/PLAN/VOLUME)

- Damage:

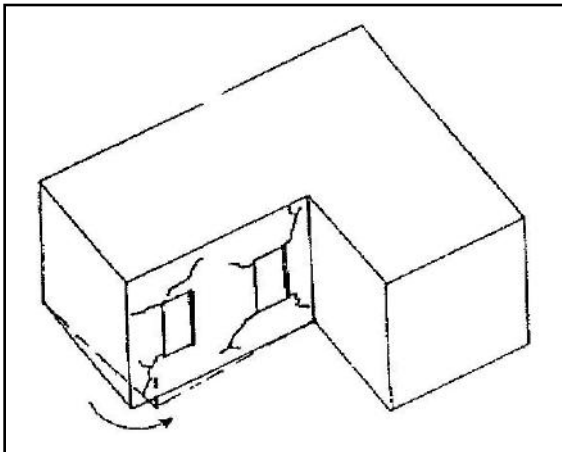
Shear cracking

- Mechanism:

Rotation of portions of the building

- Structural causes:

Irregular shape (plan) and consequent irregular distribution of horizontal forces



# BUILDINGS INTERACTION: HAMMERING OF ADJACENT BUILDINGS

- Damage:

Vertical cracking at the joint between adjacent buildings

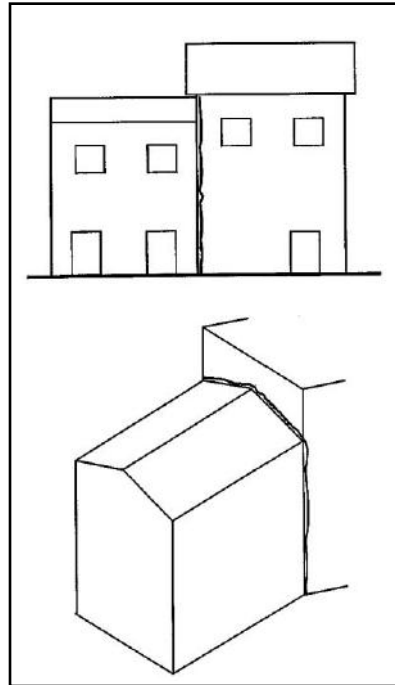
- Mechanism:

Different seismic response of adjacent buildings characterized by the presence of ineffective joint

- Structural causes:

Scarce connection between the buildings

Different stiffness of connecting structural bodies



# BUILDING-SOIL INTERACTION

- Damage:

Large cracking (vertical and sub-vertical)

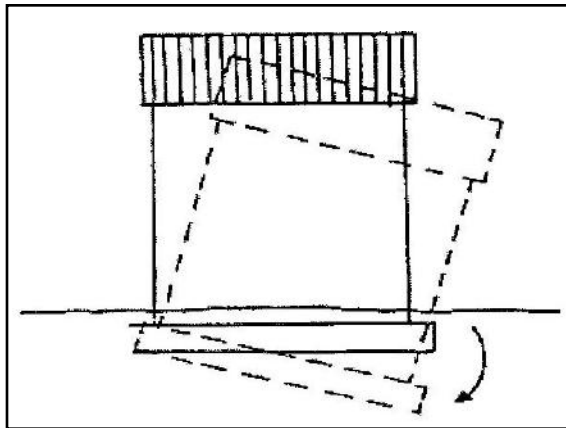
- Mechanism:

Out-of-plane rotation and/or sliding of portions or the whole building

- Structural causes:

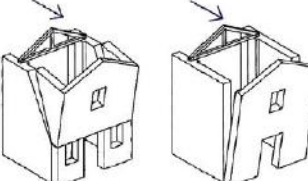
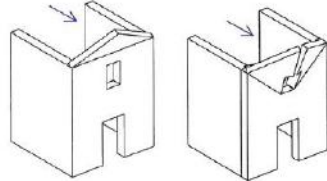
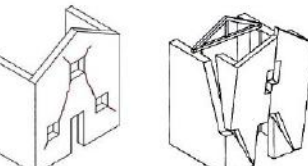
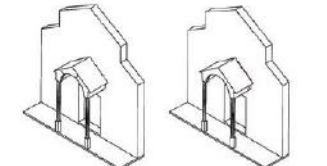
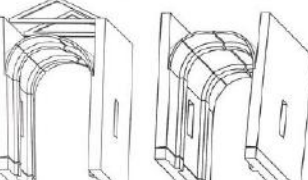
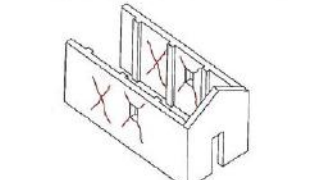

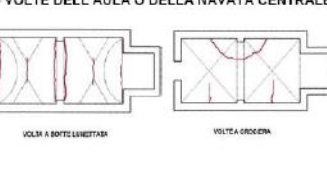
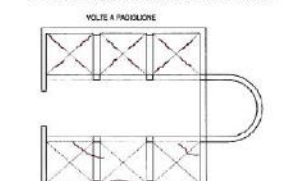
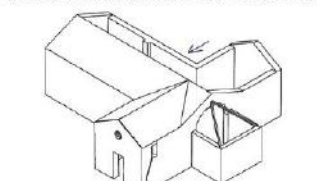
Uneven load capacity of the soil

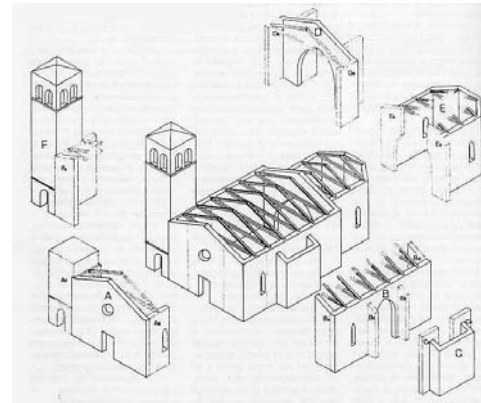
Excessive soil sloping



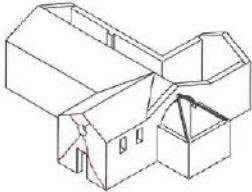
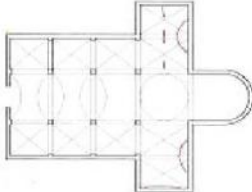
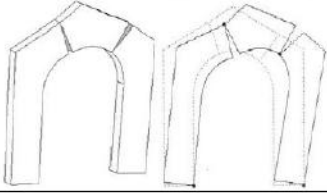
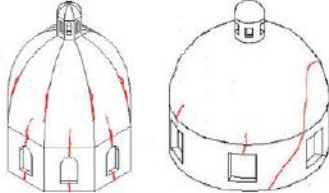
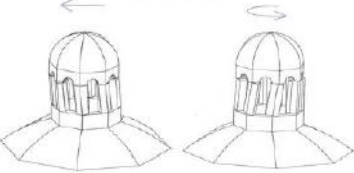
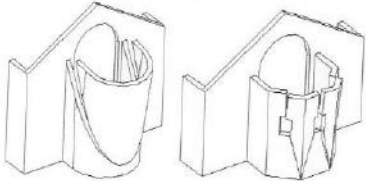
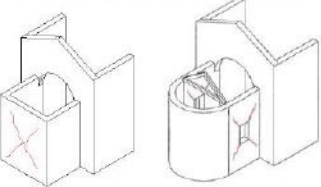
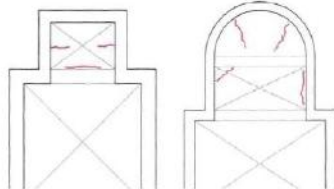
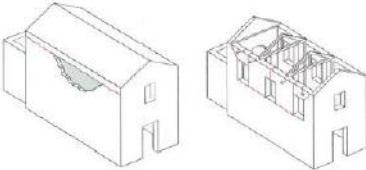
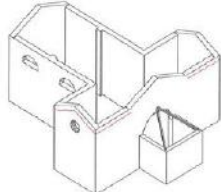
# DAMAGE CATALOGUE FOR SPECIFIC TIPOLOGIES: CHURCHES

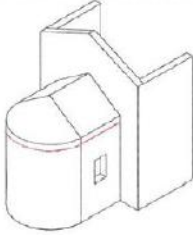
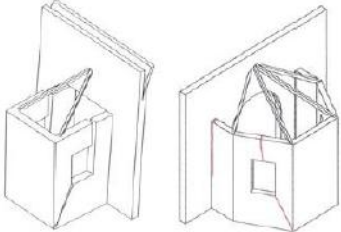
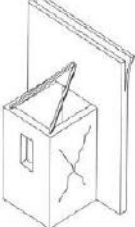
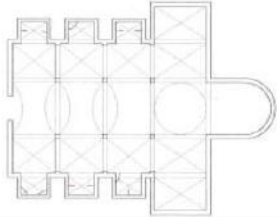
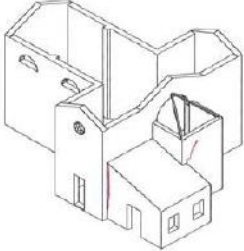
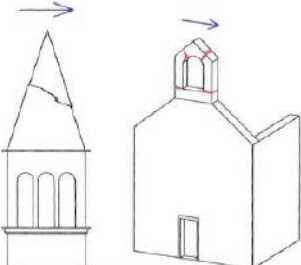
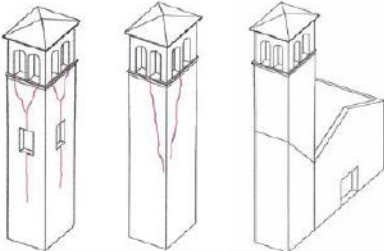
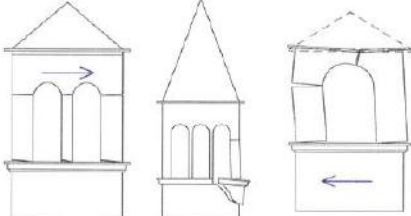
## ABACO DEI MECCANISMI DI COLLASSO DELLE CHIESE

<p>1. RIBALTAMENTO DELLA FACCIATA</p> 	<p>2. MECCANISMI NELLA SOMMITÀ DELLA FACCIATA</p> 
<p>3. MECCANISMI NEL PIANO DELLA FACCIATA</p> 	<p>4 - PROTIRO E NARTECE</p> 
<p>5 - RISPOSTA TRASVERSALE DELL'AULA</p> 	<p>6 - MECCANISMI DI TAGLIO PARETI LATERALI</p> 
<p>7 - RISPOSTA LONGITUDINALE DEL COLONNATO</p> 	<p>8 - VOLTE DELL'AULA O DELLA NAVATA CENTRALE</p>  <p>VOLTE A BOTTE LUNETTARI      VOLTE A CROCIERA</p>
<p>9 - VOLTE DELLE NAVATE LATERALI</p>  <p>VOLTE A PADIGLIONE VOLTE A CROCIERA</p>	<p>10 - RIBALTAMENTO PARETI DEL TRANSETTO</p> 



# DAMAGE CATALOGUE FOR SPECIFIC TIPOLOGIES: CHURCHES

<p>11 - MECCANISMI DI TAGLIO DEL TRANSETTO</p> 	<p>12 - VOLTE DEL TRANSETTO</p> 
<p>13 - ARCHI TRIONFALI</p> 	<p>14 - CUPOLA E TAMBURO / TIBURIO</p> 
<p>15 - LANTERNA</p> 	<p>16 - RIBALTAMENTO DELL'ABSIDE</p> 
<p>17 - MECCANISMI DI TAGLIO NELL'ABSIDE</p> 	<p>18 - VOLTE DEL PRESBITERIO O DELL'ABSIDE</p> 
<p>19 - ELEMENTI DI COPERTURA: AULA</p> 	<p>20 - ELEMENTI DI COPERTURA: TRANSETTO</p> 

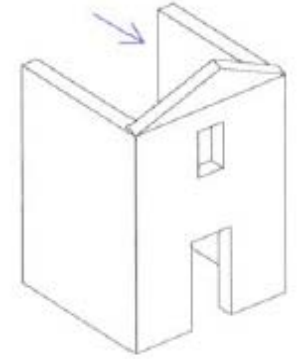
<p>21 - ELEMENTI DI COPERTURA: ABSIDE</p> 	<p>22 - RIBALTAMENTO DELLE CAPPELLE</p> 
<p>23 - MECCANISMI DI TAGLIO NELLE CAPPELLE</p> 	<p>24 - VOLTE DELLE CAPPELLE</p> 
<p>25 - INTERAZIONI IN PROSSIMITA' DI IRREGOLARITÀ</p> 	<p>26 - AGGETTI (VELA, GUGLIE, PINNACOLI, STATUE)</p> 
<p>27 - TORRE CAMPANARIA</p> 	<p>28 - CELLA CAMPANARIA</p> 

# DAMAGE OF CHURCHES: BEHAVIOR OF MACRO-ELEMENTS

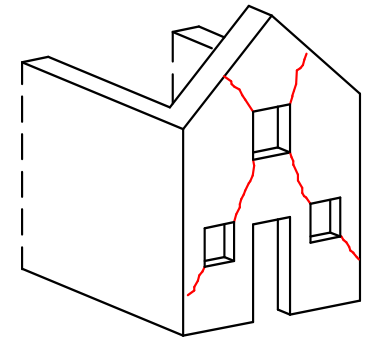
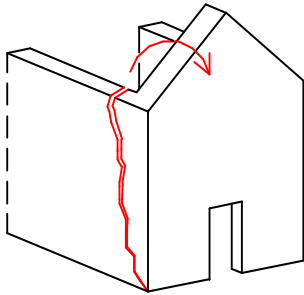
Overturning of façade



Overturning of upper part of façade



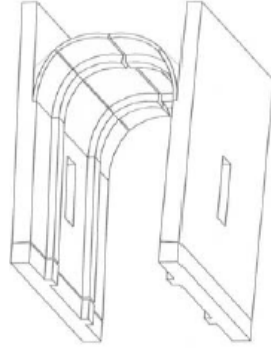
In-plane mechanisms on façade



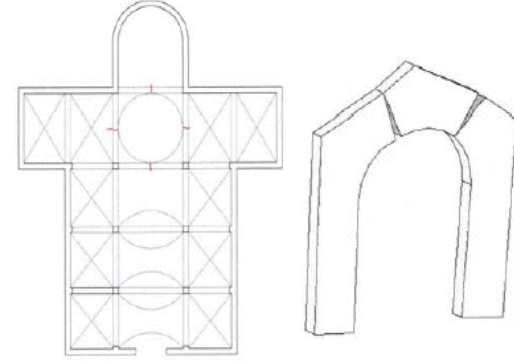


# DAMAGE OF CHURCHES: BEHAVIOR OF MACRO-ELEMENTS

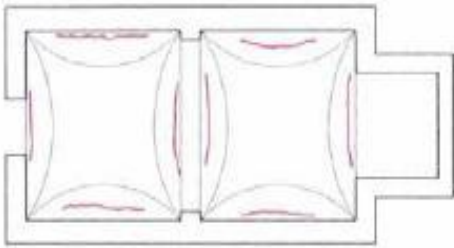
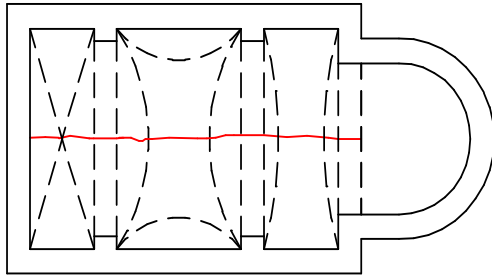
Transversal mechanism of nave



Kinematic mechanism of triumphal arch



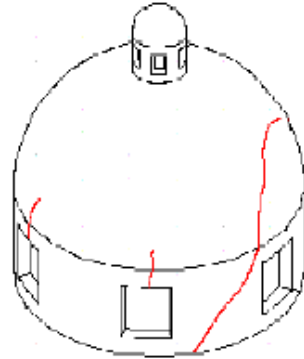
Vaults of central nave



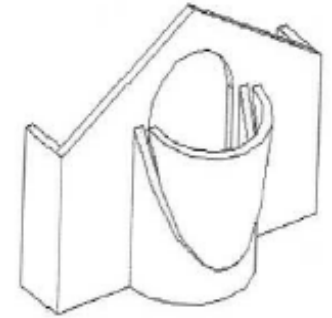
VOLTA A VELA

# DAMAGE OF CHURCHES: BEHAVIOR OF MACRO-ELEMENTS

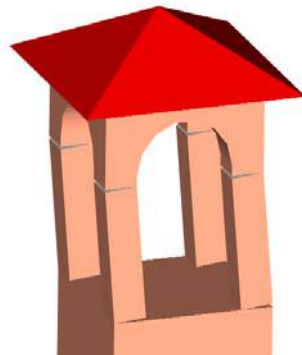
Dome



Overturning of apse

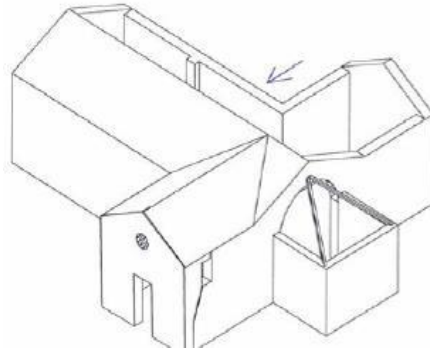


Bell tower and belfry

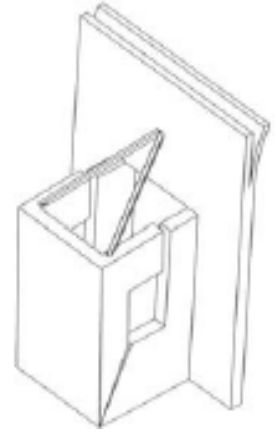


# DAMAGE OF CHURCHES: BEHAVIOR OF MACRO-ELEMENTS

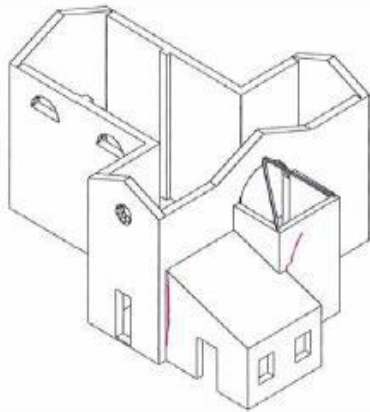
Overturning of transept



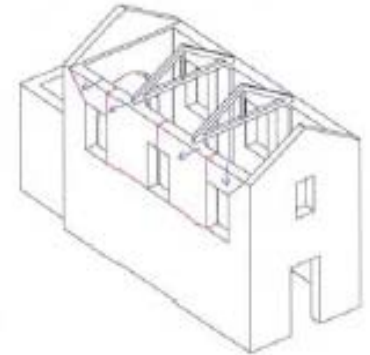
Overturning of side chapels



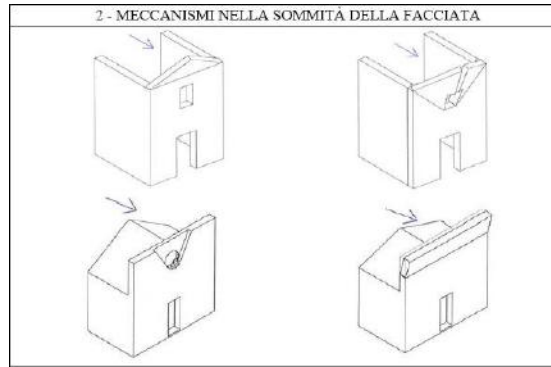
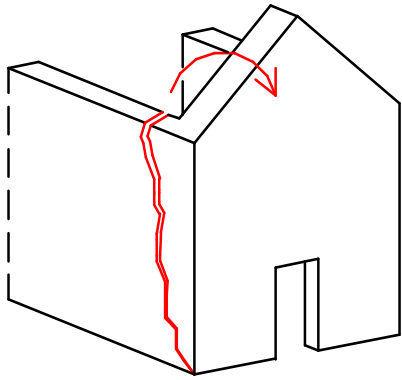
Interaction due to plan-elevation irregularities



Mechanisms in roof elements



# DAMAGE OF CHURCHES: OVERTURNING



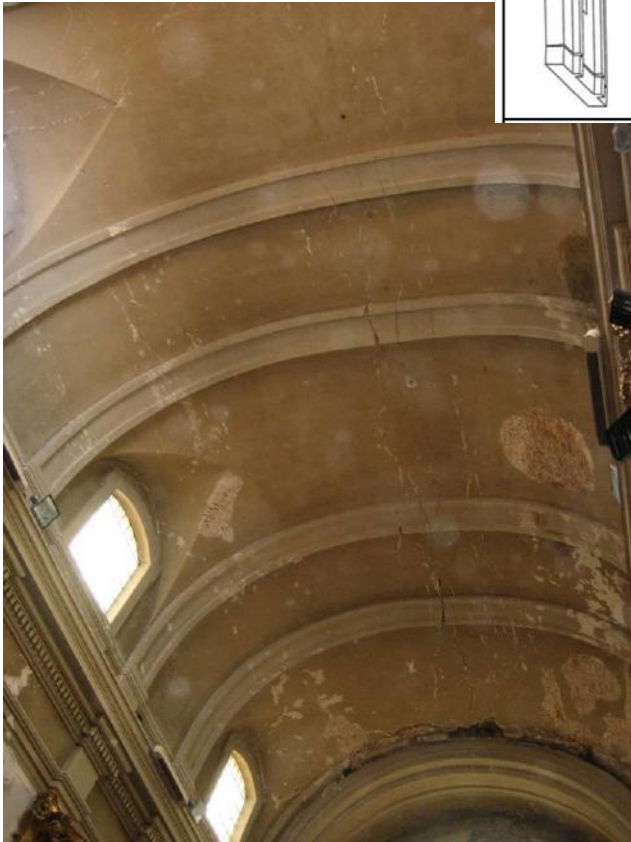
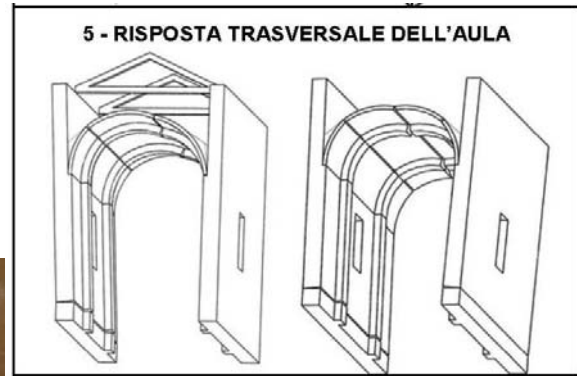
Santa Gemma, Goriano Sicoli (AQ)



San Biagio D'Amiterno, L'Aquila

# DAMAGE OF CHURCHES: LONG AND TRANSV RESPONSE

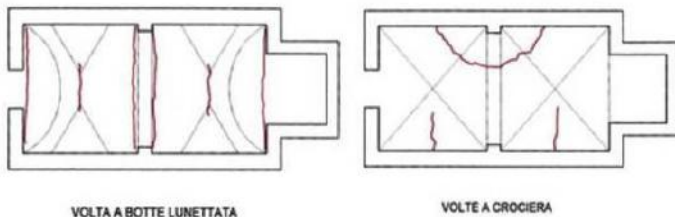
Santa Margherita (dei Gesuiti), L'Aquila



Santa Gemma, Goriano Sicoli (AQ)

# DAMAGE OF CHURCHES: NAVES AND TRIUMPHAL ARCH

## 8 - VOLTE DELL'AULA O DELLA NAVATA CENTRALE



VOLTA A BOTTE LUNETTATA

VOLTE A CROCIERA

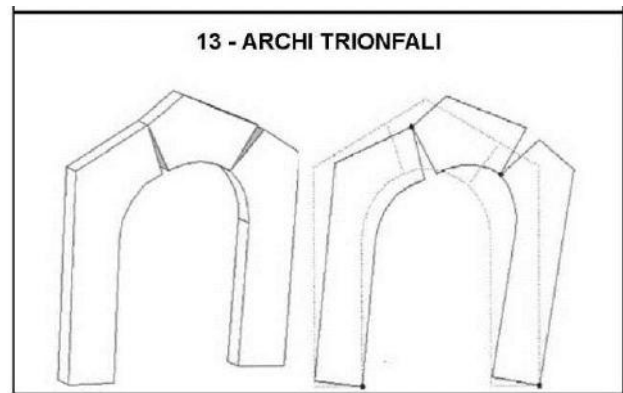
Beata Antonia, L'Aquila



San Marciano e Nicandro, L'Aquila

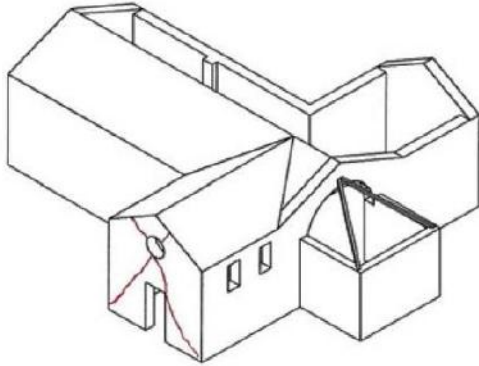


## 13 - ARCHI TRIONFALI



# DAMAGE OF CHURCHES: TRANSEPT

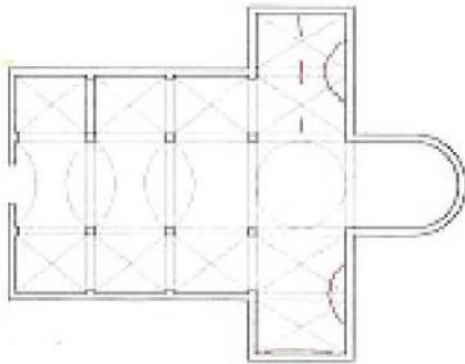
## 11 - MECCANISMI DI TAGLIO DEL TRANSETTO



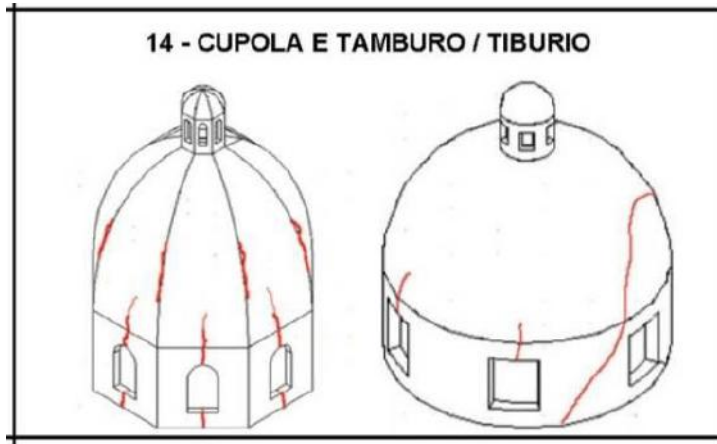
San Domenico, L'Aquila



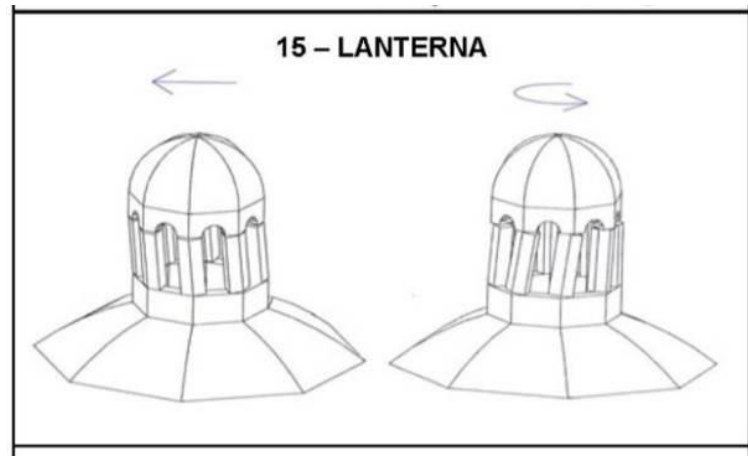
## 12 - VOLTE DEL TRANSETTO



# DAMAGE OF CHURCHES: DOME



Anime Sante, L'Aquila



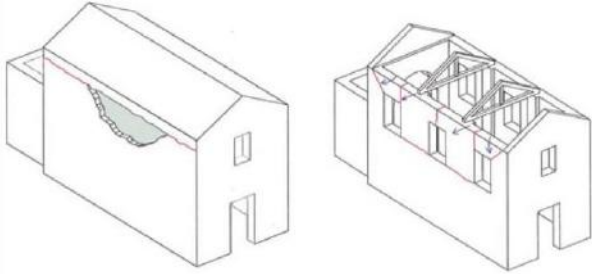
Sant'Agostino, L'Aquila



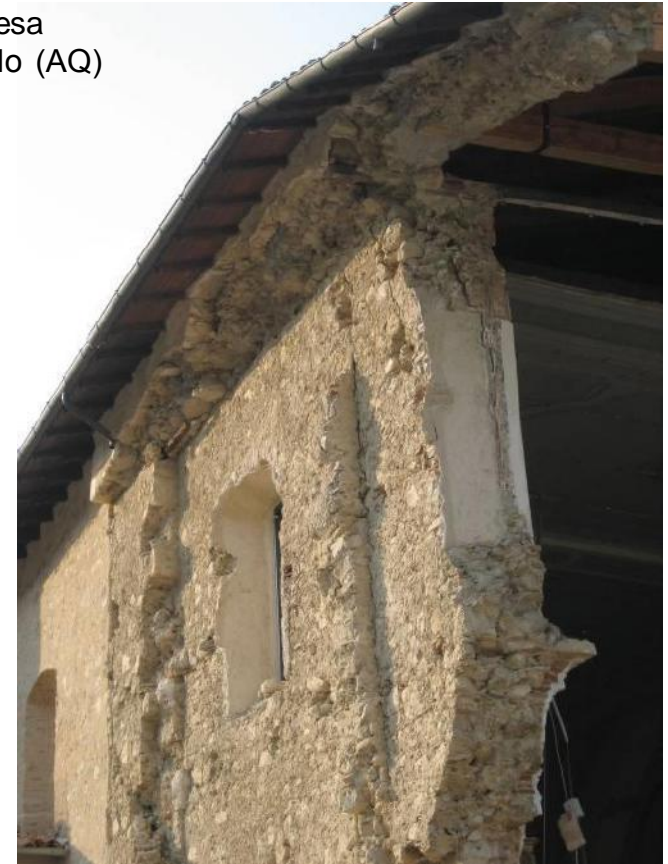


# DAMAGE OF CHURCHES: ROOF

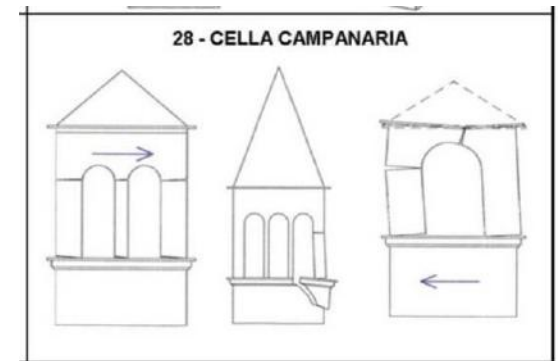
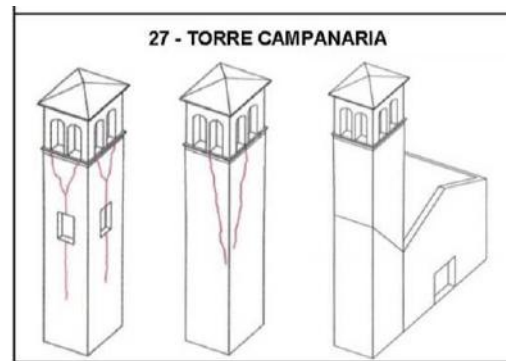
19 – ELEMENTI DI COPERTURA: AULA



Chiesa di San Michele & Chiesa  
Parrocchiale, Villa Sant'Angelo (AQ)



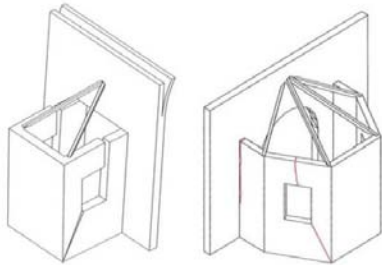
# DAMAGE OF CHURCHES: PROJECTIONS, PINNACLES, BELL TOWER



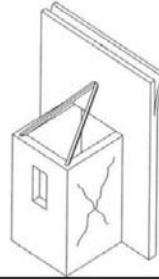
Chiesa di San Michele & Chiesa Parrocchiale, Villa Sant'Angelo (AQ)

# DAMAGE OF CHURCHES: SIDE CHAPELS AND VAULTS

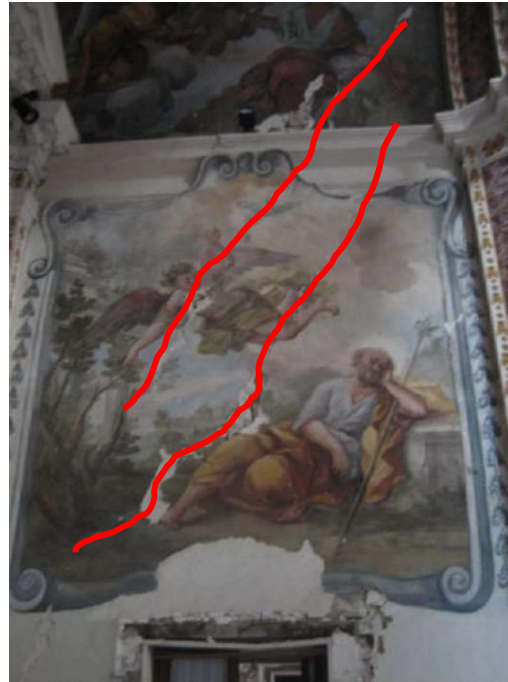
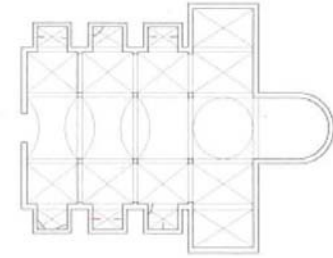
22 - RIBALTAMENTO DELLE CAPPELLE



23 - MECCANISMI DI TAGLIO NELLE CAPPELLE



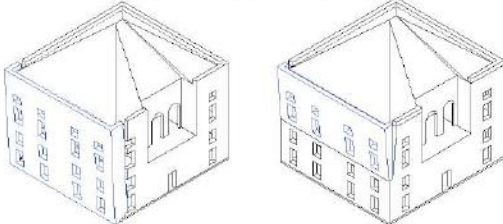
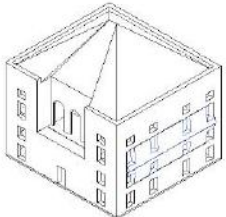
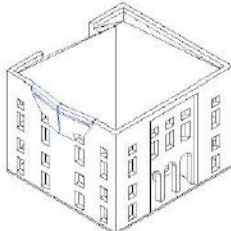
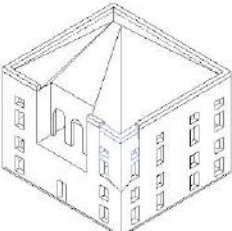
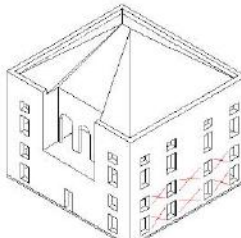
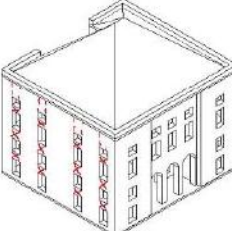
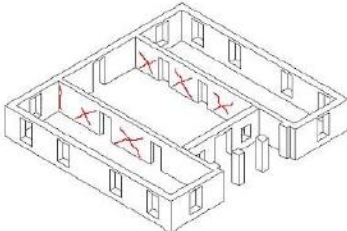
24 - VOLTE DELLE CAPPELLE

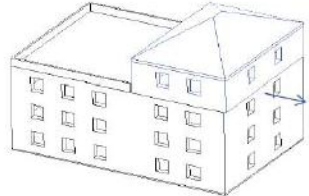
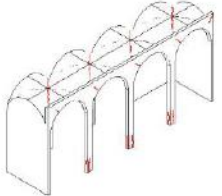
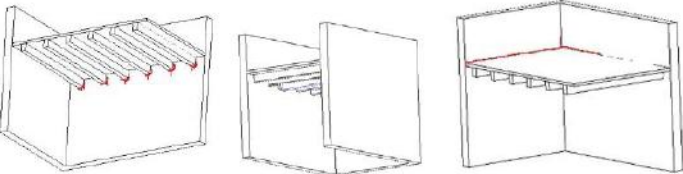
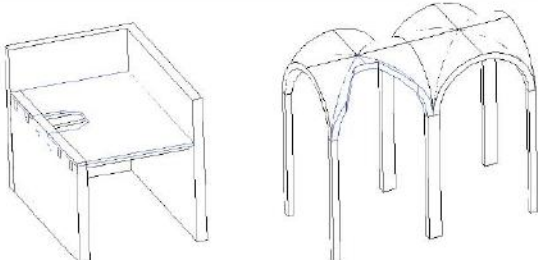
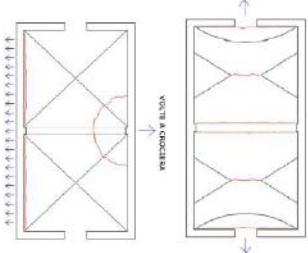
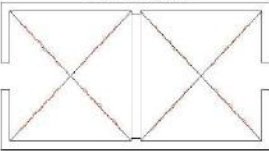


Santa Margherita (dei Gesuiti), L'Aquila

# DAMAGE CATALOGUE FOR SPECIFIC TIPOLOGIES: PALACES

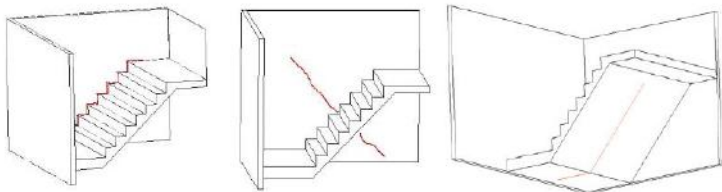
## ABACO DEI MECCANISMI DI COLLASSO DEI PALAZZI

<p><b>M1. RIBALTAMENTO DELLE PARETI</b></p> 	
<p><b>M2. INSTABILITA' VERTICALE DELLE PARETI</b></p> 	<p><b>M3. ROTTURA A FLESSIONE DELLE PARETI</b></p> 
<p><b>M4. RIBALTAMENTO DEL CANTONALE</b></p> 	<p><b>M5. TAGLIO NELLE PARETI ESTERNE: MASCHI</b></p> 
<p><b>M6. TAGLIO NELLE PARETI ESTERNE: FASCE</b></p> 	<p><b>M7. TAGLIO NELLE PARETI INTERNE</b></p> 

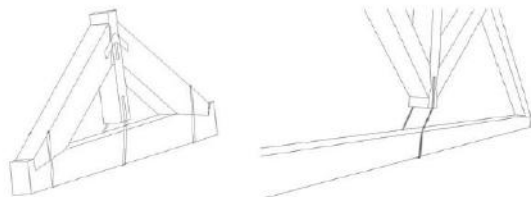
<p><b>M8. SCORRIMENTO DI PIANO</b></p> 	<p><b>M9. DANNO AI PORTICATI/ LOGGE</b></p> 
<p><b>M10. SFILAMENTO TESTA DELLE TRAVI E/O MARTELLAMENTO</b></p> 	
<p><b>M11. COLLASSI LOCALI DELL'IMPALCATO O DELLA VOLTA</b></p> 	
<p><b>M12. DANNO ALLE VOLTE PER ROTAZIONE DELLE IMPOSTE</b></p> 	<p><b>M13. DANNO ALLE VOLTE PER DEFORMAZIONE DI PIANO</b></p> <p>VOLTE A PADIGLIONE</p> 

# DAMAGE CATALOGUE FOR SPECIFIC TIPOLOGIES: PALACES

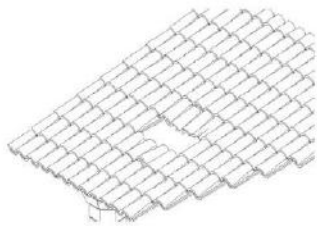
M14. DANNO ALLE SCALE



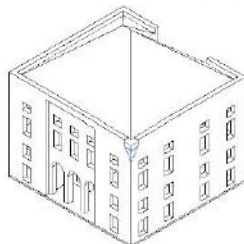
M15. DANNO NEGLI ELEMENTI DI COPERTURA



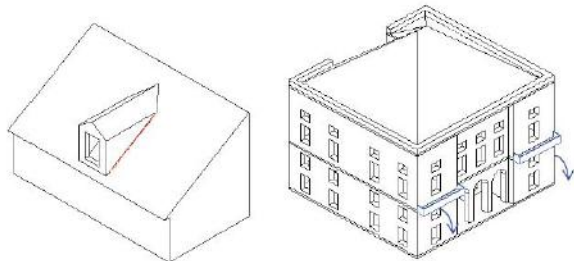
M16. DANNO AL MANTO DI COPERTURA



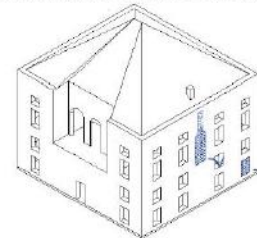
M17. RIBALTAMENTO DELLE FASCE SOTTOTETTO E DEL TIMPANO



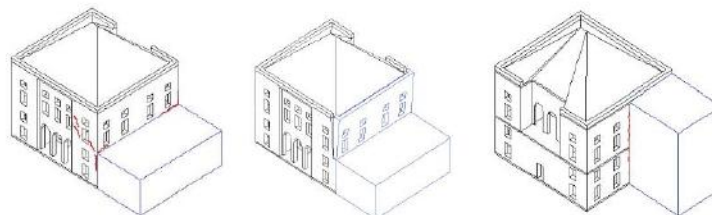
M18. DANNO AGLI ELEMENTI AGGETTANTI/SVETTANTI



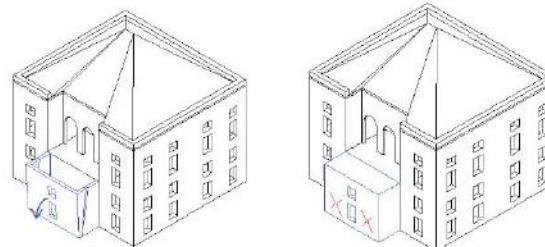
M19. COLLASSI LOCALI PER IRREGOLARITA' COSTRUTTIVE E DEL MATERIALE



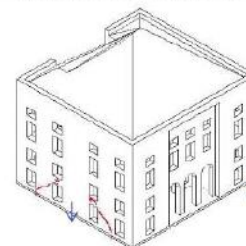
M20. DANNO PER IRREGOLARITA' DI FORMA



M21. DANNO NEI CORPI ANNESSI

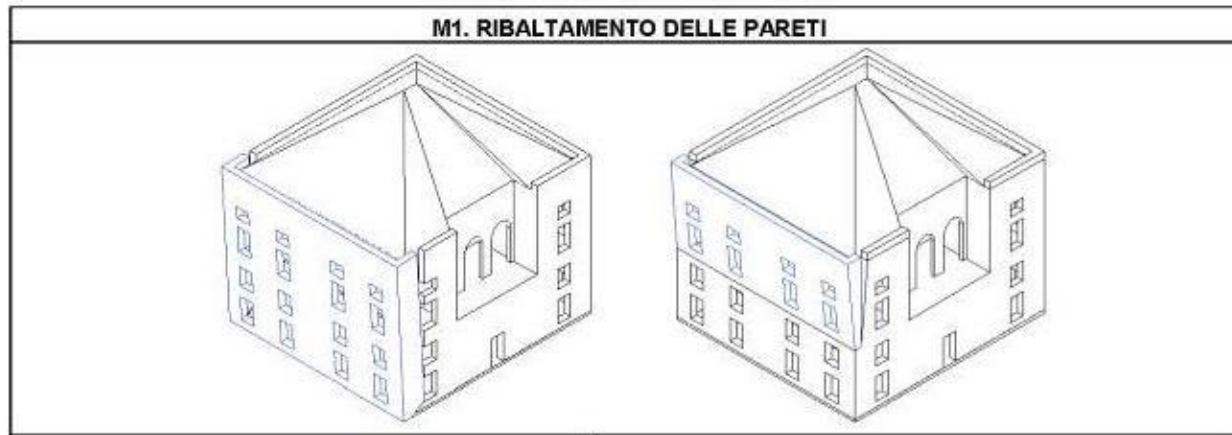


M22. CEDIMENTO DI FONDAZIONI



Modello B-DP\_PCM-DPC MiBAC 2006

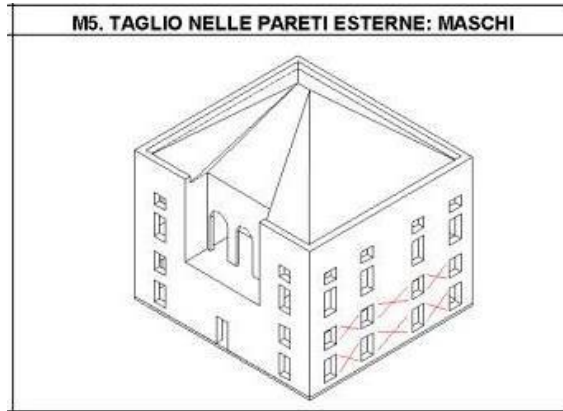
# DAMAGE OF PALACES: OUT-OF-PLANE COLLAPSE



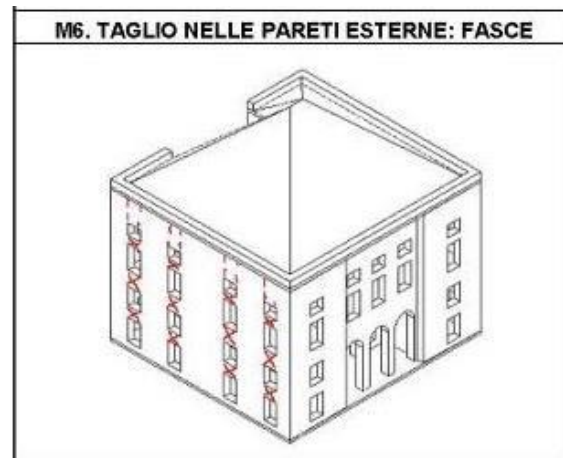
via Roma, L'Aquila



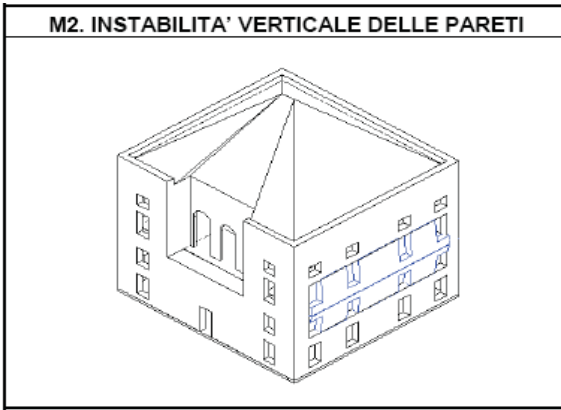
# DAMAGE OF PALACES: SHEAR FAILURE



Villa Sant'Angelo, AQ



# DAMAGE OF PALACES: FLEXURE OF WALLS



Ex Monastero di Santa Teresa, L'Aquila



Palazzo in Piazza San Pietro, L'Aquila

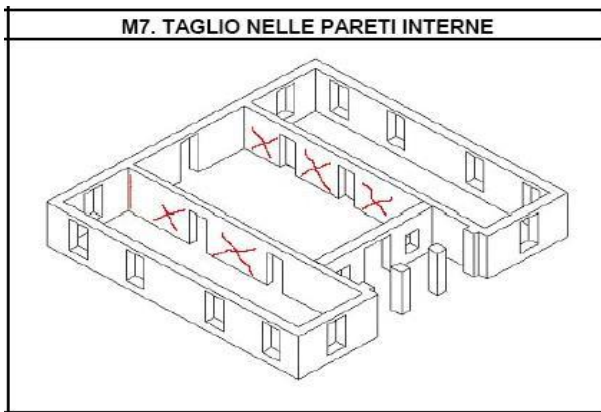




# DAMAGE OF PALACES: CORNER EXPULSION AND SHEAR DAMAGE



Via Roma e Piazza San Domenico, L'Aquila

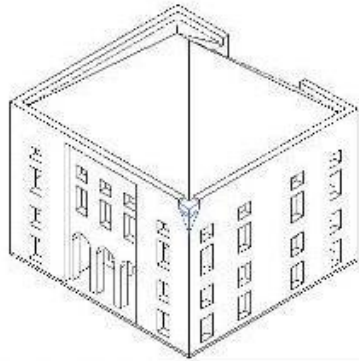


Ex Monastero di Santa Teresa, L'Aquila



# DAMAGE OF PALACES: PARTIAL OVERTUNING, IRREGULARITY

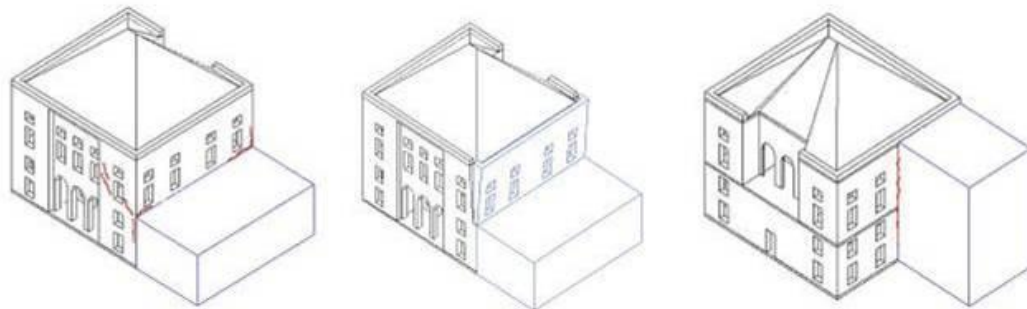
M17. RIBALTAMENTO DELLE  
FASCE SOTTOTETTO E DEL TIMPANO



Via Duca degli Abruzzi, L'Aquila



M20. DANNO PER IRREGOLARITA' DI FORMA

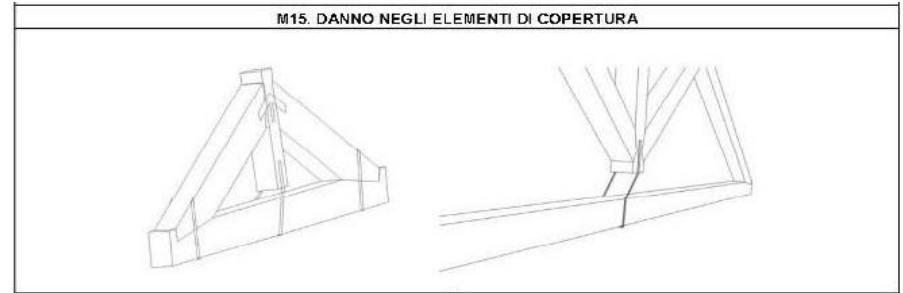


Ex Monastero di Santa Teresa, L'Aquila

# DAMAGE OF PALACES: VAULTS AND ROOFS



Ex Monastero Santa Teresa,  
L'Aquila



Via Roma, L'Aquila



# DAMAGE CATALOGUE: POOR QUALITY MASONRY



San Michele Arcangelo, Celano



Prefettura, L' Aquila

# DAMAGE CATALOGUE: POOR QUALITY MASONRY

## Emilia, 2012

- Thick walls made with solid clay brick
- Multi-layer walls with scarce interconnection



Novi, SS Rovereto



San Martino, Buonacompra



Collegiata Santa Maria Maggiore, Mirandola

# DAMAGE CATALOGUE: POOR QUALITY MASONRY

## Abruzzo, 2009



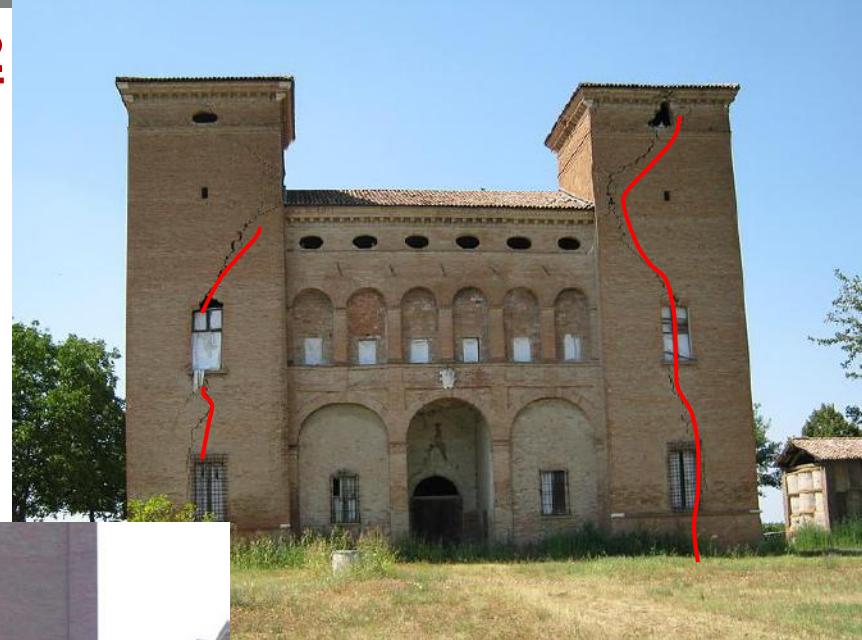
San Michele, Villa Sant' Angelo



- **Unstable masonry, disaggregation**

## Emilia, 2012

San Prospero



San Prospero,  
Cavezzo



Collegiata Santa Maria

- **Cracking and mortar joint sliding**



Maggiore, Mirandola

# EFFECT OF INTERVENTIONS



**ABSENCE OF TIES**

**USE OF REINFORCED CONCRETE**



# EFFECT OF INTERVENTIONS: ABSENCE OF TIES

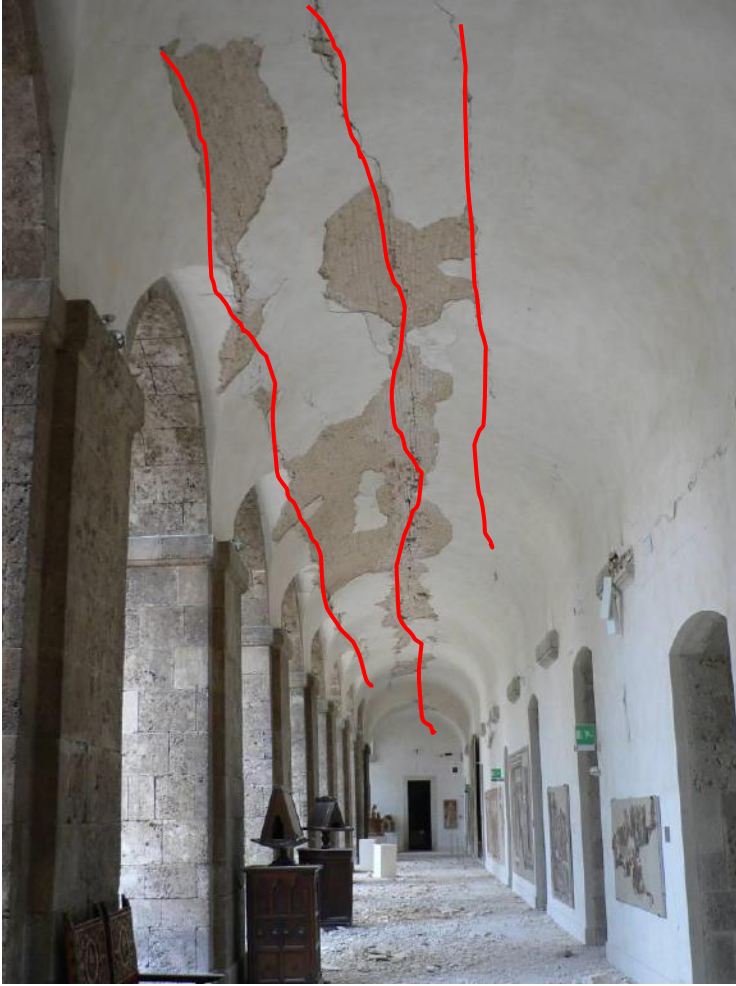
2009





# EFFECT OF INTERVENTIONS: ABSENCE OF TIES

2009

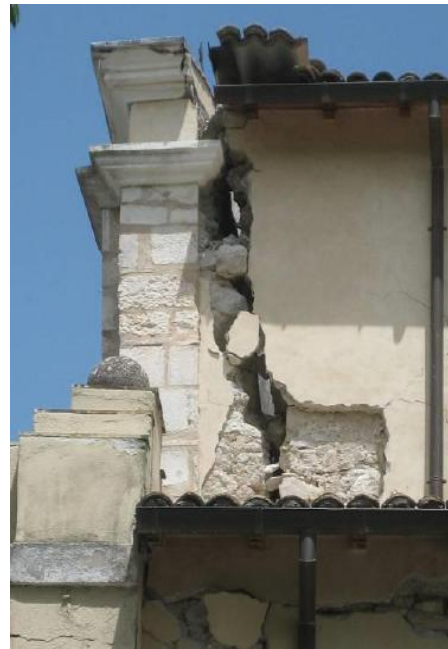
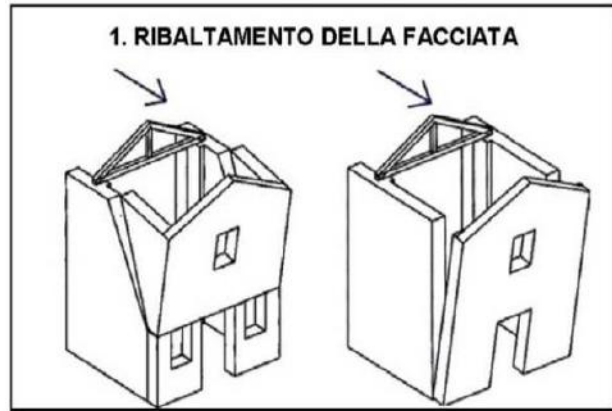


Forte Spagnolo, L'Aquila



# EFFECT OF INTERVENTIONS: ABSENCE/LACK OF TIES

2009



# EFFECT OF INTERVENTIONS: PRESENCE OF TIES

**2009**



# EFFECT OF INTERVENTIONS: PRESENCE OF TIES

Palazzo in via Buccio di Ranallo: **wood elements for ties and fixing**

**2009**



# EFFECT OF INTERVENTIONS: PRESENCE OF TIES



**2009**

Santa Maria del Soccorso:  
wood elements for ties  
and fixing



# EFFECT OF INTERVENTIONS: PRESENCE OF TIES

**2012** Collegiata Santa Maria Maggiore, Mirandola



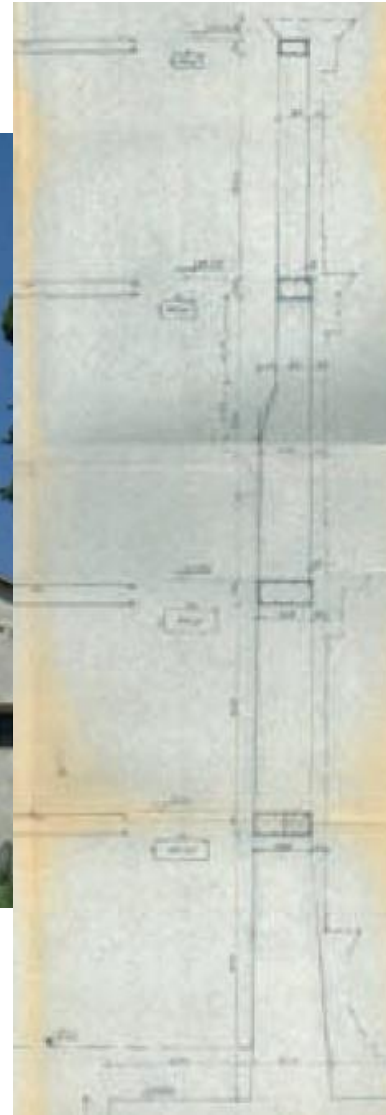
- Presence of ties but not adequately evaluated
- Damage of fixing elements

# EFFECT OF INTERVENTIONS: USE OF REINFORCED CONCRETE

SAN BERNARDINO, L'AQUILA



The façade is supported by a R.C. frame executed on 1960



# EFFECT OF INTERVENTIONS: USE OF REINFORCED CONCRETE



FORTE SPAGNOLO, L'AQUILA



# EFFECT OF INTERVENTIONS: USE OF REINFORCED CONCRETE

DUOMO, L'AQUILA



# EFFECT OF INTERVENTIONS: USE OF REINFORCED CONCRETE

SAN MARCO, L'AQUILA



# EFFECT OF INTERVENTIONS: USE OF REINFORCED CONCRETE



San Domenico, L'Aquila



San Biagio d'Amiterno,  
L'Aquila

# EFFECT OF INTERVENTIONS: USE OF REINFORCED CONCRETE

Asilo via Antonelli, L'Aquila



# EFFECT OF INTERVENTIONS: USE OF REINFORCED CONCRETE

Teatro Comunale,  
L' Aquila



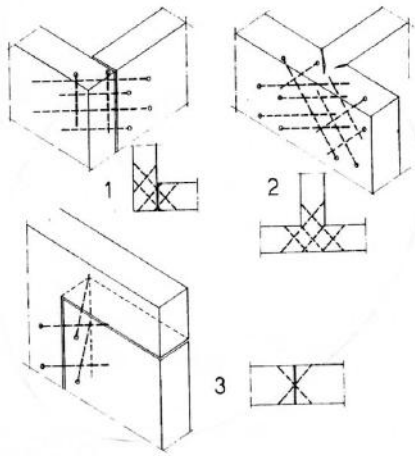
Palazzo via Roma , L' Aquila



# EFFECT OF INTERVENTIONS: USE OF REINFORCED CONCRETE



# EFFECT OF INTERVENTIONS: STITCHING OF MASONRY

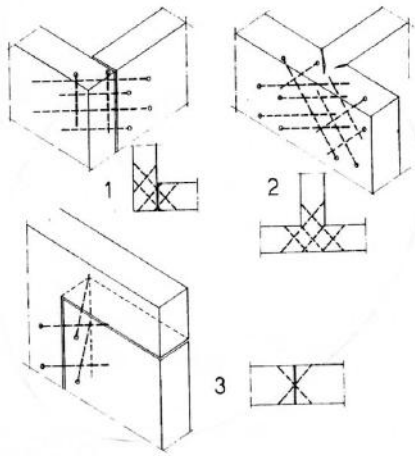


- obtrusive
- low effective connections
- problem of bond between masonry and rebars

Onna (L' Aquila)



# EFFECT OF INTERVENTIONS: STITCHING OF MASONRY



- obtrusive
- low effective connections
- problem of bond between masonry and rebars

Onna (L' Aquila)







ועדת הרייטי הבין-משרדית להערכות והעידות אדמה  
National Steering Committee for  
Earthquake Preparedness



UNIVERSITA  
DEGLI STUDI  
DI PADOVA



## International Seminar

**Assessment and improvement of structural safety under seismic actions of existing constructions: Reinforced Concrete Structures and Historical buildings**

SCE - Shamoon College of Engineering, Beer Sheva - 29 November 2015

International Conservation Center, Citta' di Roma, Old Acre - 1 December 2015

**Lessons learned from the past earthquakes:  
damages catalogues and interpretation**

**Prof. Maria Rosa Valluzzi**

*University of Padova, Department of Cultural Heritage*  
[mariarosa.valluzzi@unipd.it](mailto:mariarosa.valluzzi@unipd.it)

**THANKS FOR YOUR  
ATTENTION**