ORDINE DEGLI INGEGNERI
DELLA PROVINCIA DI LATINA

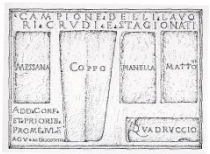
con il contributo incondizionato di

Leca soluzioni leggere e isolanti
Laterlite
RUREGOLD INNOVATION & SAFETY FOR BUILDING

Seminario webinar "RINFORZO E CONSOLIDAMENTO STATICO E ANTISISMICO DEGLI EDIFICI ESISTENTI"

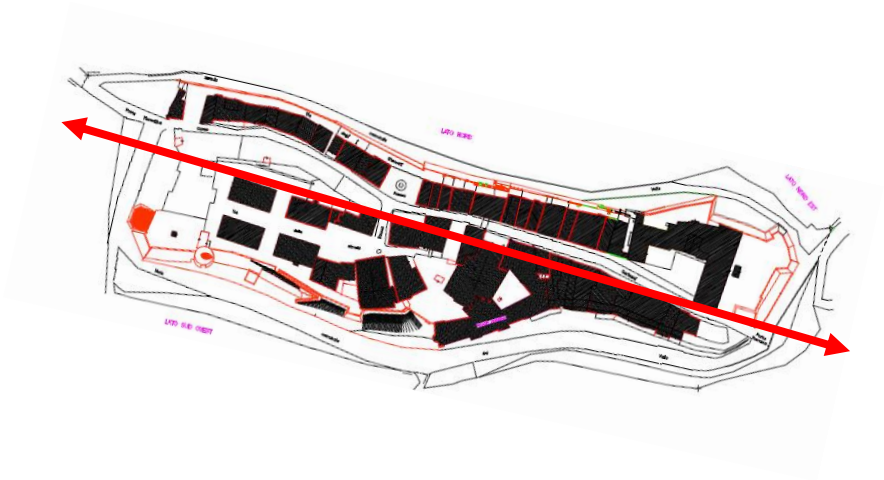
Principi di meccanica delle murature e di archi e volte per la valutazione del comportamento statico e della risposta sismica degli edifici storici in riferimento al quadro normativo.
Analisi del danno e delle lesioni sugli edifici storici, casistiche e approccio alla lettura del quadro fessurativo

Ing. Giovanni Cangi – libero professionista



Terremoto di Citerna-Monterchi (26 aprile 1917)

Monterchi (AR)



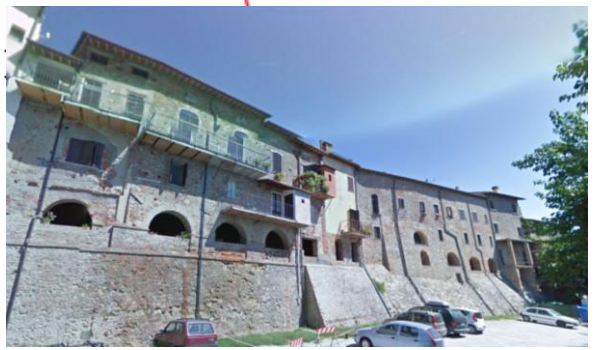
Citerna (PG)

Borghi collinari a sviluppo circolare e lineare

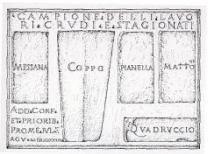
G. Cangi

Vulnerabilità sismica alla scala urbana

Citerna (PG), 26 aprile 1917



G. Cangi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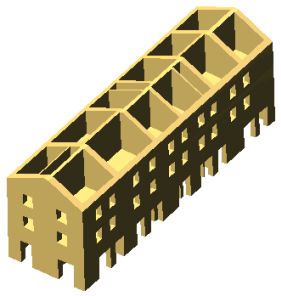
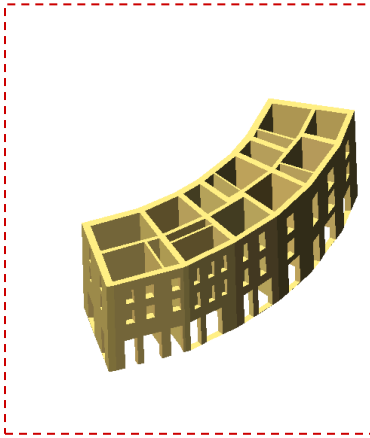
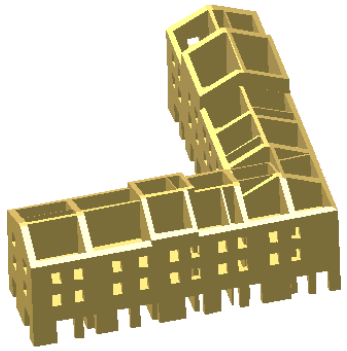
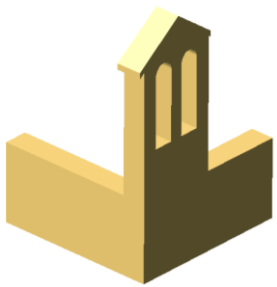
RICRVDI E STAGIONATI
MESSANA
COPPO
PANELLA
MATTO
QVADRVCCIO

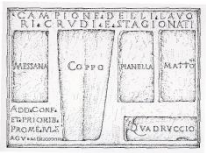




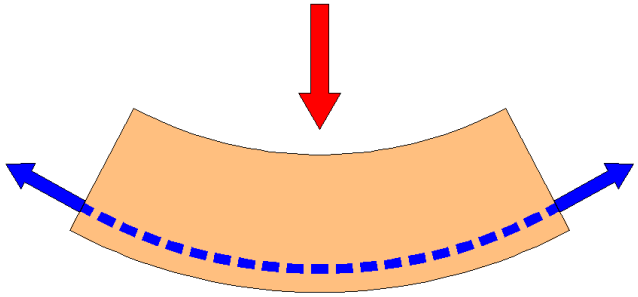




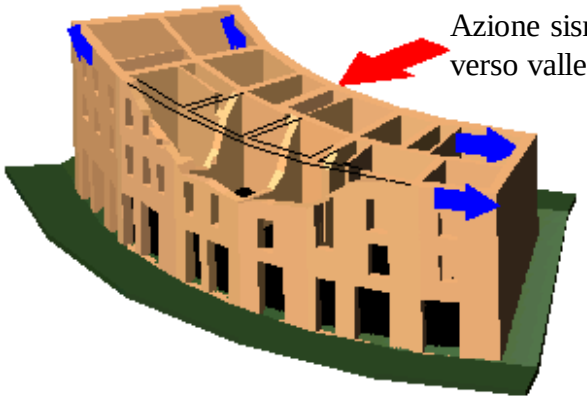
G. Cangi



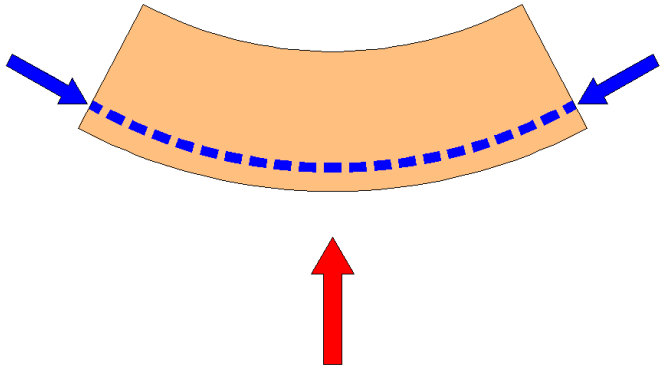
Effetti del sisma ortogonale negli isolati ad impianto curvilineo



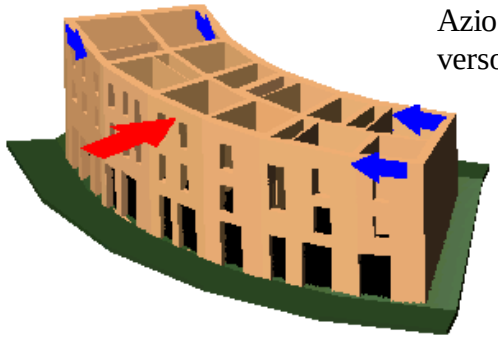
L'azione sismica verso valle mette in trazione la parete di facciata ((Allentamento parete di valle)



Azione sismica verso valle

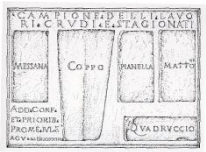


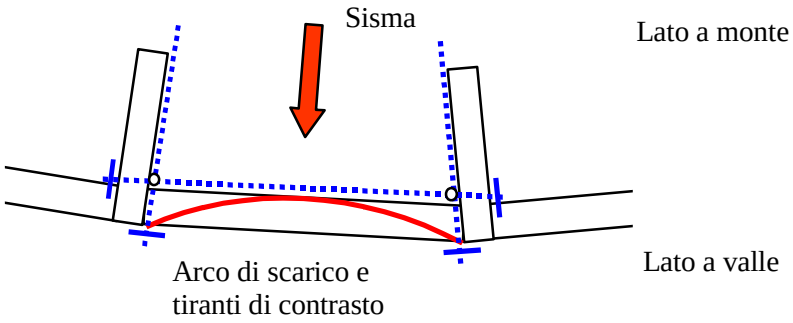
L'azione sismica verso monte comprime le pareti di facciata (Effetto arco)



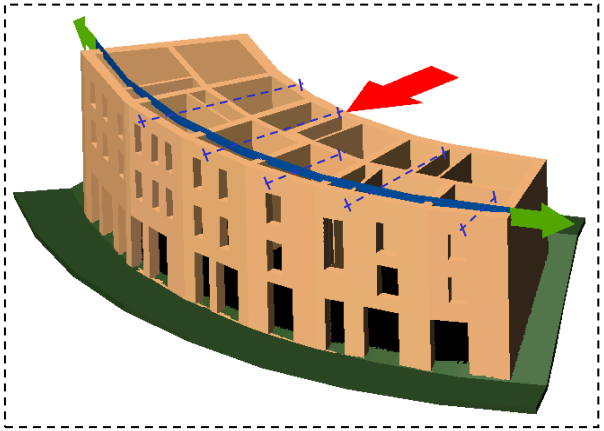
Azione sismica verso valle

G. Cangi

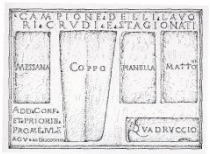




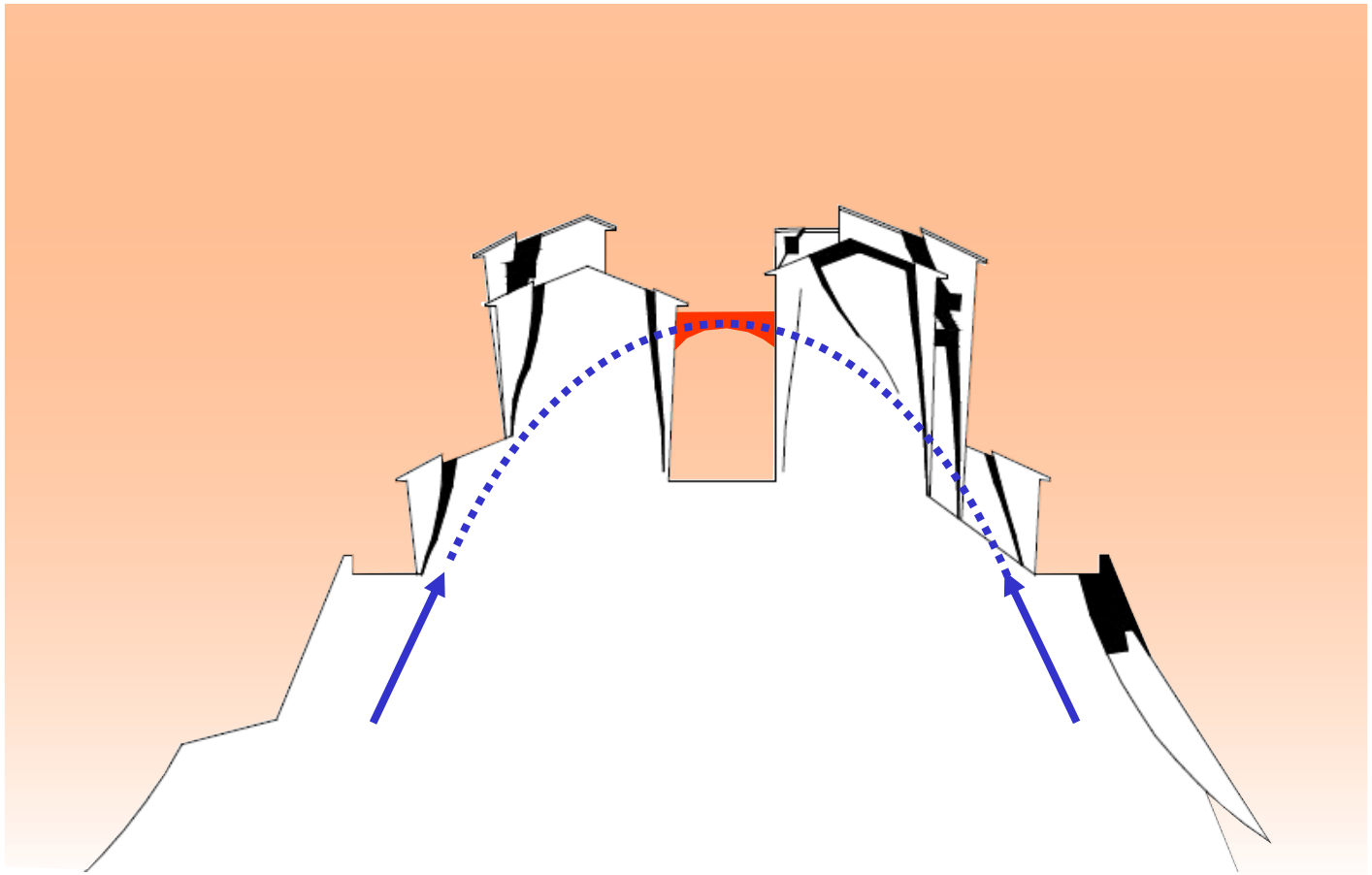
Azione sismica sulla singola parete con meccanismo resistente locale

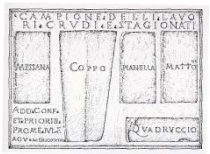


Meccanismo resistente assicurato da
collegamenti metallici sommitali e di piano

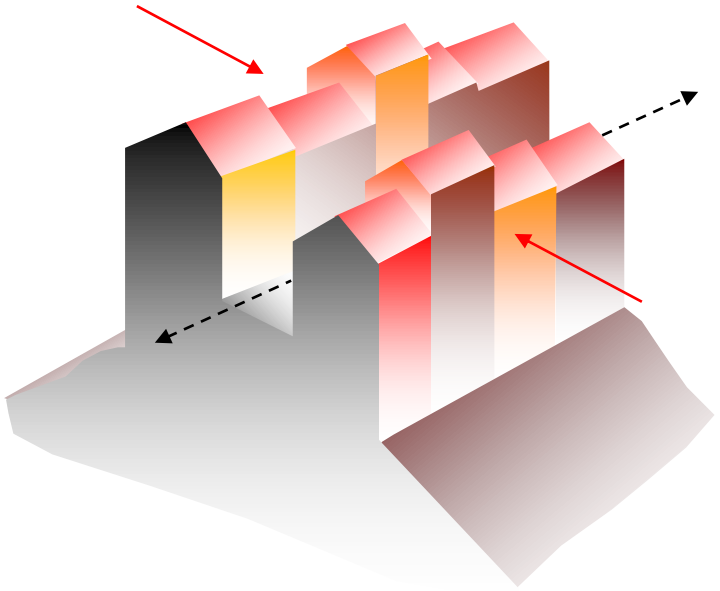


Meccanismi resistenti alla scala urbana





Valutazione del rischio sismico alla scala urbana



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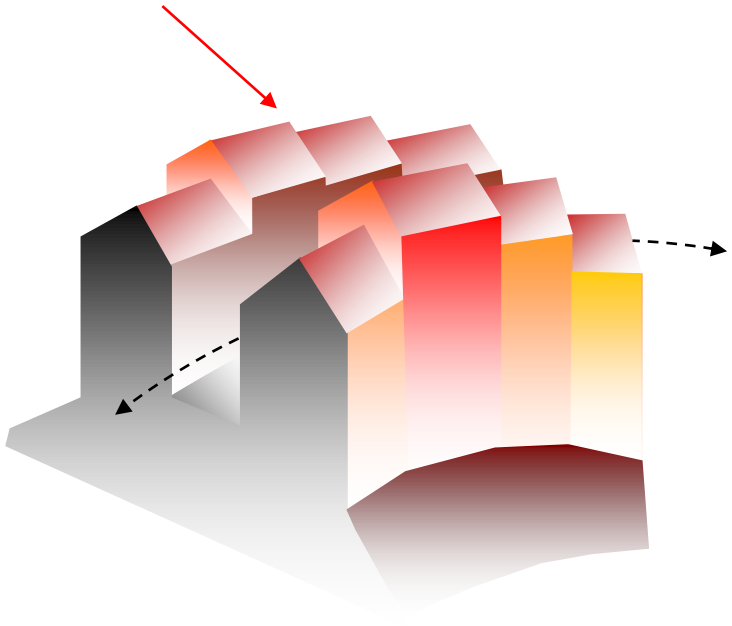

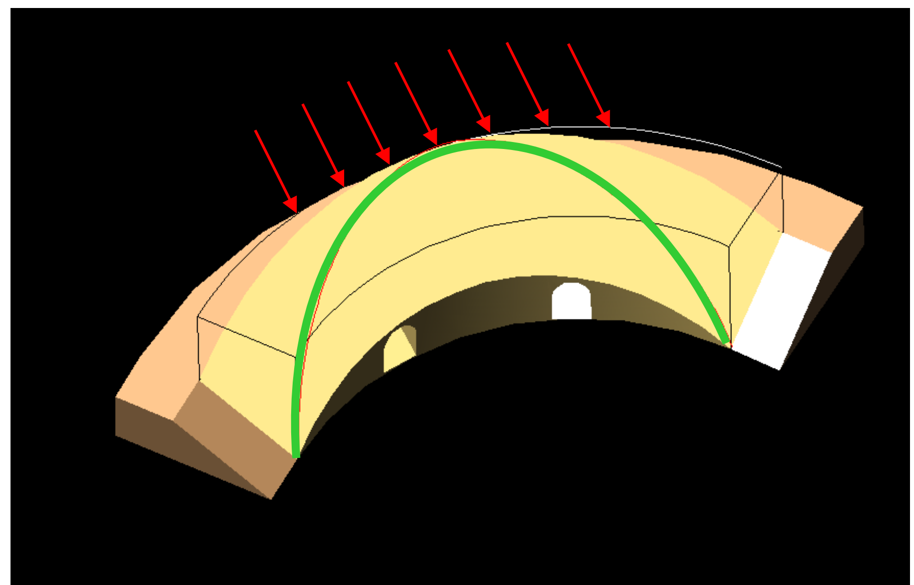

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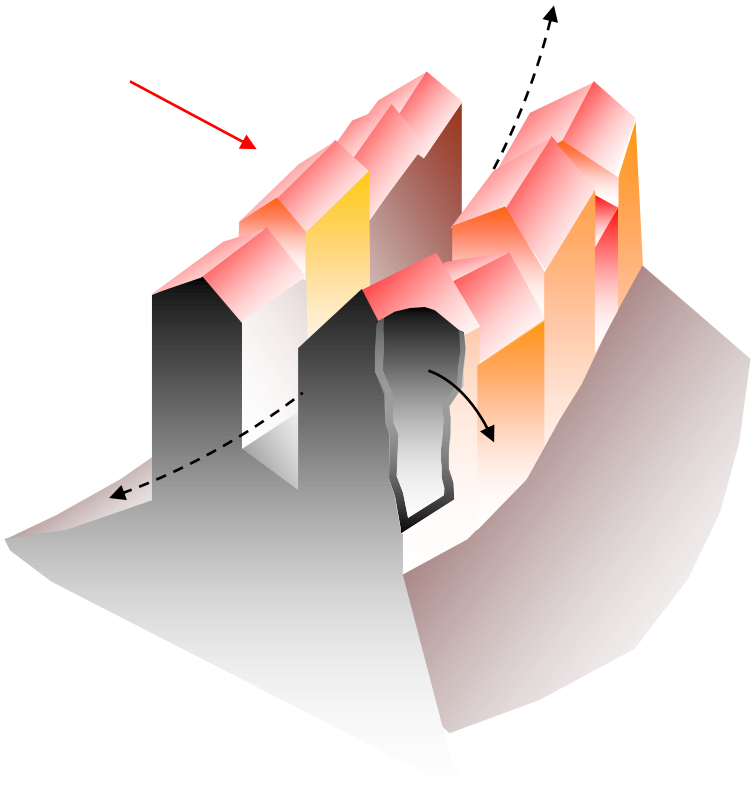
Valutazione del rischio sismico alla scala urbana



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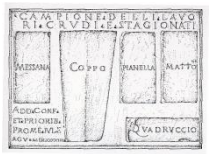

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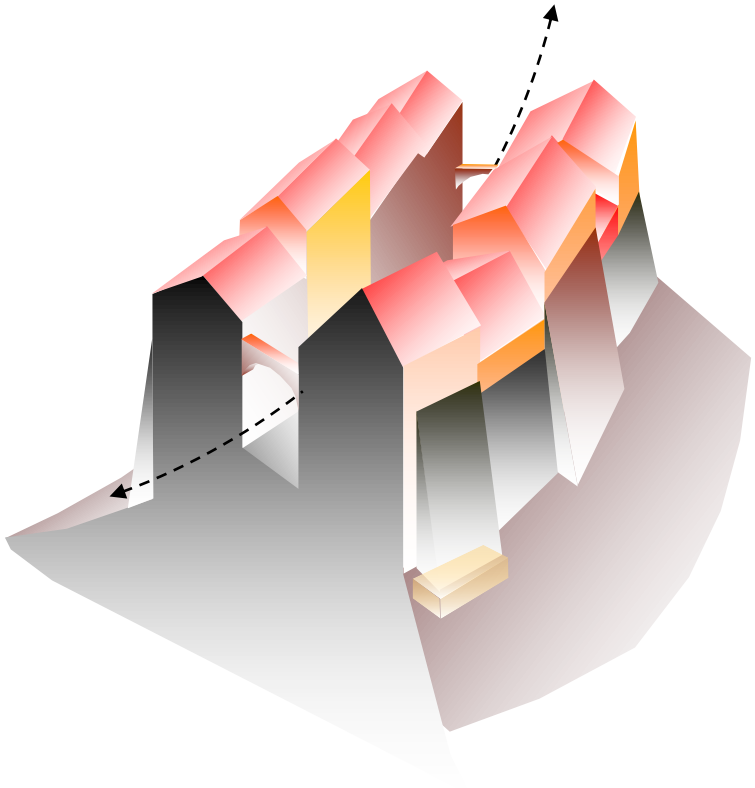

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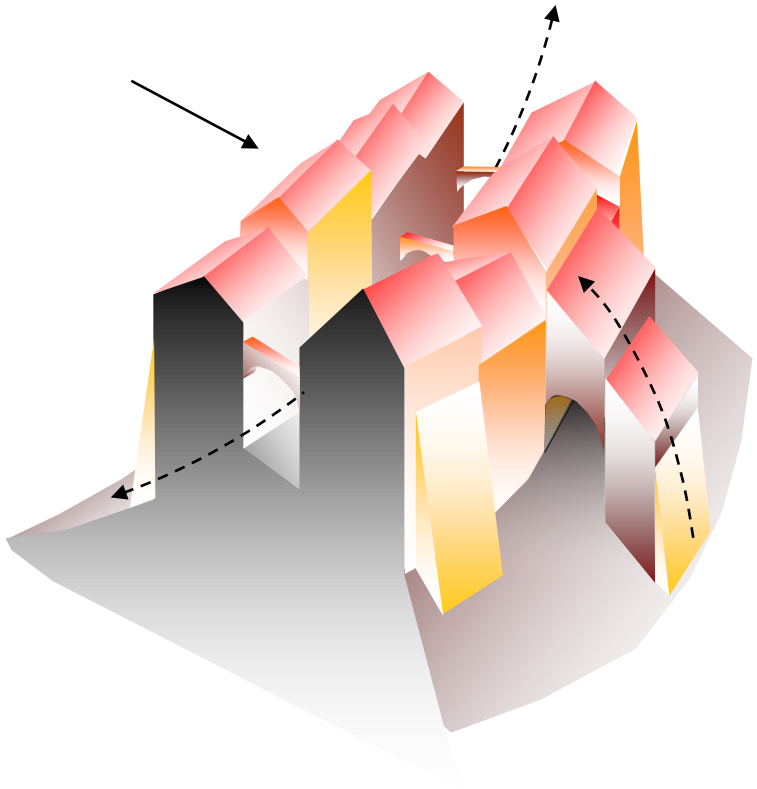
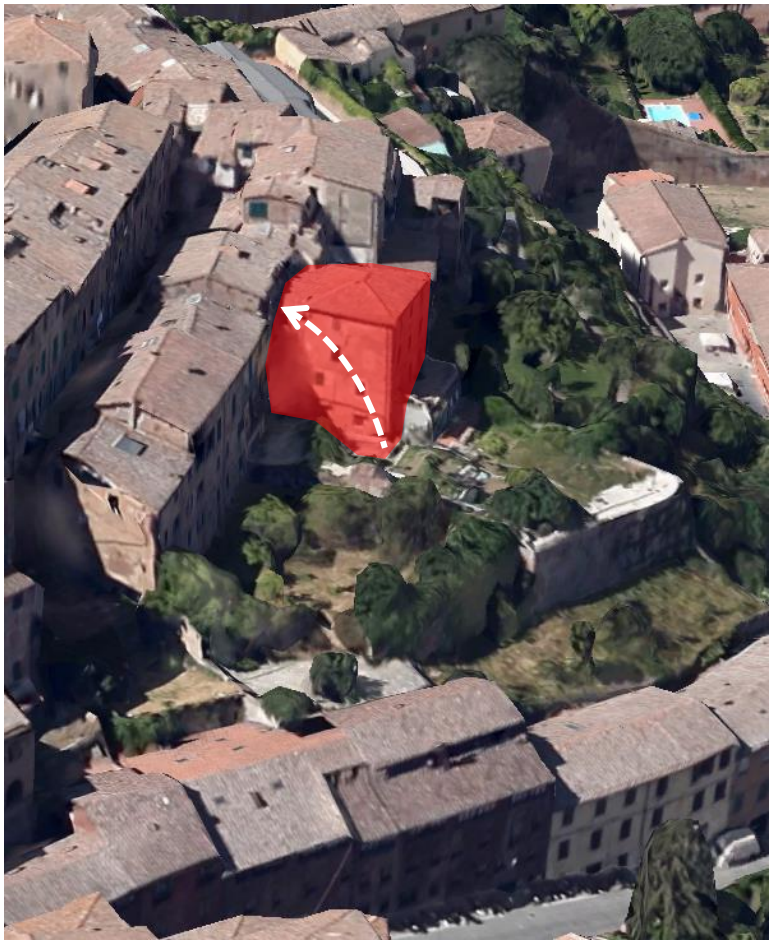
Valutazione del rischio sismico alla scala urbana





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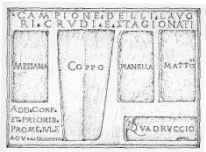
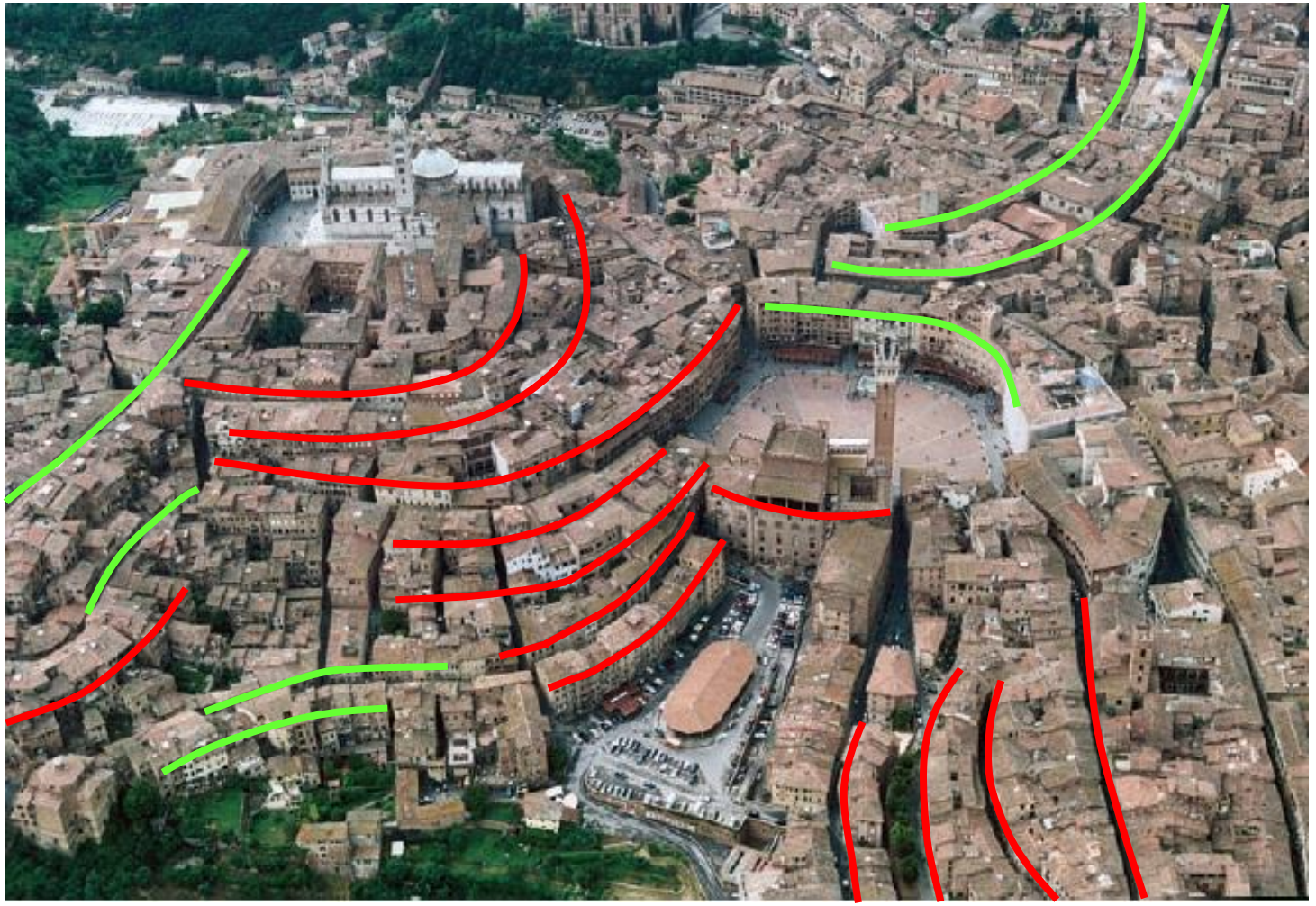
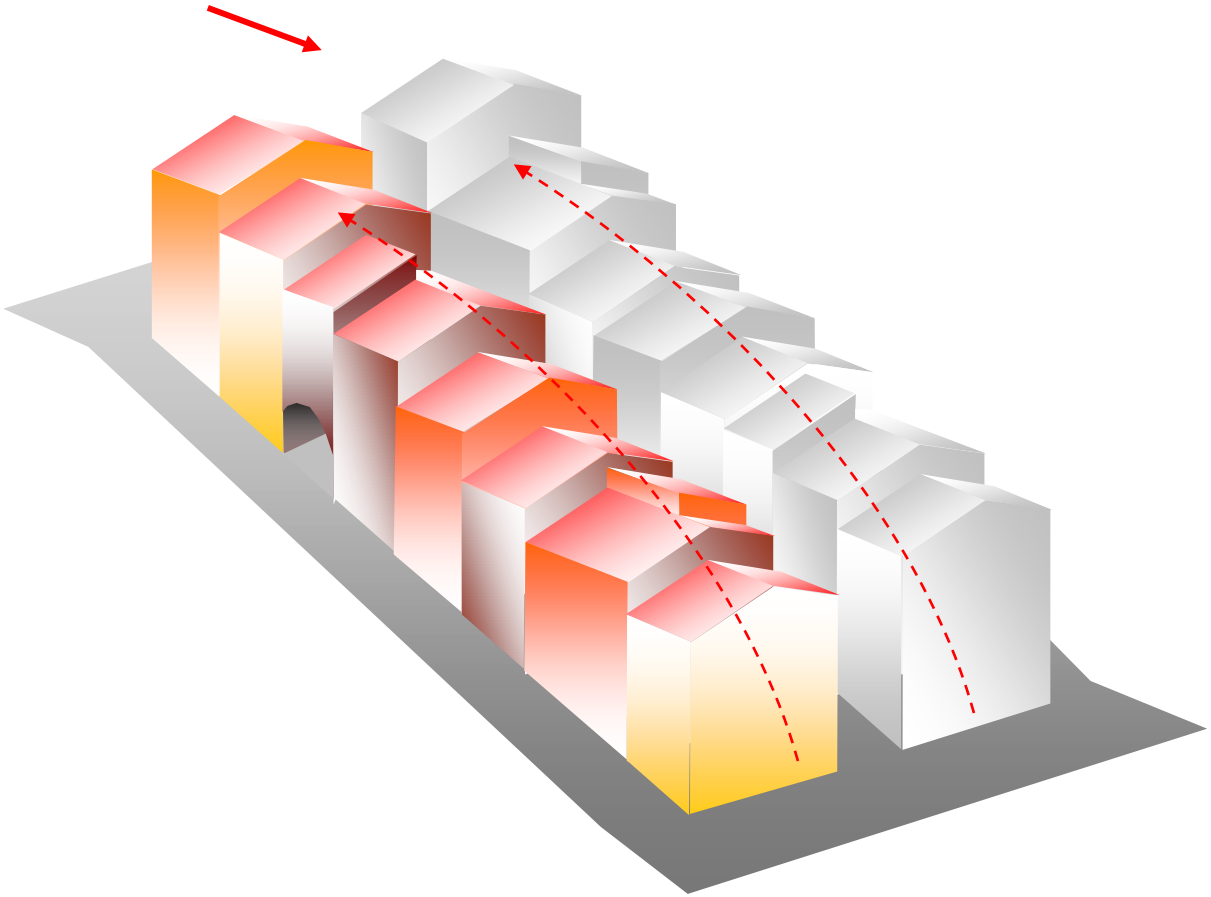




Siena: criticità determinate dalla conformazione planimetrica degli aggregati edilizi in relazione alla configurazione di pendio (concavità e convessità del lato a valle)

G. Cangi

Valutazione del rischio sismico alla scala urbana



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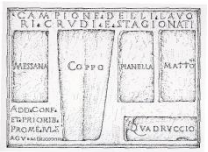
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MANELLA
MATTO
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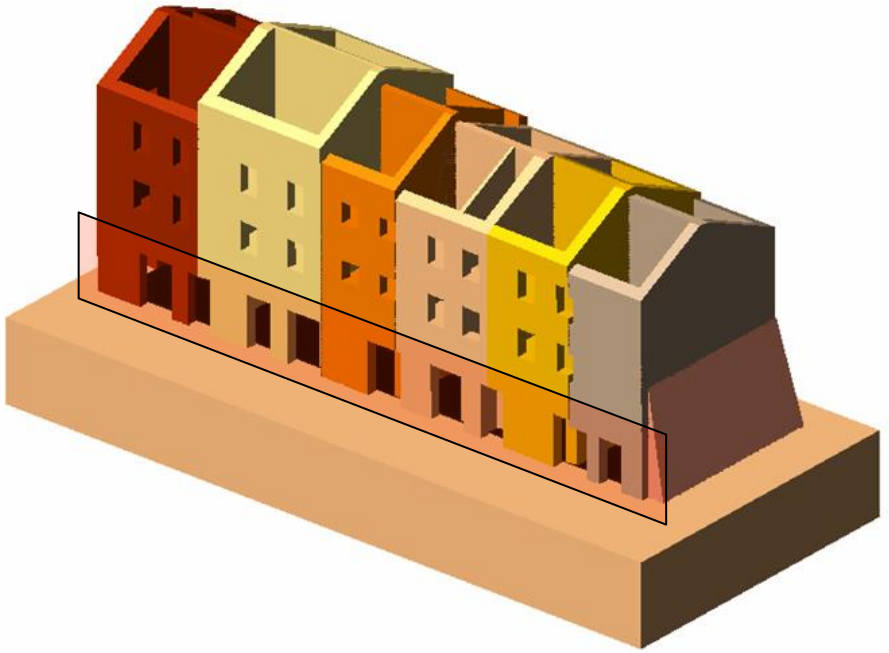

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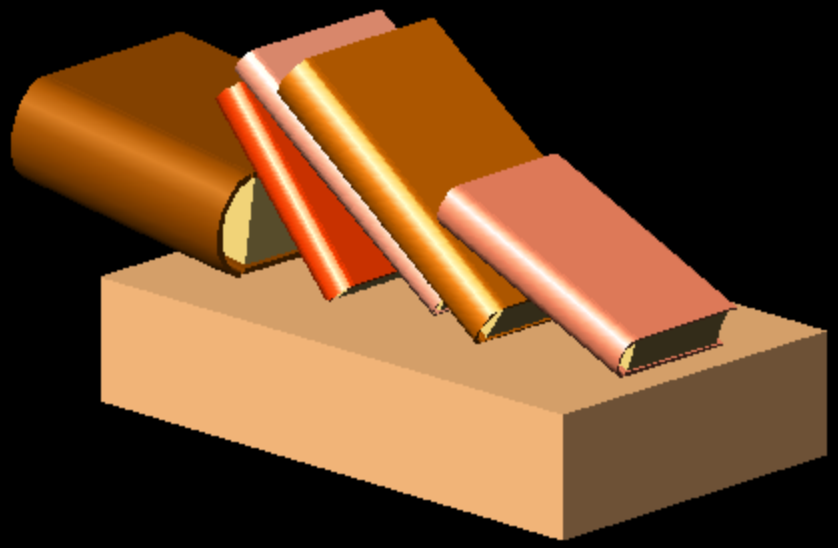
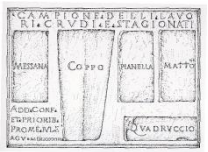


G. Cangi

L’Aquila – 6 aprile 2009

G. Cangi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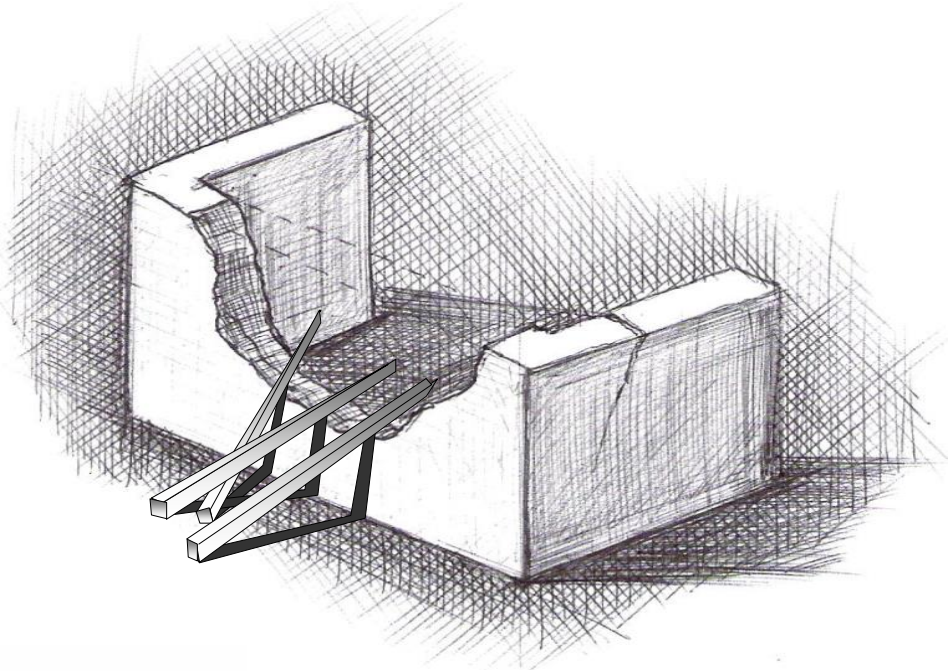

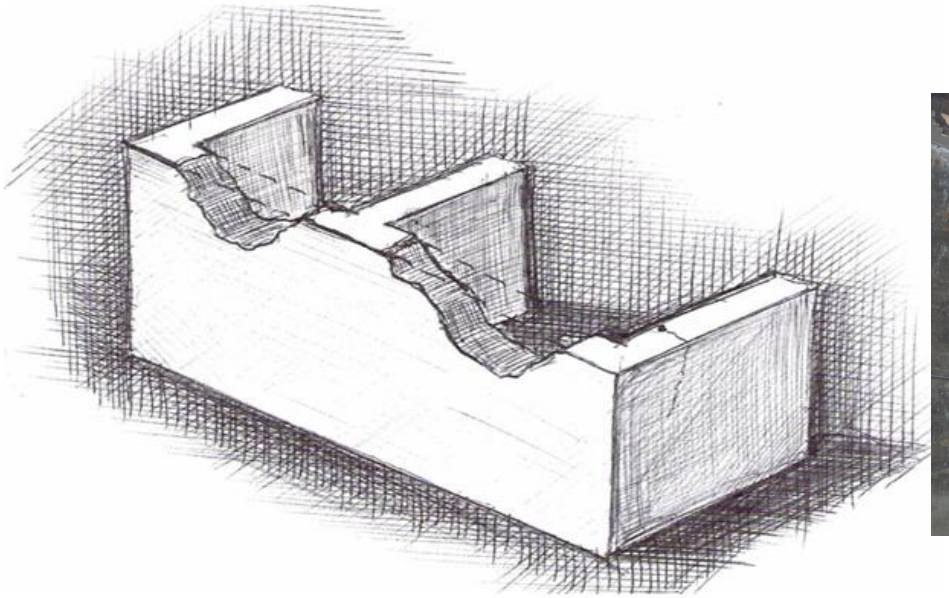

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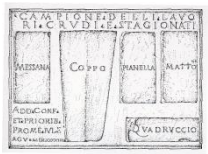
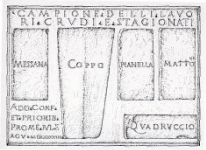


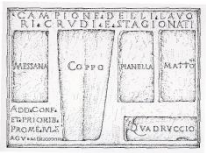
Terremoto dell'Emilia (maggio 2012):
ribaltamento di pareti sollecitate da azioni ortogonali

G. Cangi



Camillo Ricci
(Terremoto di Argenta, 1624)

G. Cangi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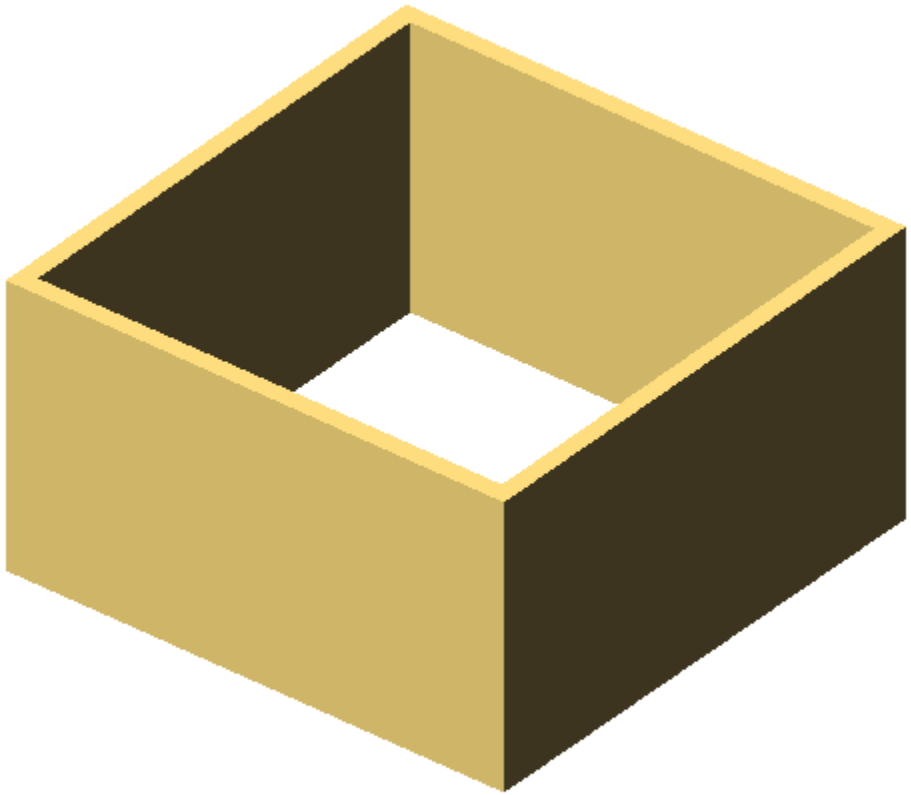

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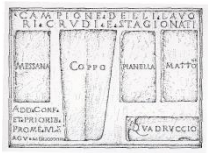
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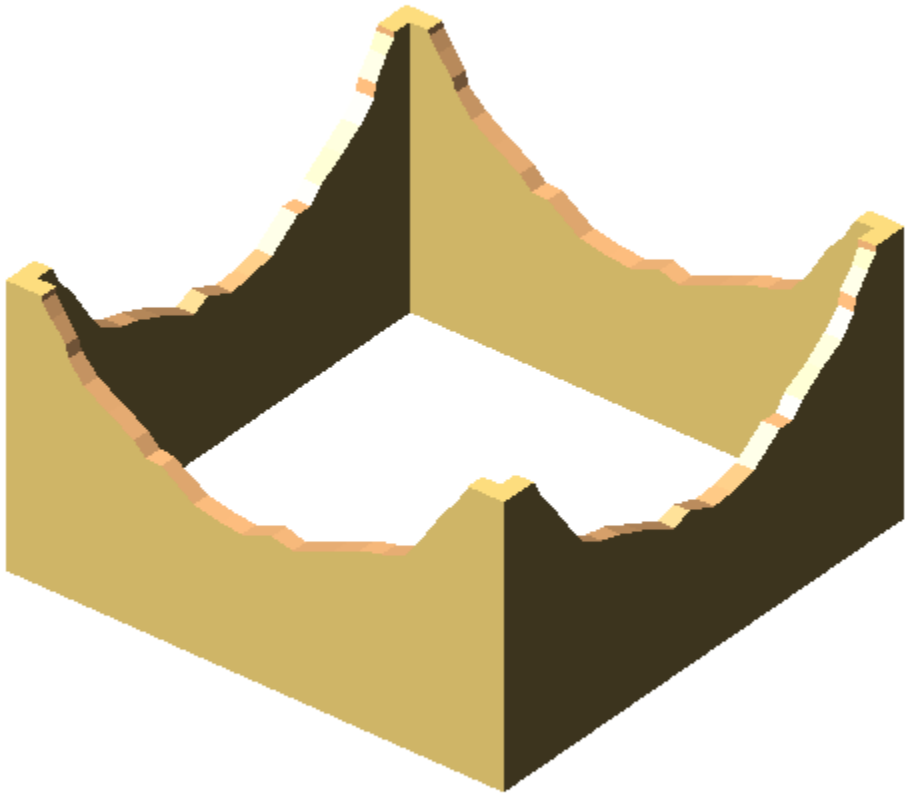
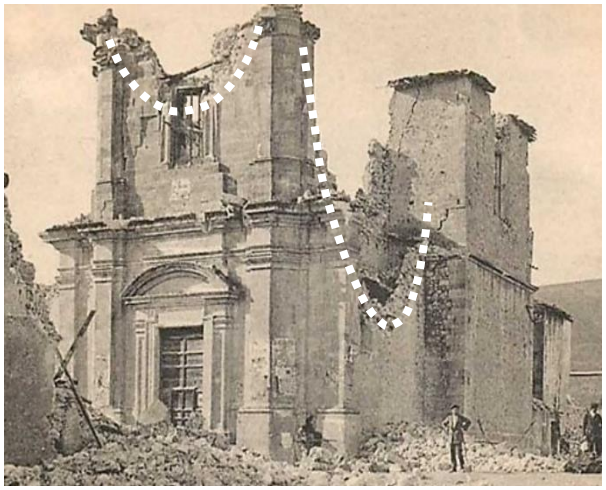
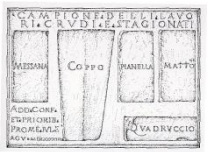


G. Cangi

Umm al Jimal (Giordania), 749 dC



Chiesa di San Francesco - Avezzano (1915)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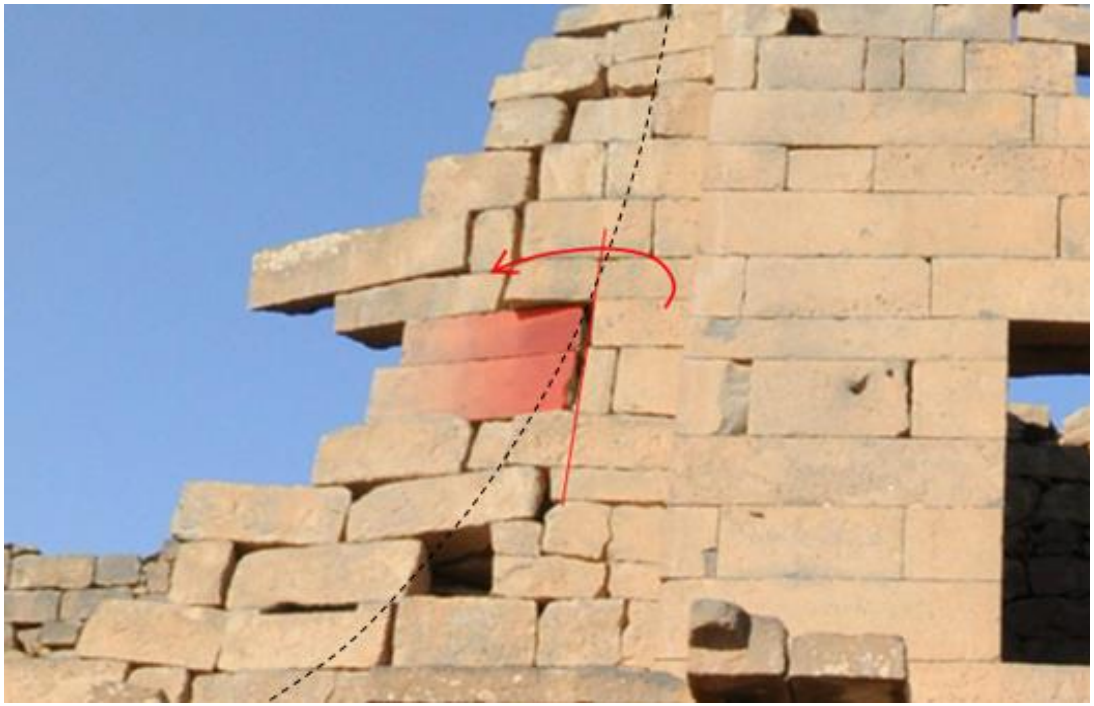

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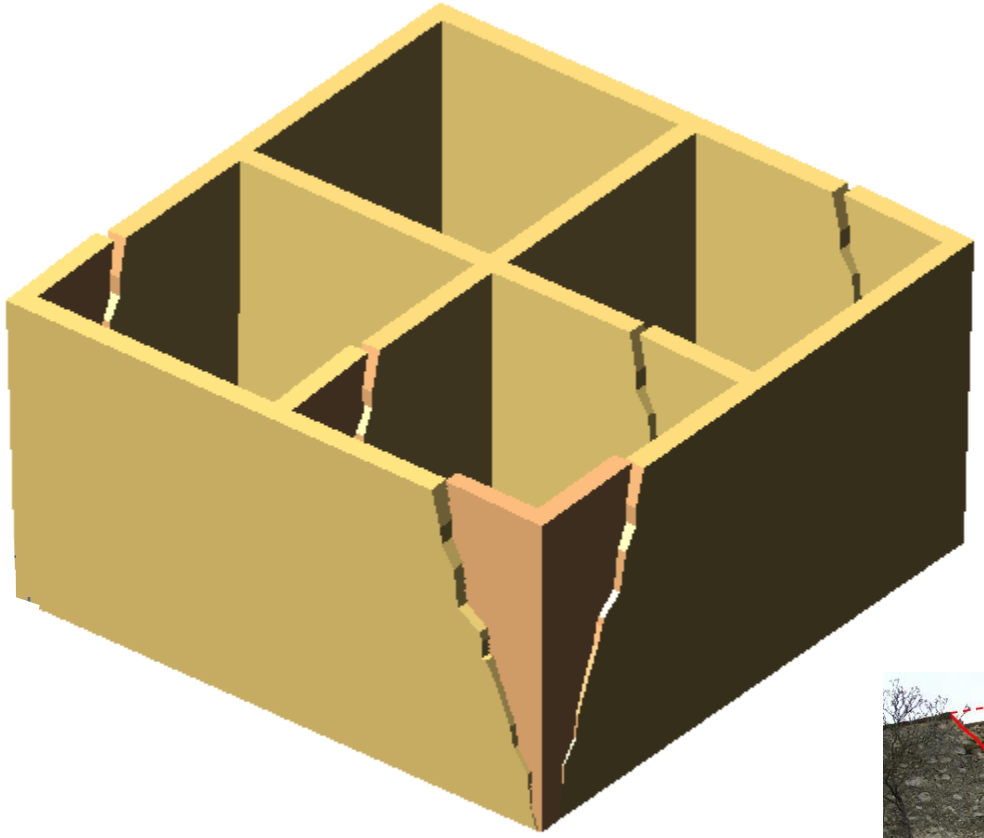


G. Cangi

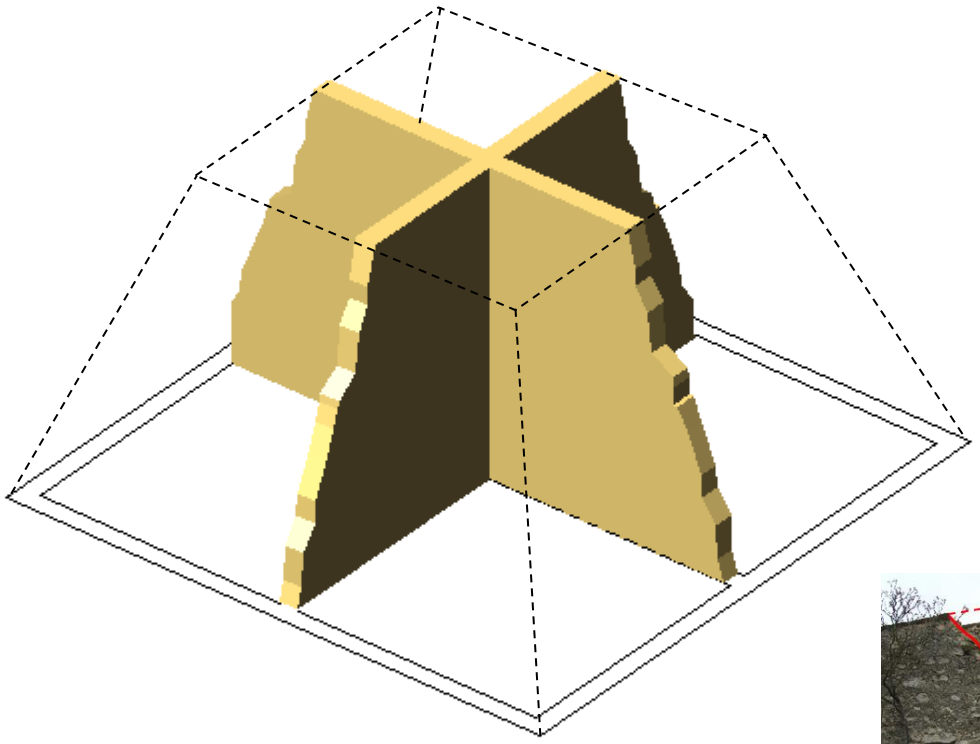
Torre di Babele

Ziqqurat (Persia)

Piramidi egizie

Piramidi Maia

Castelli giapponesi



G. Cangi

Torre di Babele

Ziqqurat (Persia)

Piramidi egizie

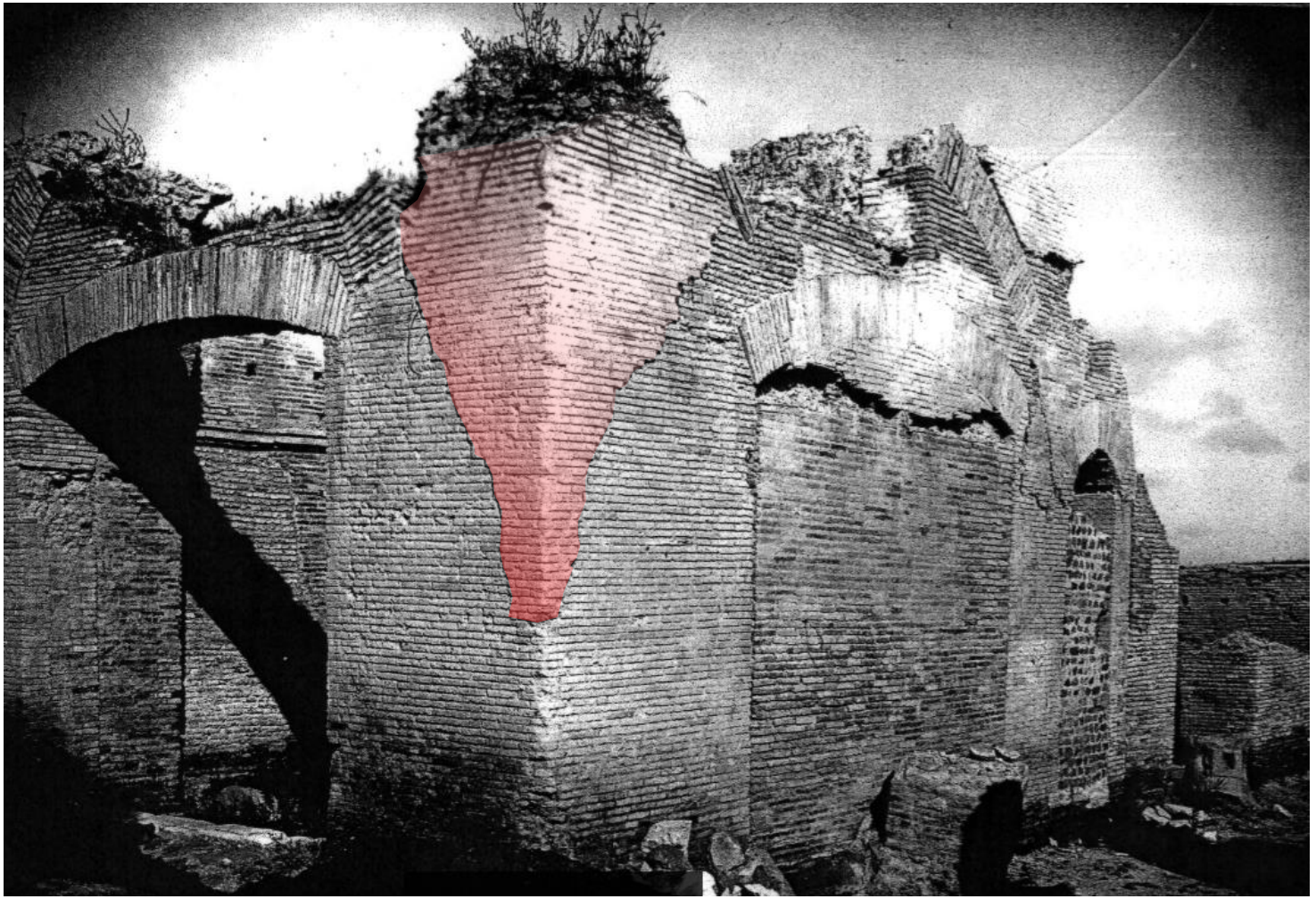
Piramidi Maia

Castelli giapponesi

G. Cangi

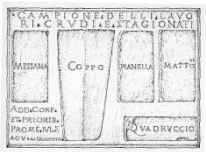
CD n° AC7

SOPRINTENDENZA ALLE ANTICHITA' DI OSTIA
Arch. Foto Soprint. - Nega. Serie B n. 2214/5 Inv. 4703



Via della Casa di Diana

L. Pecchioli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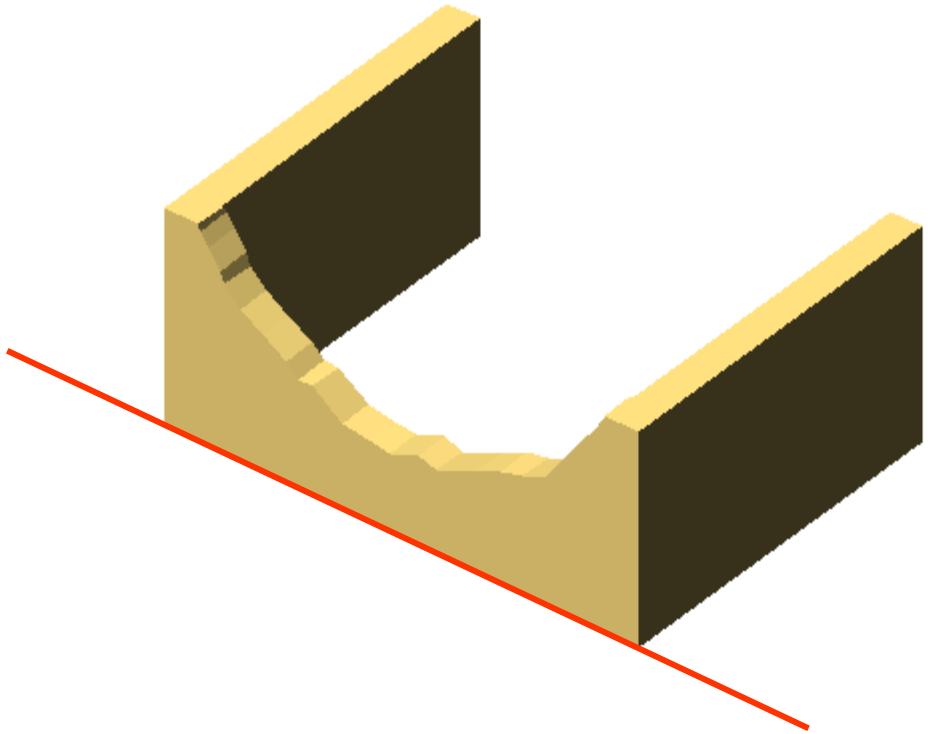

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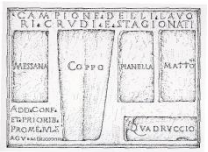
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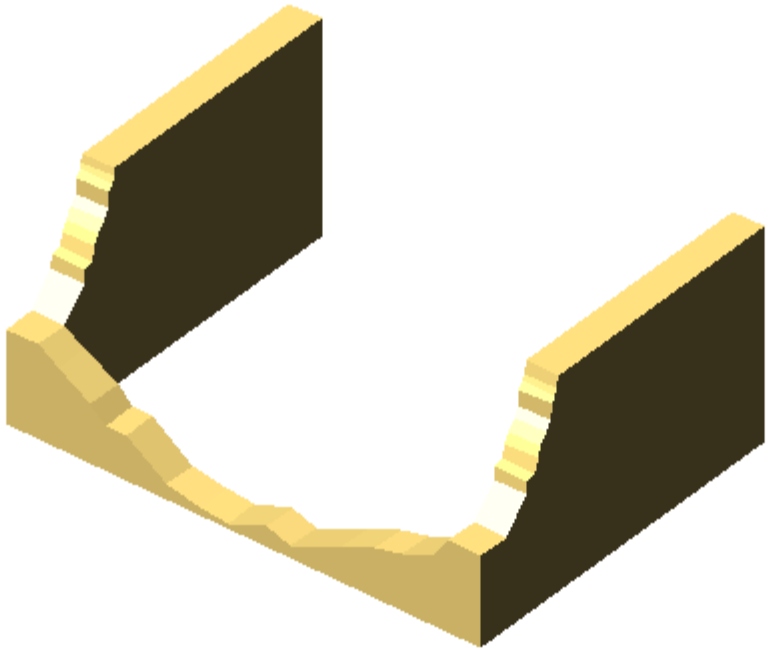
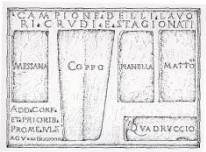
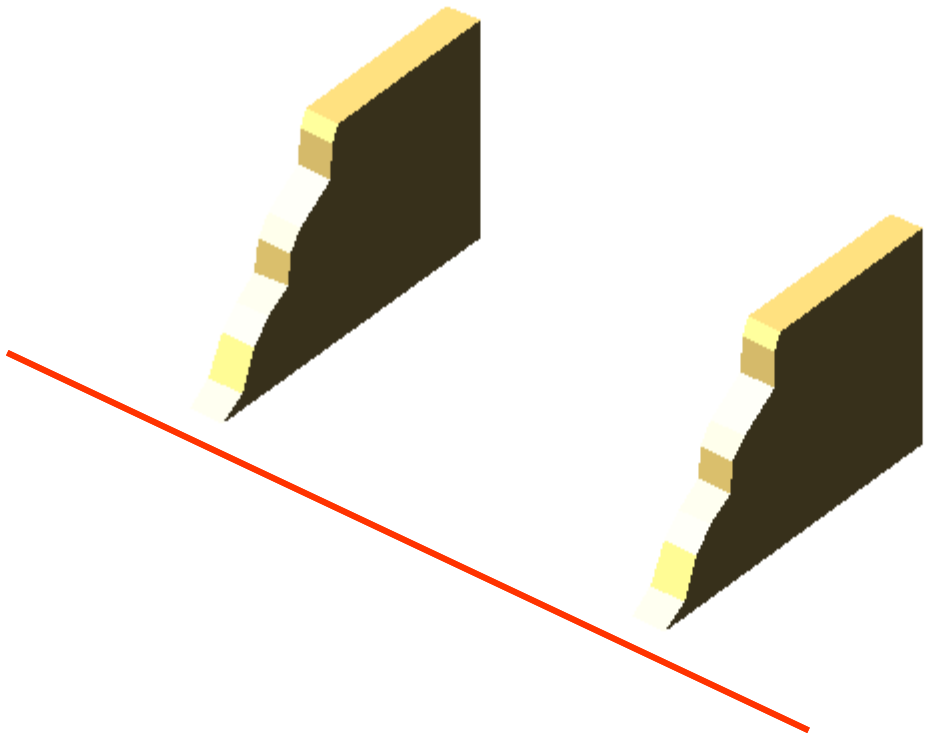


G. Cangi


CAMPIONE DI LEGNO CAVO
RICRVDI E STAGIONATI
MESSANA
COPPO
MANELLA
MATTO
QVADRVCCIO



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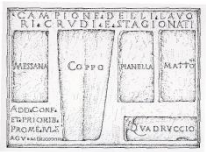
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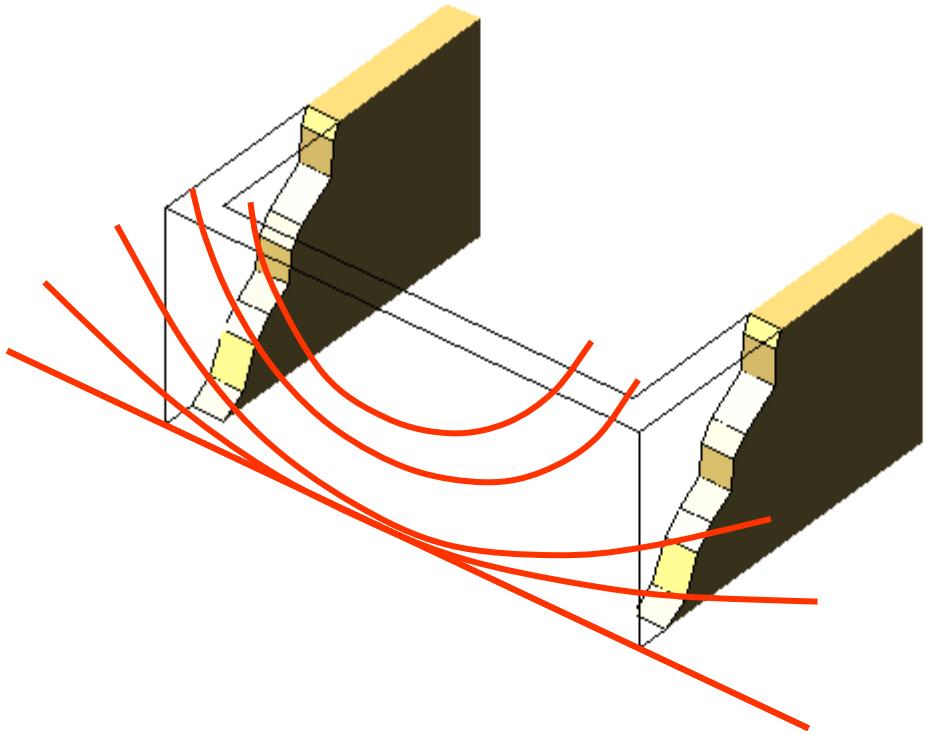
RICRVDI E STAGIONATI
MESSANA
COPPO
MANELLA
MATTO
QVADRVCCIO



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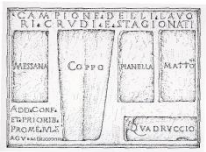
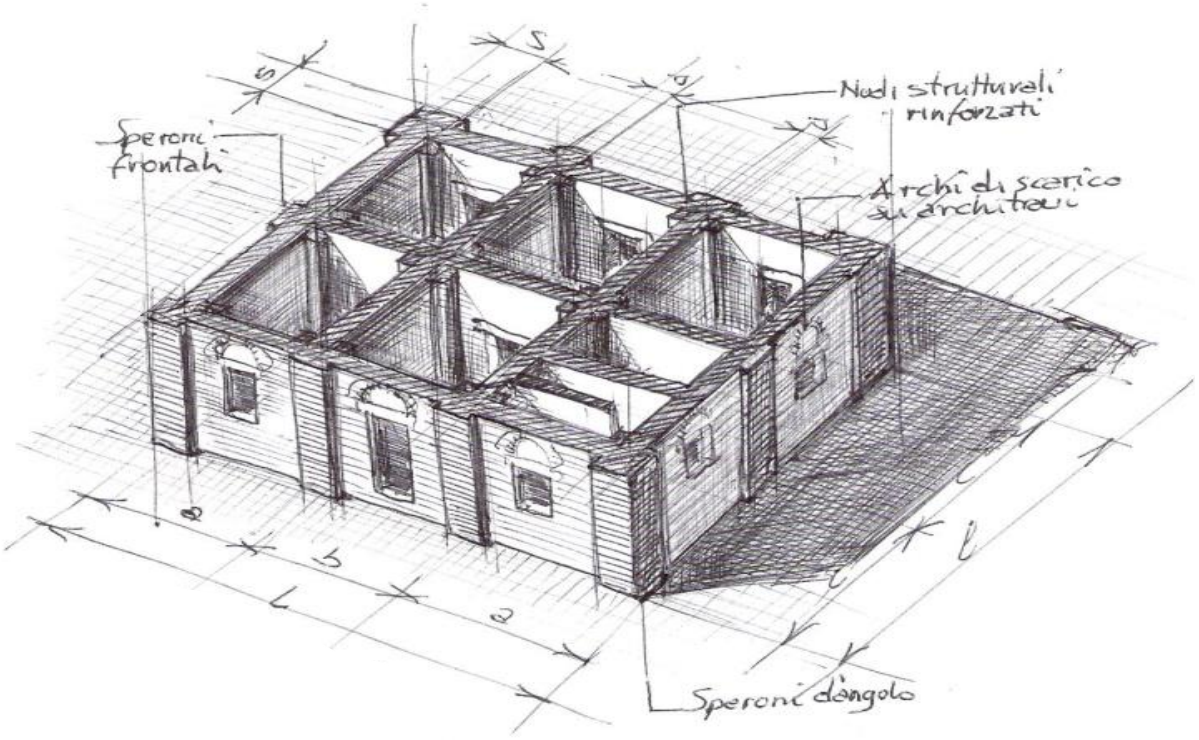


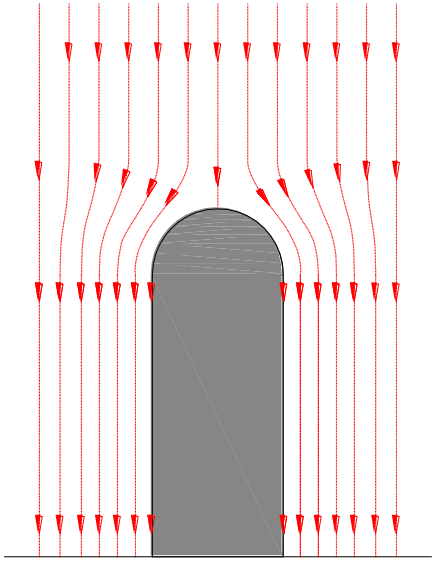
Progetto di “casa antisismica” elaborato dopo il terremoto del 1570 a Ferrara dall’architetto Pirro Ligorio, succeduto a Michelangelo presso la Fabbrica di San Pietro e trasferitosi alla corte degli Estensi nel 1568.

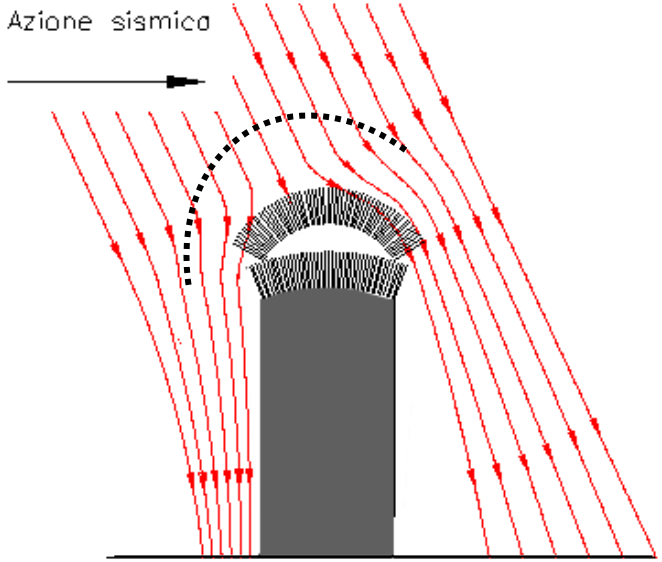


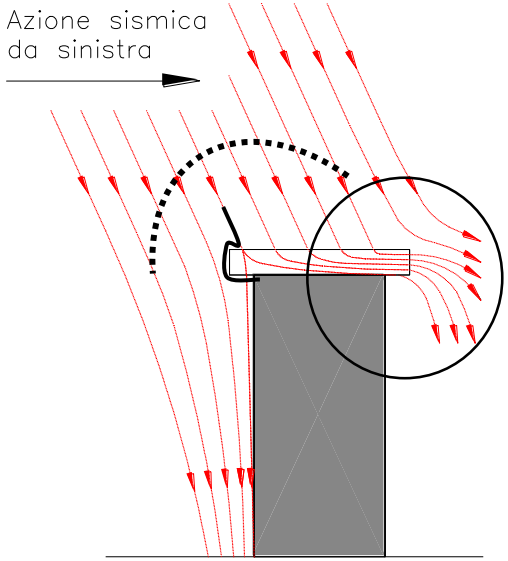
Punti fondamentali della “casa antisismica”:

- *regolarità in pianta;*
- *interassi contenuti fra i muri portanti;*
- *spessori consistenti delle murature;*
- *cantonali rinforzati;*
- *rinforzo degli incroci murari;*
- *ordinata disposizione delle aperture;*
- *presenza di archi di scarico sopra gli architravi.*

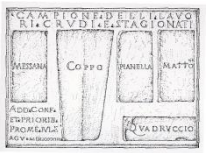
G. Cangi





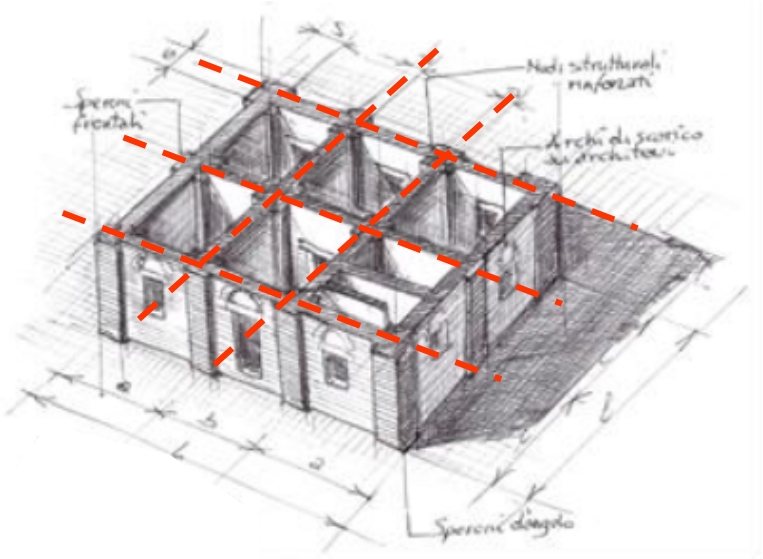


Archi di parete predisposti per diffondere i flussi di compressione in condizioni statiche e sismiche in presenza di archi e anomalie prodotte dagli architravi

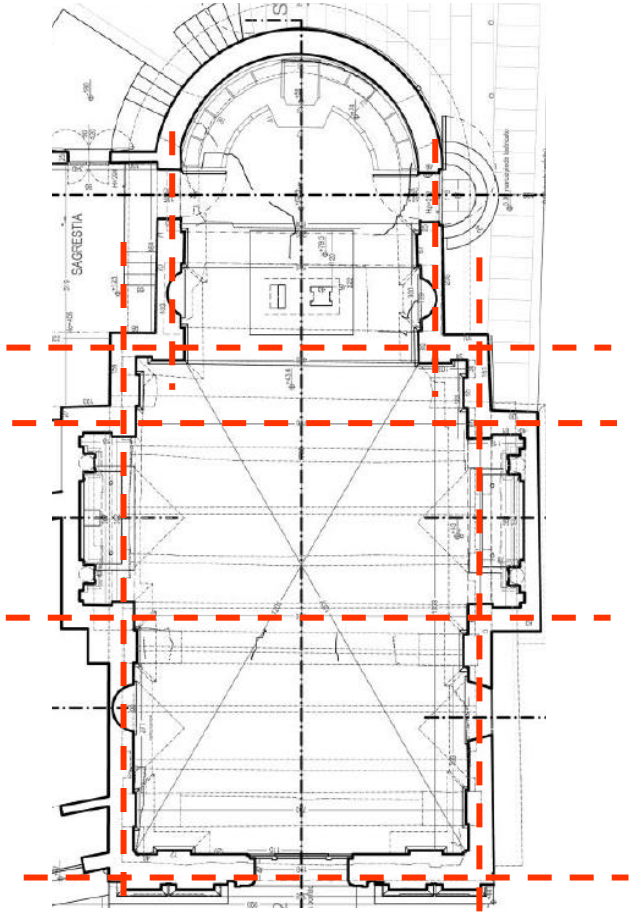


Pirro Ligorio
di una casa antisismica

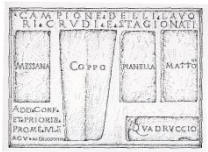
Progetto
Ferrara - 1574

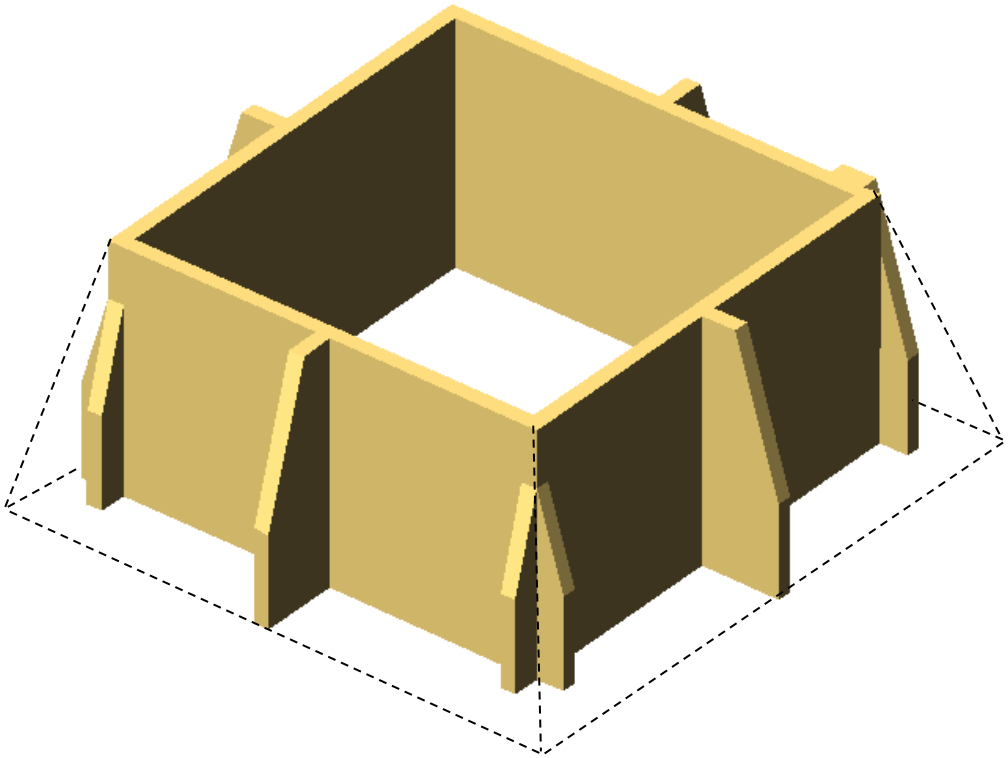


VALENTINA BARONCINI architetto
via Giuseppe Martucci 10
40136 BOLOGNA
Tel.-fax: 051/580817 cell. 338/9211687
valentina.baroncini@tiscali.it
valentina.baroncini@archiworldpec.it
CF. BRNVNT70P64A944K
P. IVA 03105041200



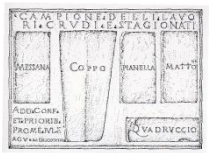
ORATORIO DI SANTA CROCE
SAN FELICE SUL PANARO (MO)



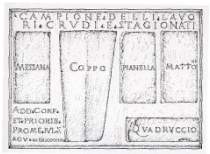


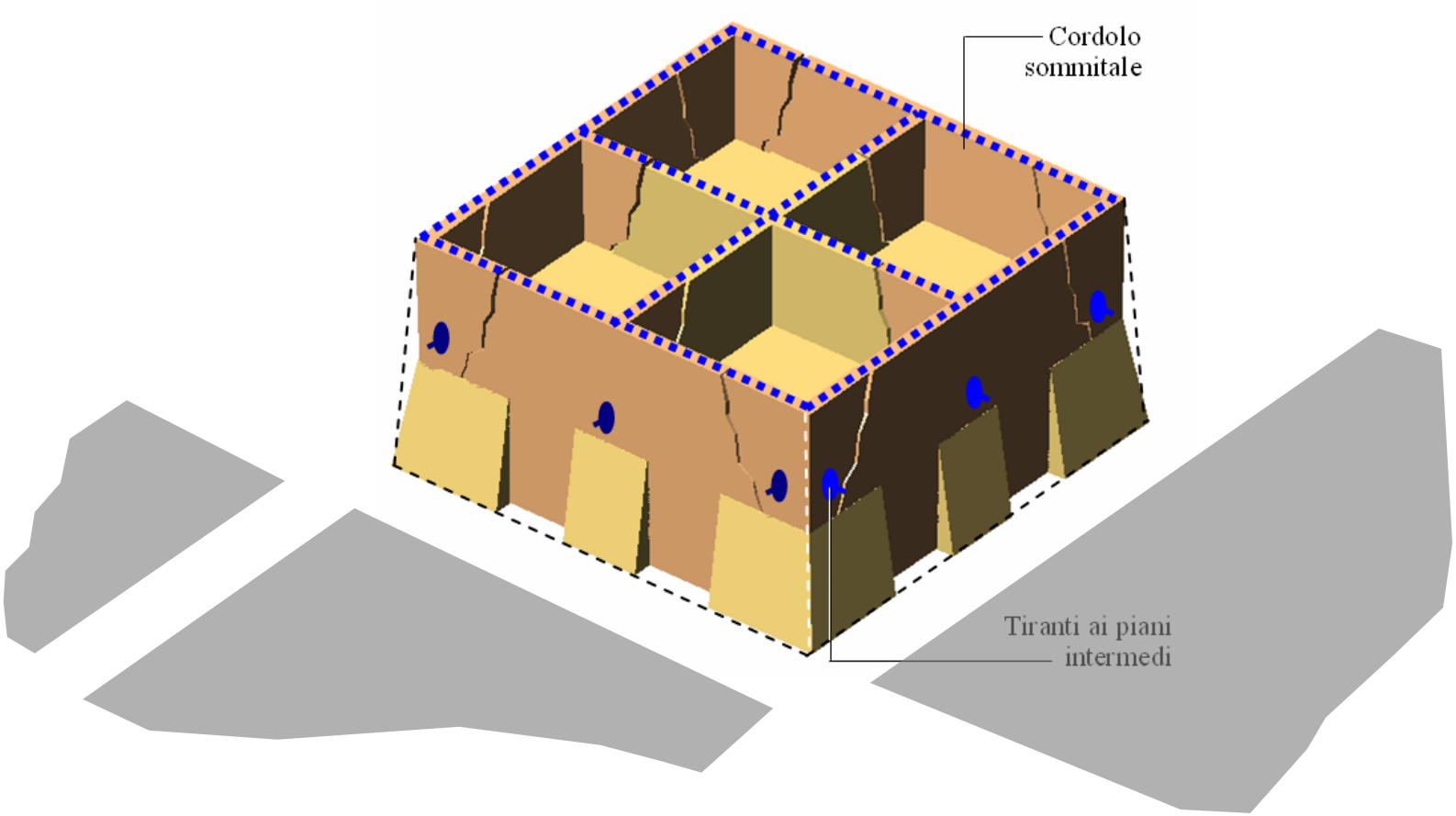
Lo stesso principio!

G. Cangi

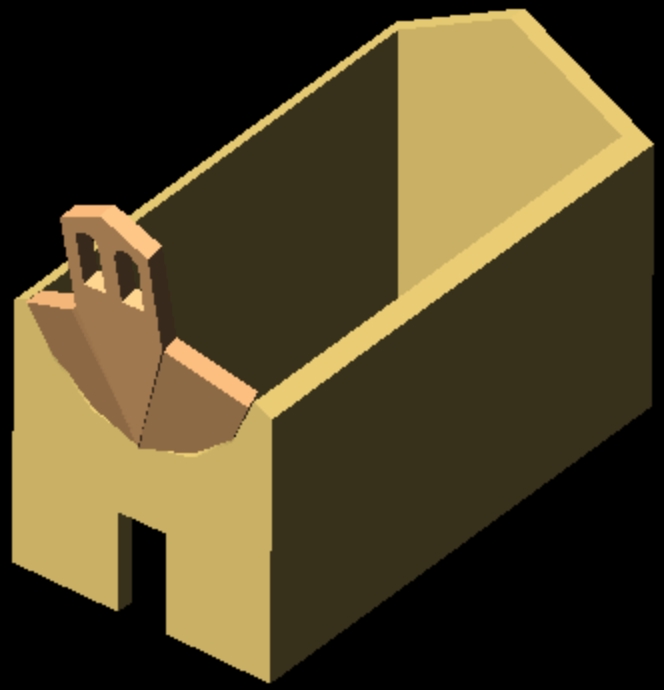

CAMPIONE DI LEGNAME
RICRVDI E STAGIONATI
MESSANA
COPPO
MANELLA
MATTO
QVADRVCCIO

G. Cangi


CAMPIONE DI LATERIZIO
RICRVDI E STAGIONATI
MESSANA
COPPO
PANELLA
MATTO
QVADRVCCIO


Cordolo
sommitale
Tiranti ai piani
intermedi

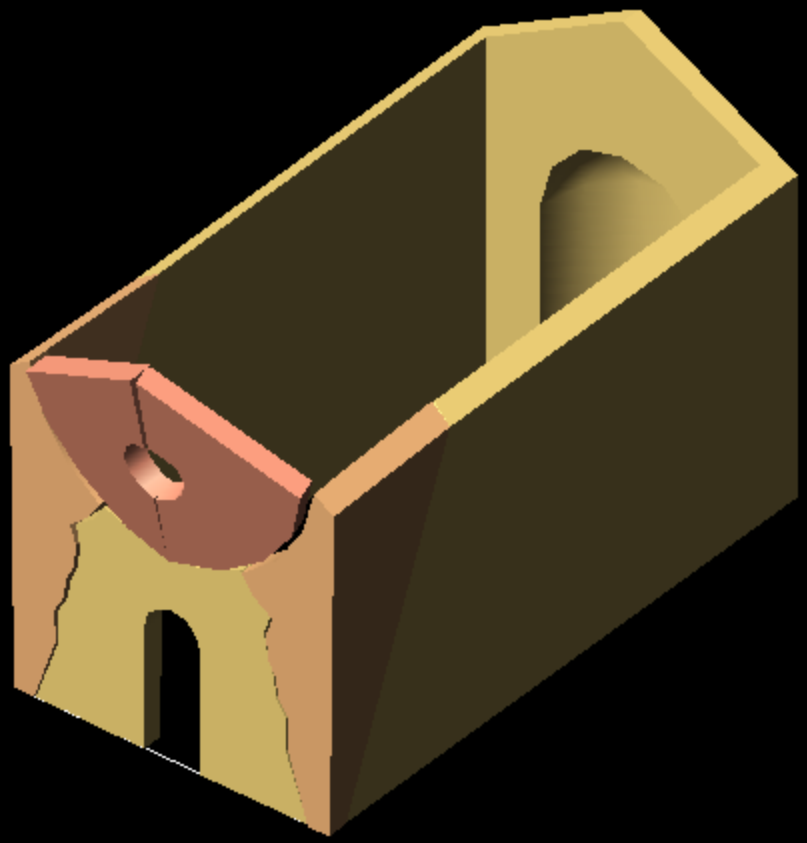
G. Cangi



Cinematismi di danno tipici
delle chiese a navata unica

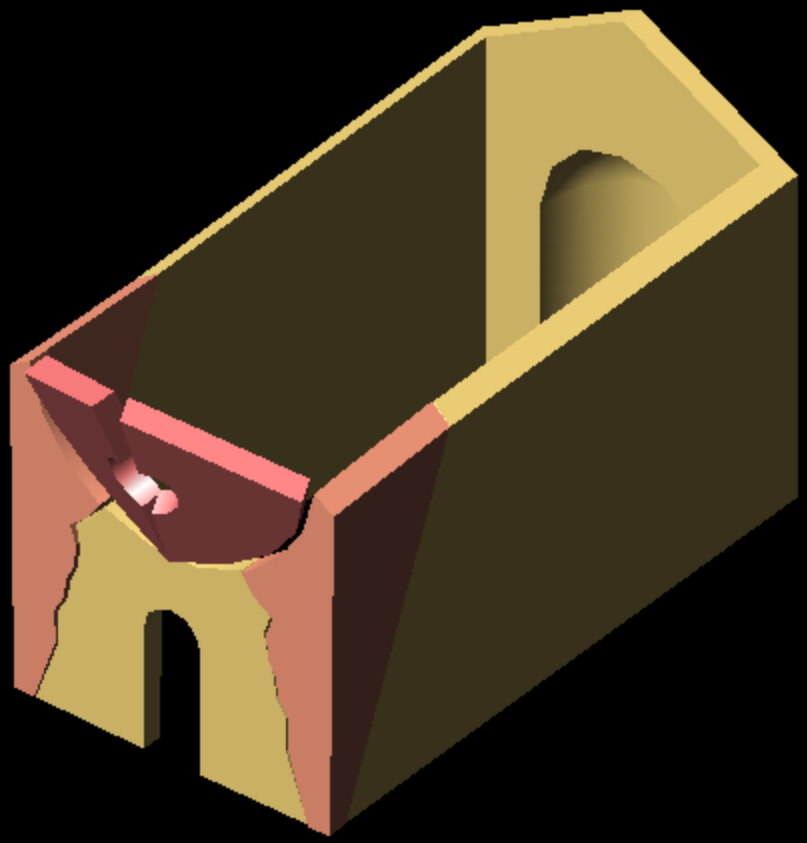
G. Cangi


CAMPIONE DI LEGNO AVO
RICRVDI E STAGIONATI
MESSANA
COPPO
MANELLA
MATTO
QVADRVCCIO



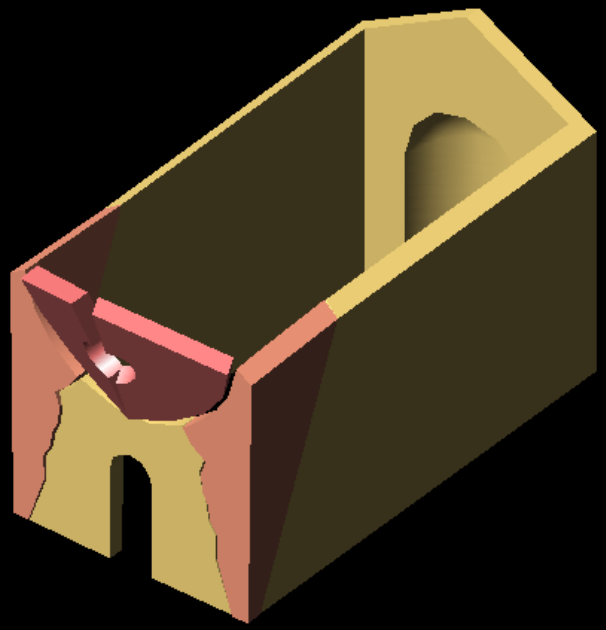
G. Cangi

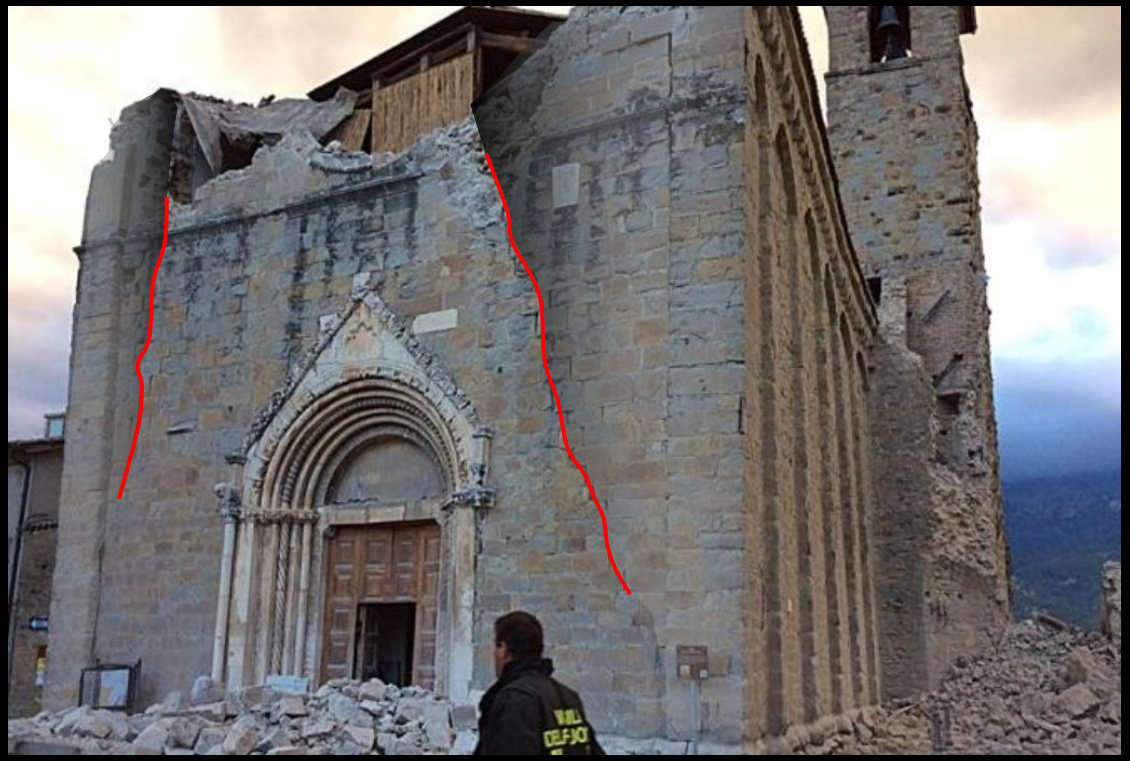

CAMPIONE DI LEGNAME
RICRVDI E STAGIONATI
MEZZANA
COPPO
MANELLA
MATTO
QVADRVCCIO



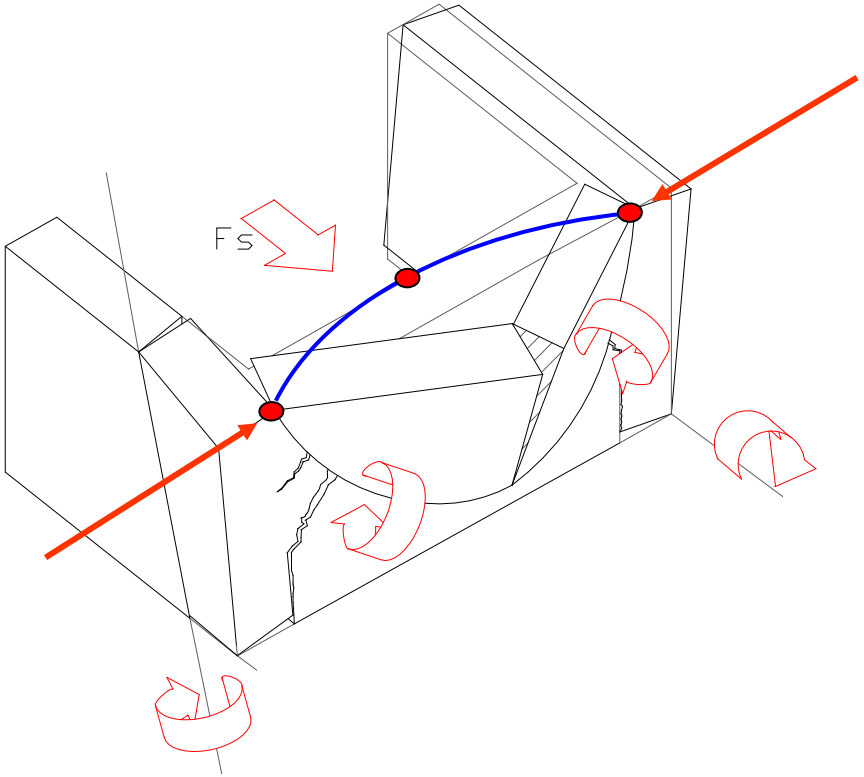
G. Cangi


CAMPIONE DI LEGNAME
RICRVDI E STAGIONATI
MESSANA
COPPO
MANELLA
MATTO
QVADRVCCIO

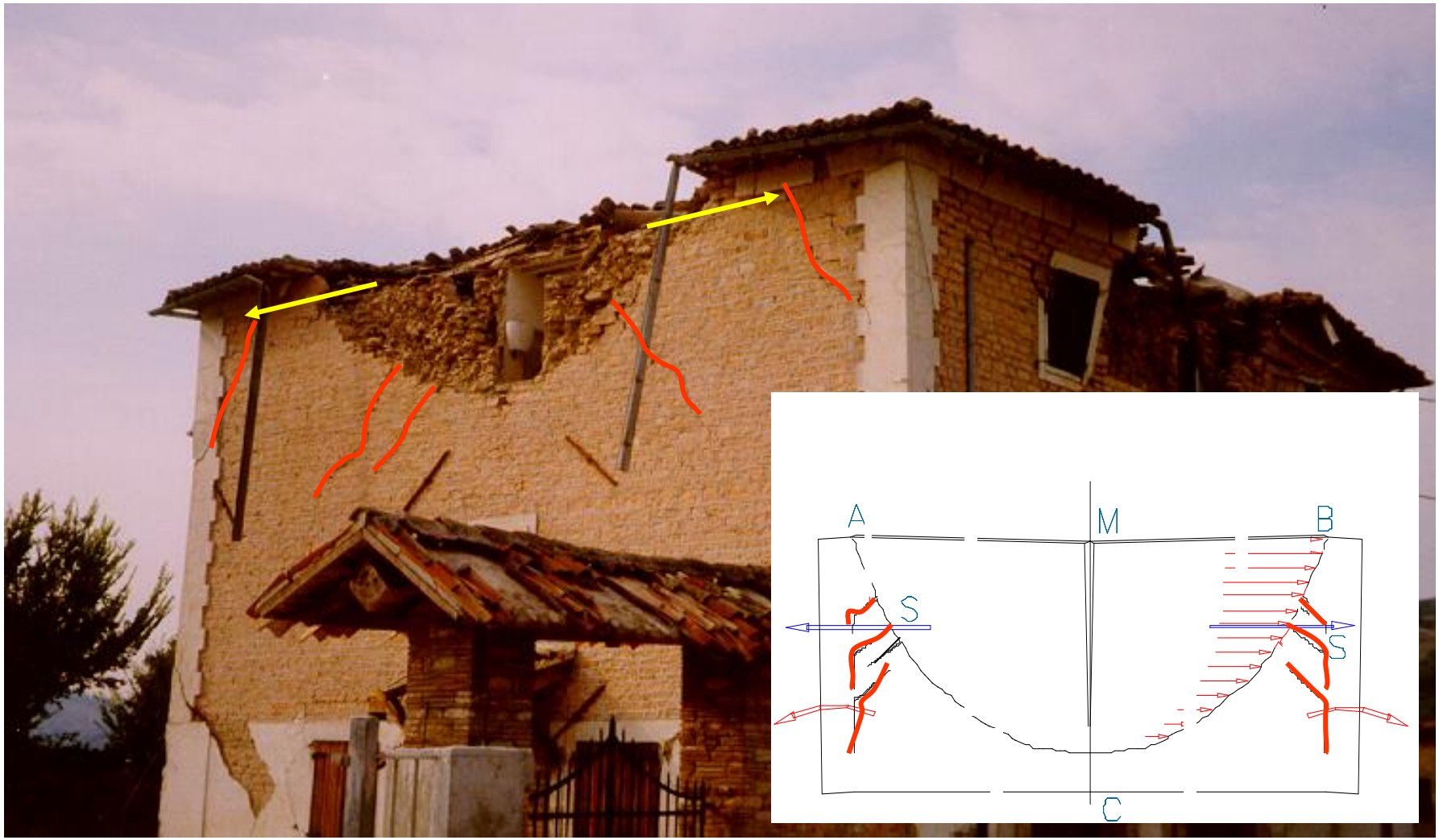




G. Cangi

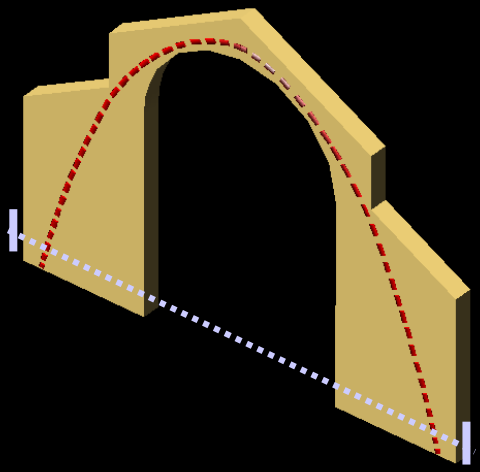


Ribaltamento pareti sollecitate da azioni ortogonali



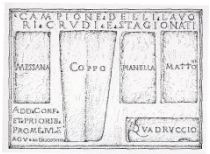
Edificio di Sellano (PG) danneggiato dal sisma del 1997

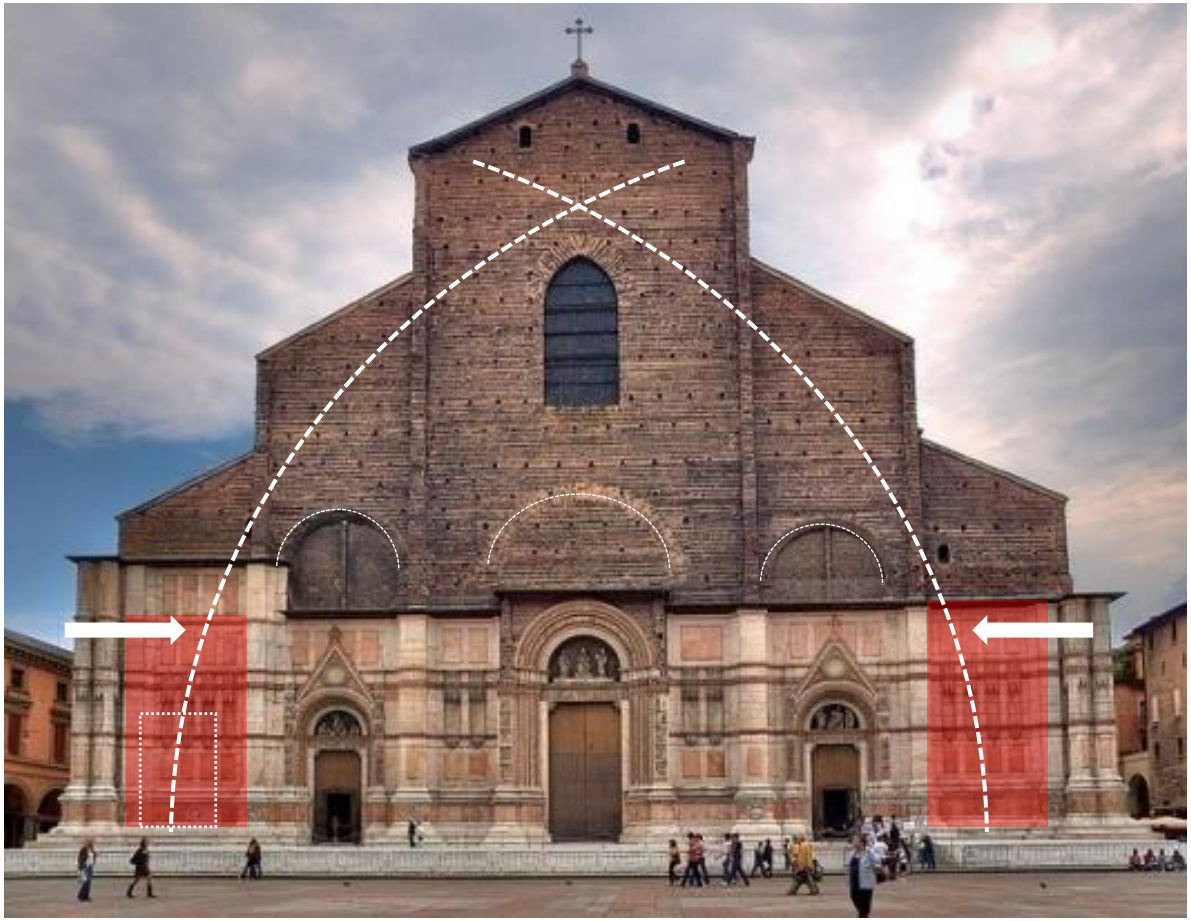
Foto Ing. A. Anastasi



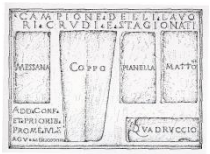
Cinematismi di danno tipici
delle chiese a navata unica

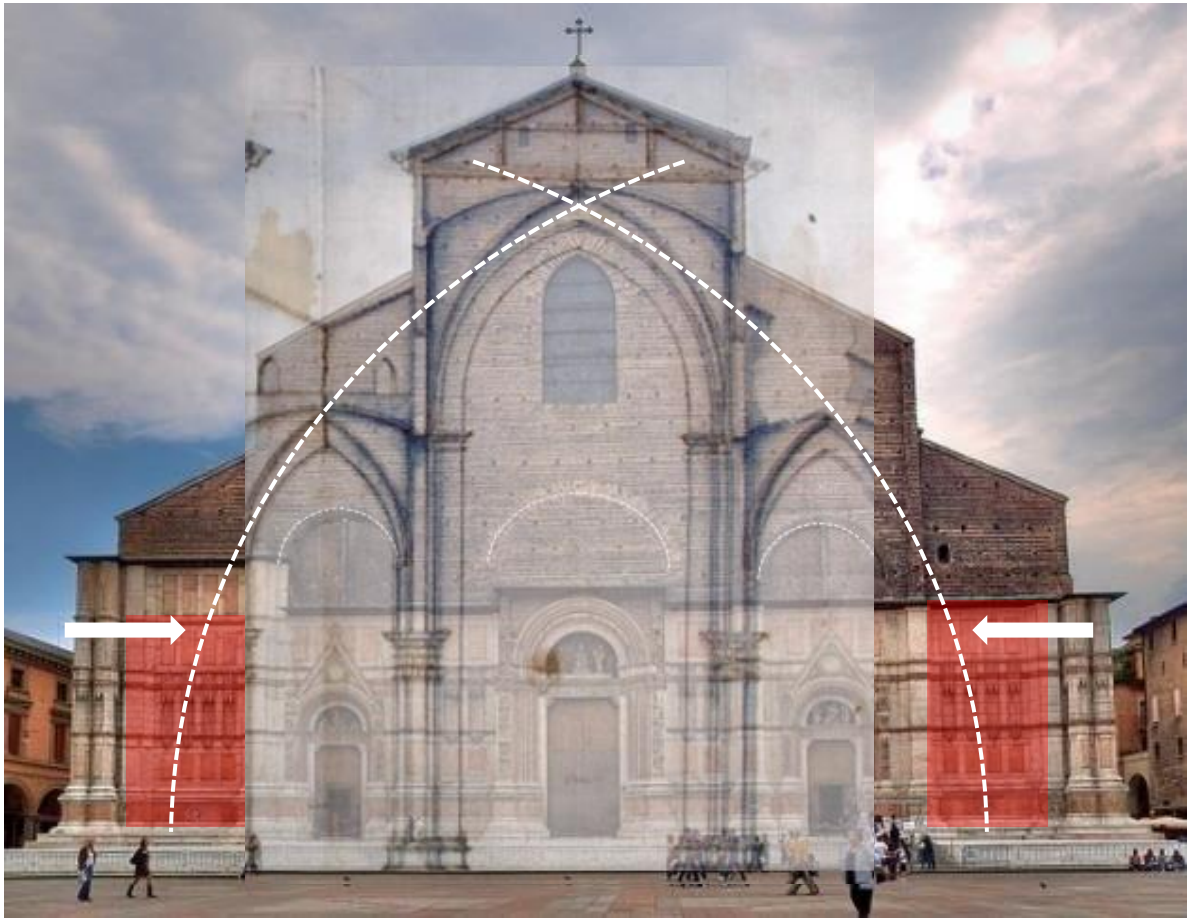
G. Cangi


CAMPIONE DEL CAVO
RICRVDI E STAGIONATI
MESSANA
COPPO
MANELLA
MATTO
QVADRVCCIO



G. Cangi


CAMPIONE DELLA FACCIATA
RICOSTRUITA STAGIONATI
MESSANA
COPPO
MANELLA
MATTIO
QVADRVCCIO



G. Cangi

Cinematismi di danno tipici delle chiese a navata unica

G. Cangi

Cinematismi di danno tipici delle chiese a navata unica

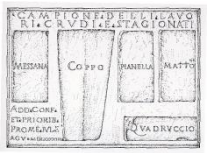
G. Cangi

Cinematismi di danno tipici delle chiese a navata unica

G. Cangi

Vetulonia

G. Cangi



Rilievo critico

Ministero delle Infrastrutture
Ministero dell'Interno
Dipartimento di Protezione Civile

PROCEDURE PER LA VALUTAZIONE DELLA SICUREZZA E LA REDAZIONE DEI PROGETTI

NUOVE NORME TECNICHE PER LE COSTRUZIONI

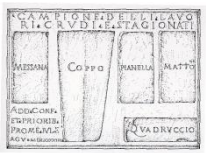
DM Infrastrutture 17 gennaio 2018

CAP. 8 - COSTRUZIONI ESISTENTI

8.5 – DEFINIZIONE DEL MODELLO DI RIFERIMENTO PER LE ANALISI

….. è impossibile prevedere regole specifiche per tutti i casi. Di conseguenza, **il modello per la valutazione della sicurezza dovrà essere definito e giustificato dal Progettista caso per caso** …..tenendo conto:

- dell'analisi storico-critica;
- del rilievo geometrico-strutturale;
- della caratterizzazione meccanica dei materiali
- del livello di conoscenza e fattori di confidenza

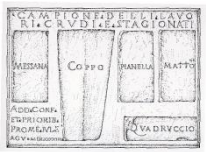


Tecniche costruttive e materiali da costruzione

Città di Castello

Evoluzione di una casa torre in Corso V.Emanuele

G. Cangi - R.Argalia


CAMPIONE DI FILATO
RICRVDI E STAGIONATI
MESSANA
COPPO
PANELLA
MATTO
QVADRVCCIO


Canonica
Impianto originario
(Chiesa romanica)
Ampliamento
(1630)
N
Pianta del Piano Terra
1 XI-XII Sec.
2 XVII Sec.
3 XVII-XVIII Sec.
4 XVIII Sec.
5 XVIII-XIX Sec.
6 XIX-XX Sec.

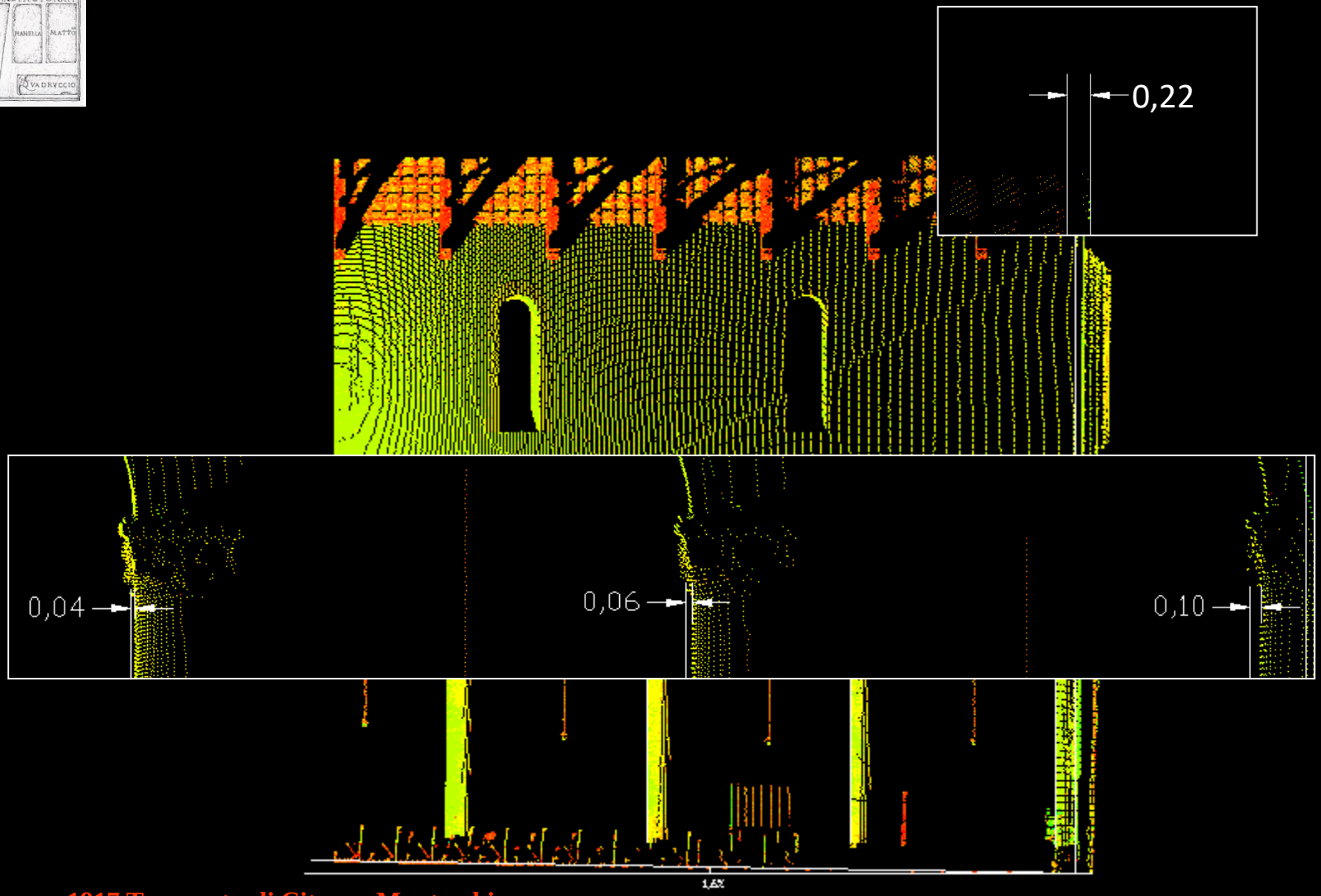
G. Cangi


CAMPIONE DI LEGNO CAVO
RICRVDI E STAGIONATI
MESSANA
COPPO
MANELLA
MATTO
QVADRVCCIO

G. Cangi


CAMPIONE DI LEGNO AVO
RICRVDI E STAGIONATI
MESSANA
COPPO
MANELLA
MATTO
QVADRVCCIO

G. Cangi



1917 Terremoto di Citerna-Monterchi

Atterrato il timpano della chiesa e scosse due ultime arcate della navata centrale sopra l'organo

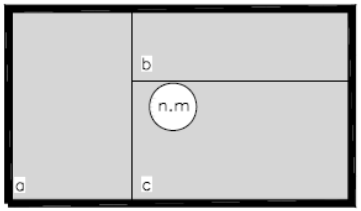
Danneggiato il campanile (altre scosse nel 1919)

Segue demolizione della navata centrale – Rifacimento dei muri di soprelevazione con le antiche finestre a feritoia

Demolito il tetto (ripristinato l'antico rosone di facciata)

G. Cangi

Maglia tipo

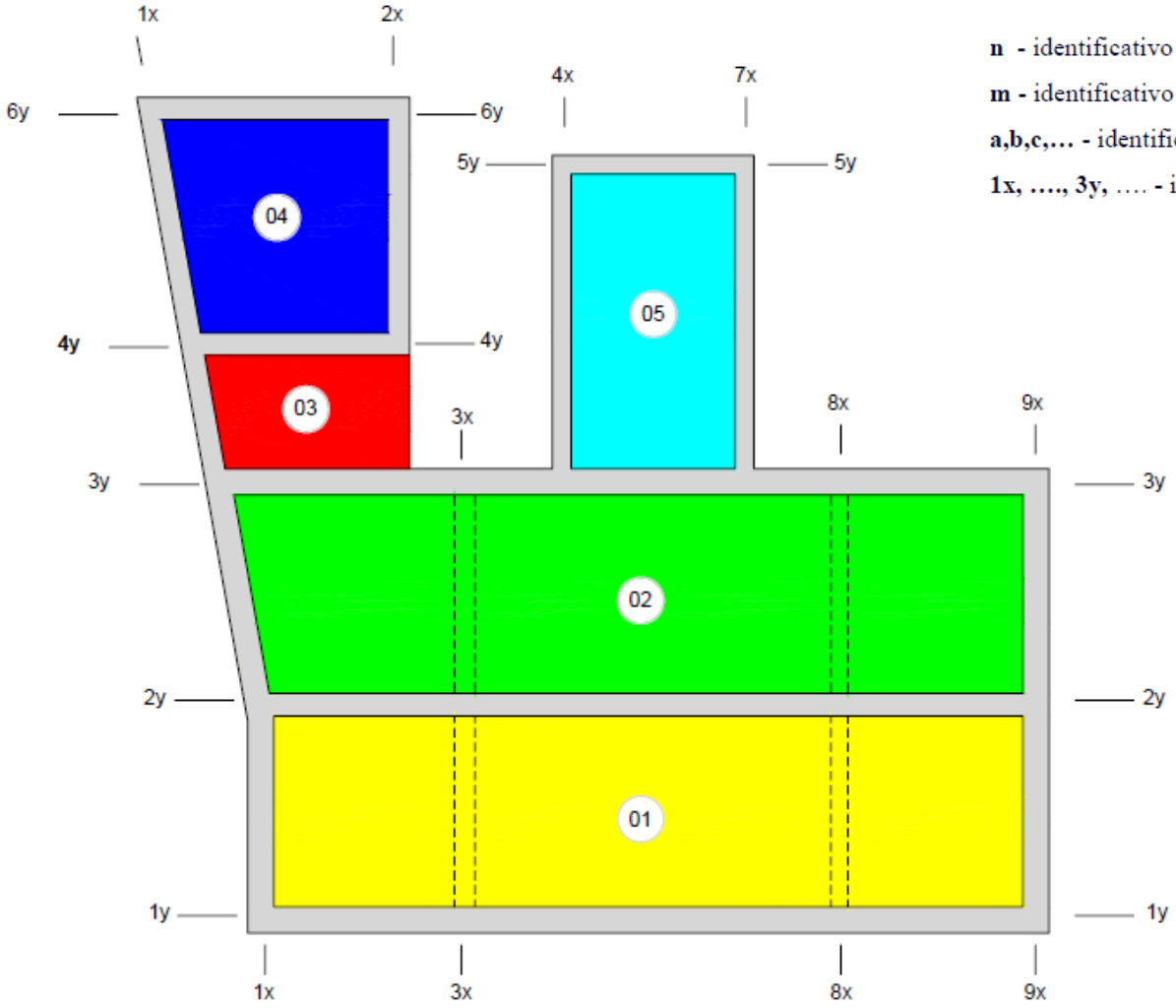


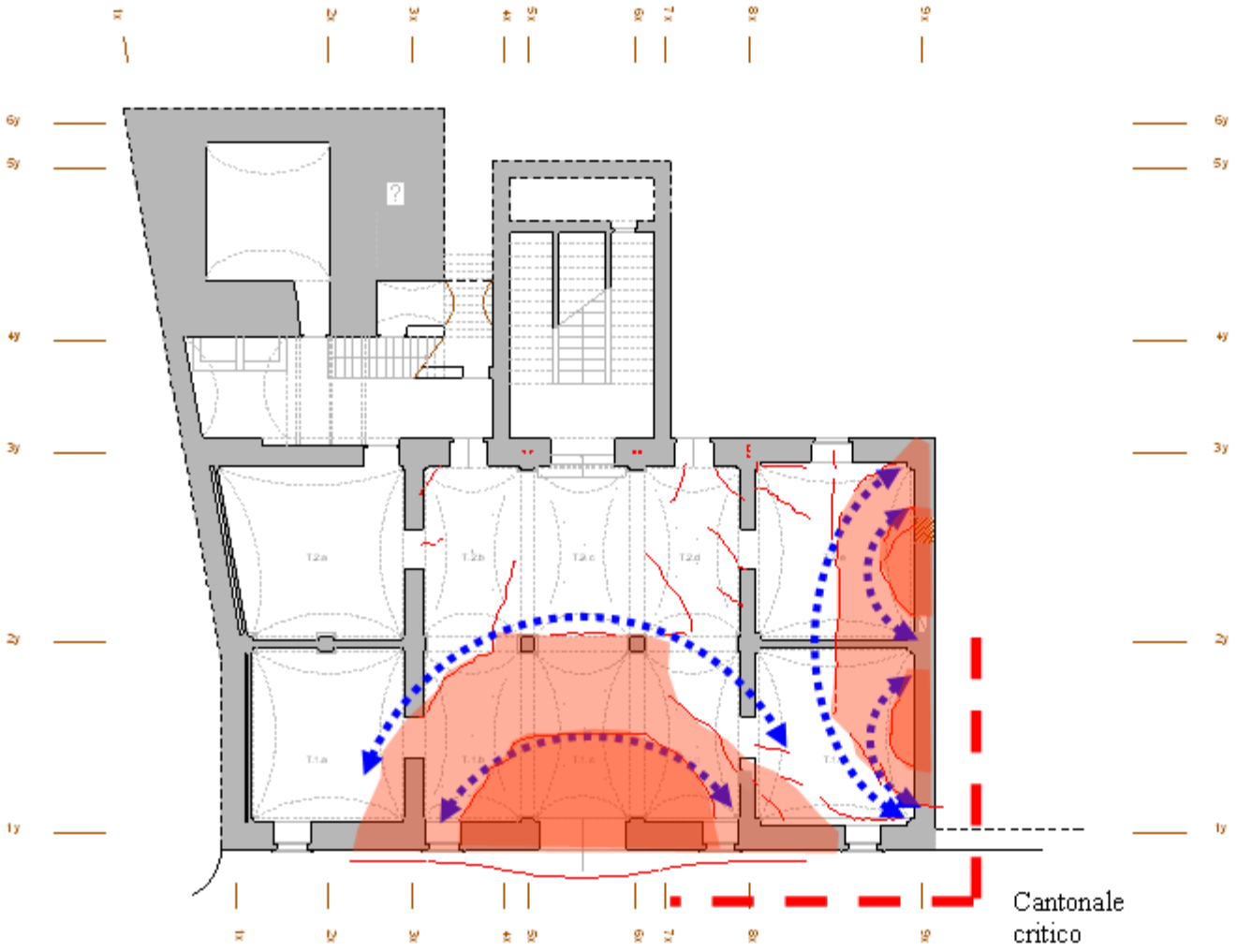
n - identificativo della maglia muraria

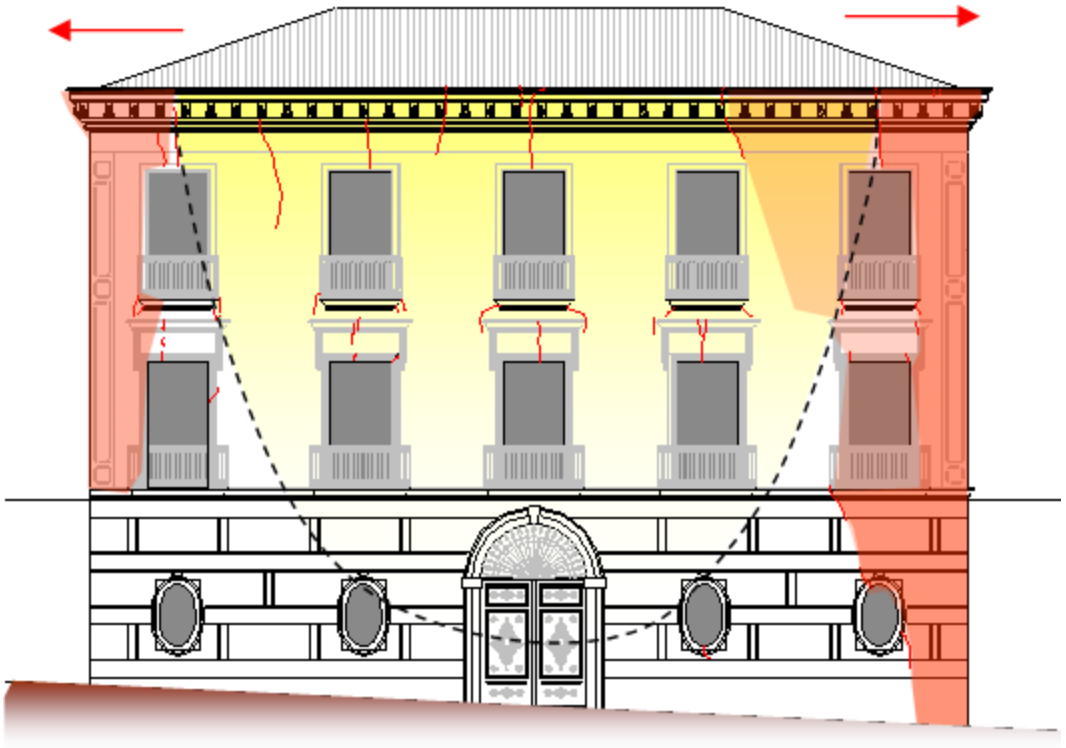
m - identificativo del piano (T, 1, 2, 3)

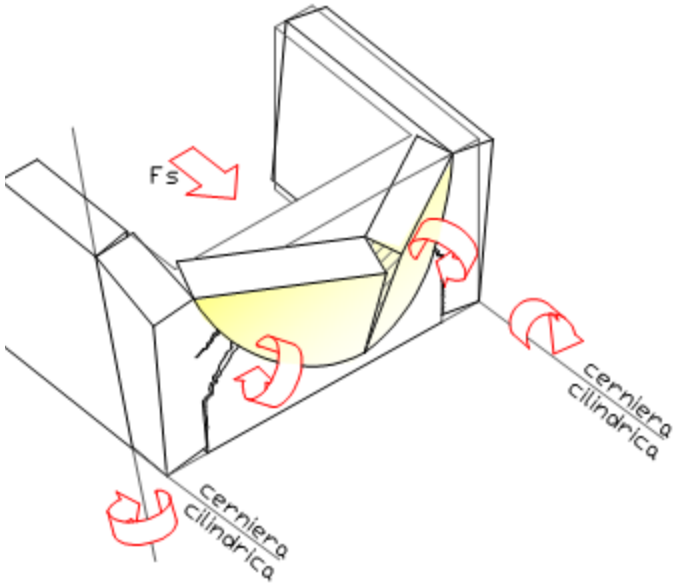
a,b,c,… - identificativo ambiente

1x, …., 3y, …. - identificazione delle pareti portanti

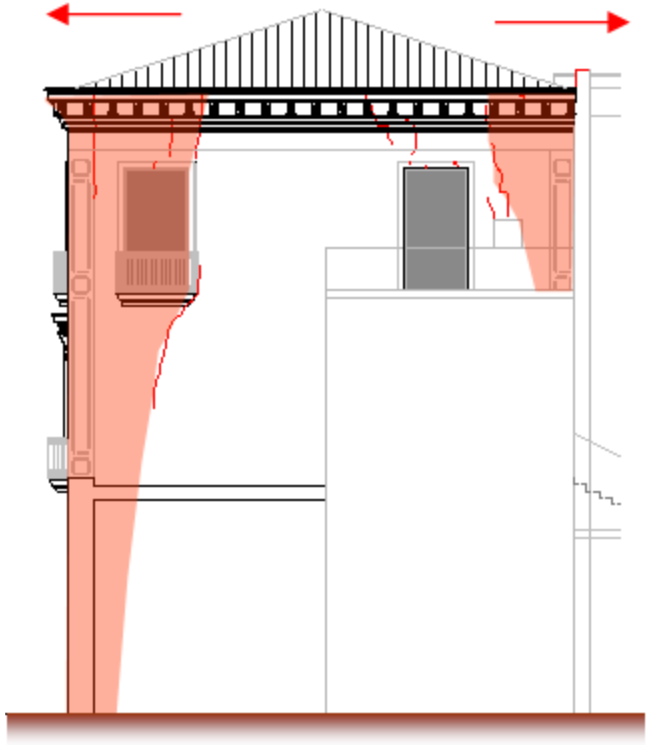



Cantonale
critico

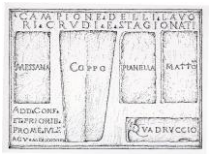


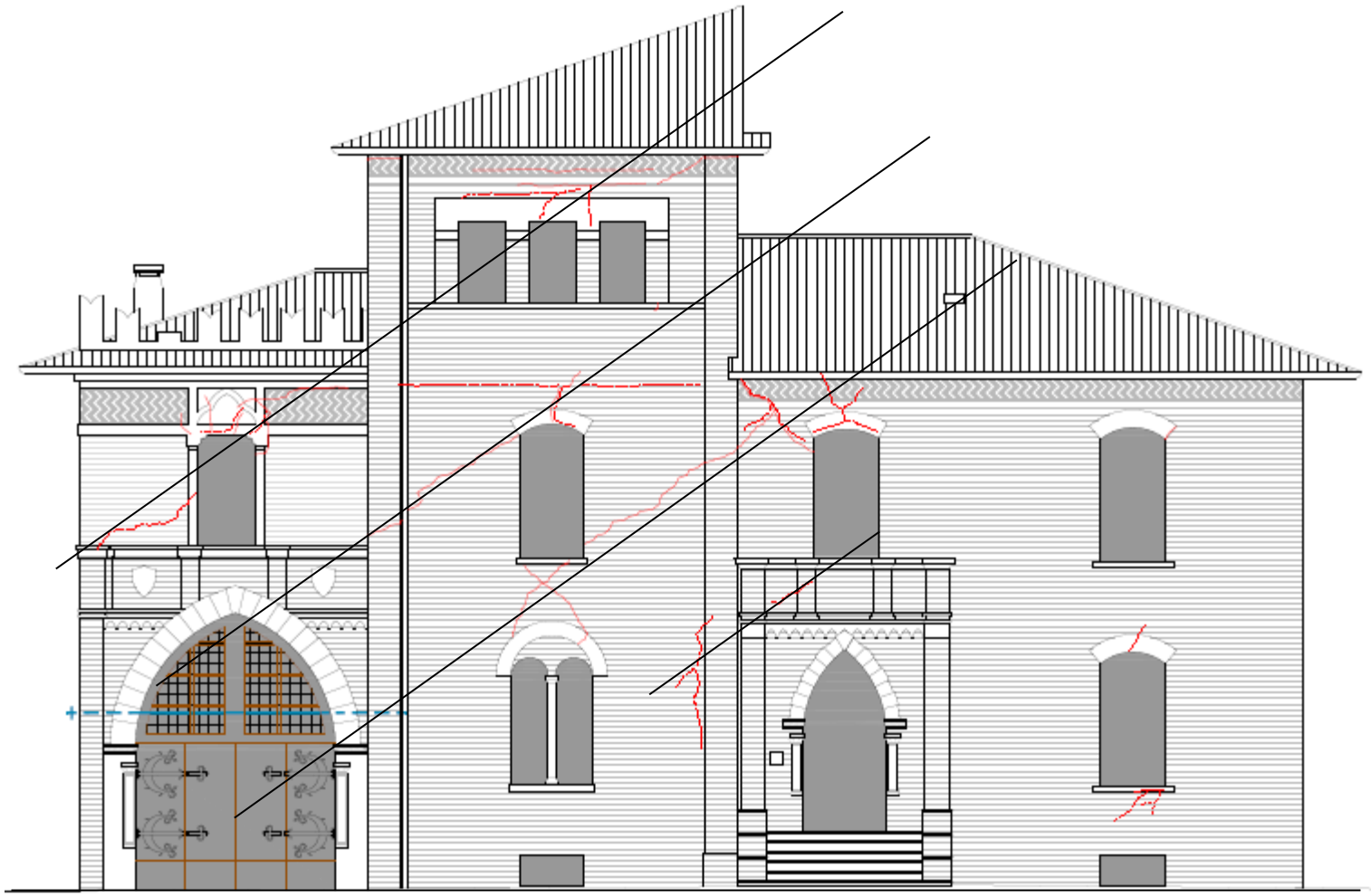


Schema di dissesto della parete di facciata per effetto di azioni sismiche complanari e ortogonali

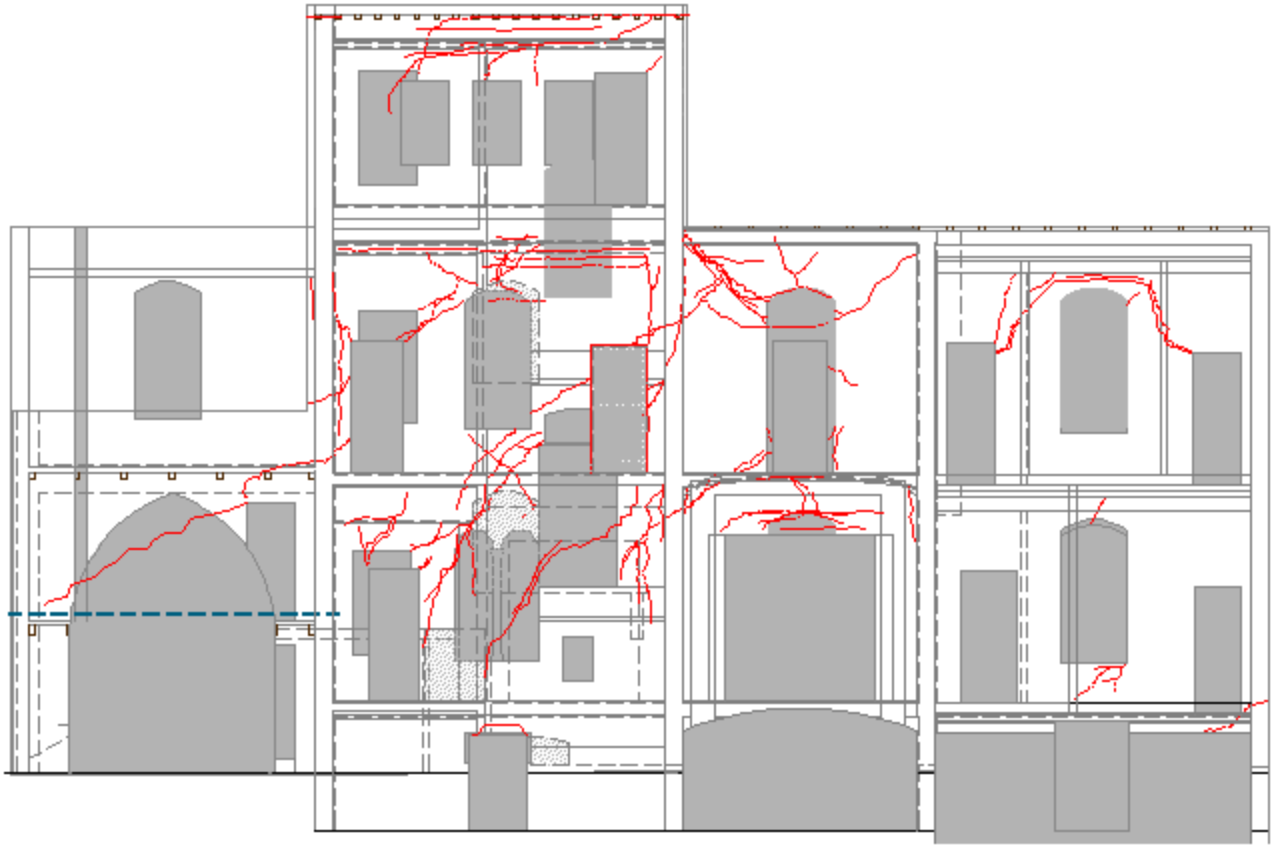


Schema di dissesto della parete laterale di valle per azioni complanari, con dettaglio del quadro fessurativo sommitale d'angolo

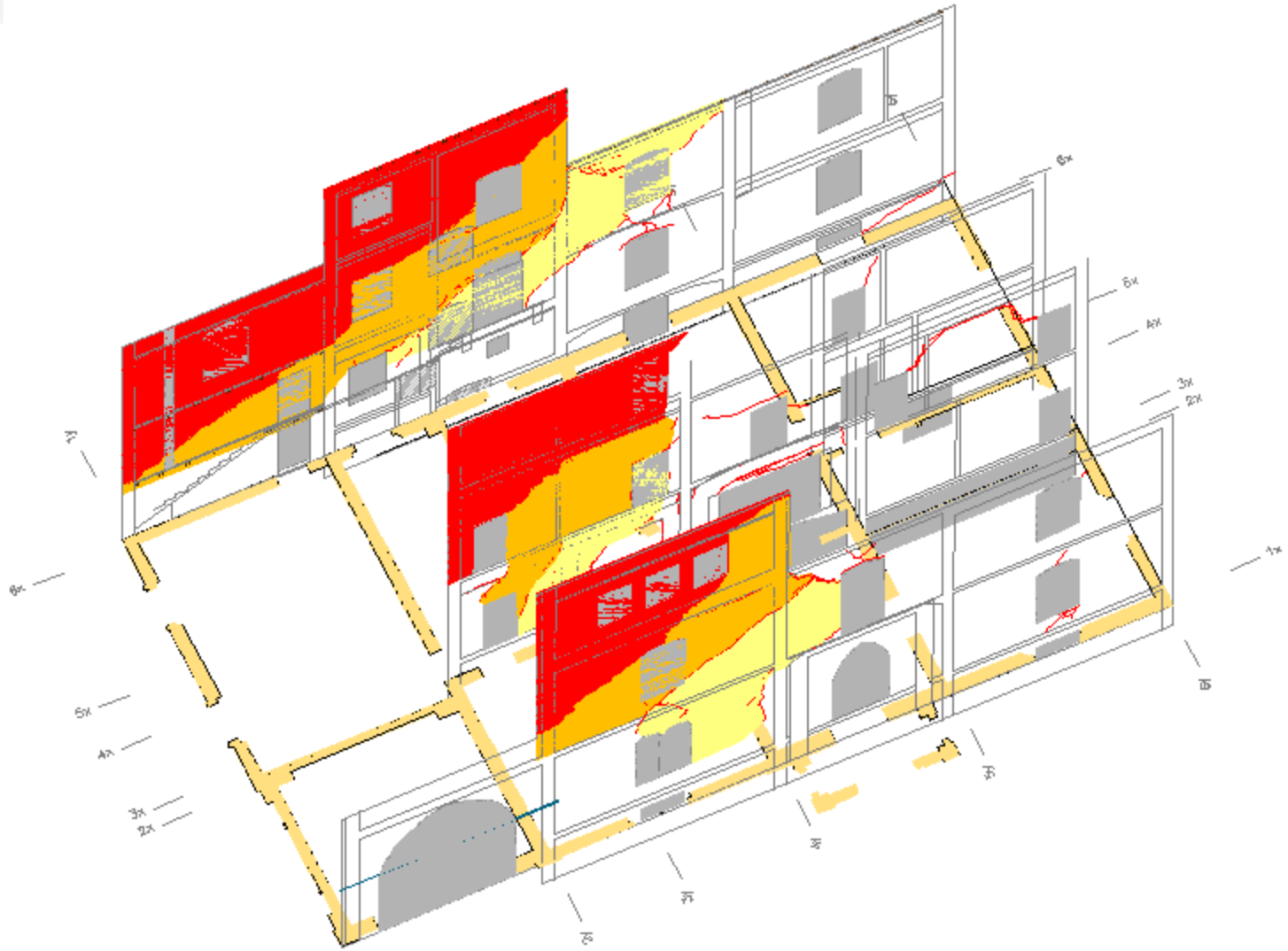

CAMPIONE DI LEGNAME
RICRVDI E STAGIONATI
MISSANA
COPPO
MANELLA
MATTE
QVADRVCCIO



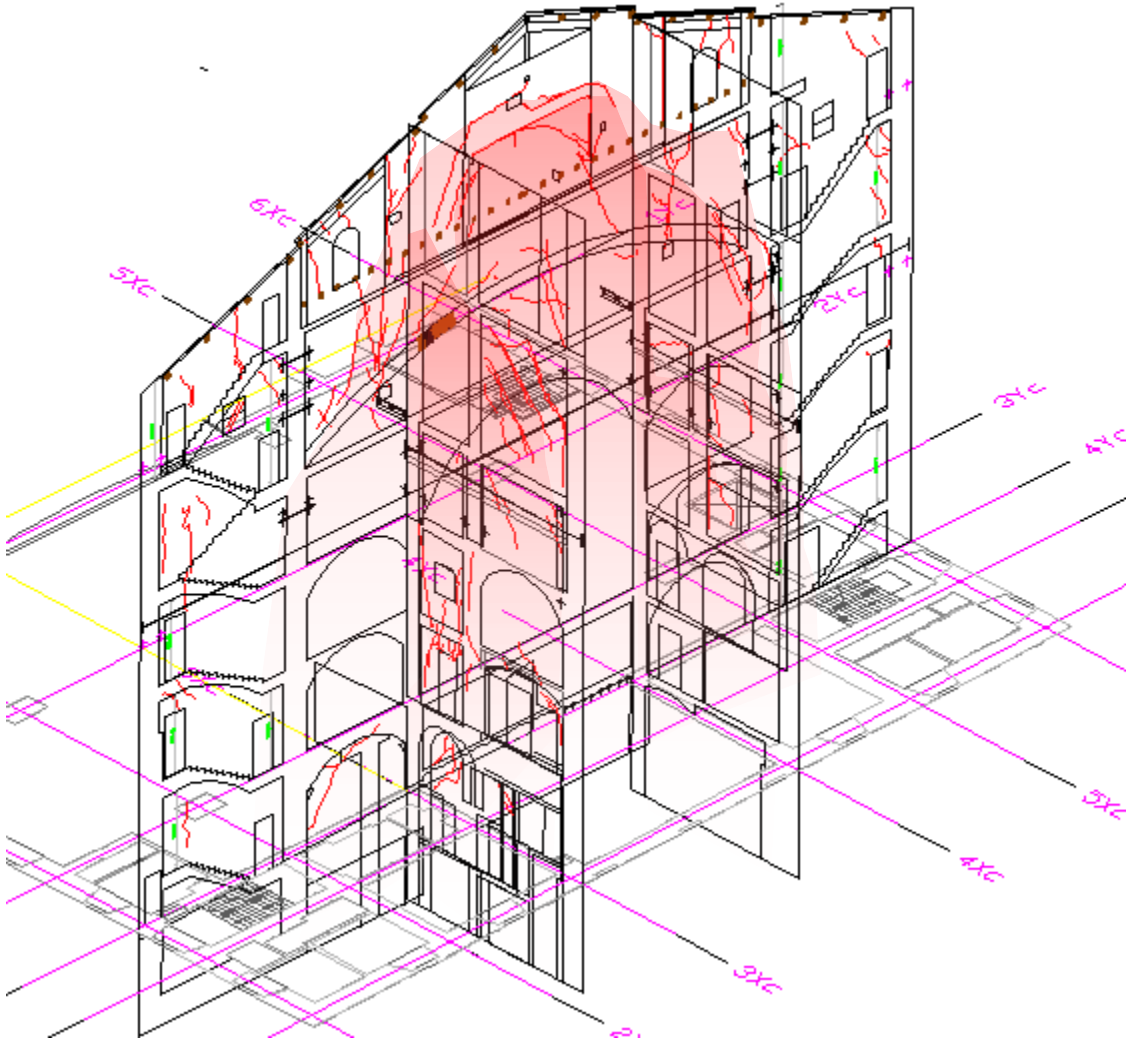
G. Cangi



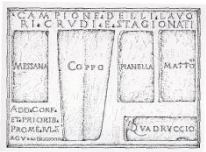
G. Cangi



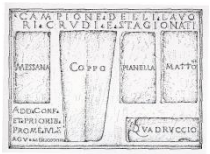
G. Cangi

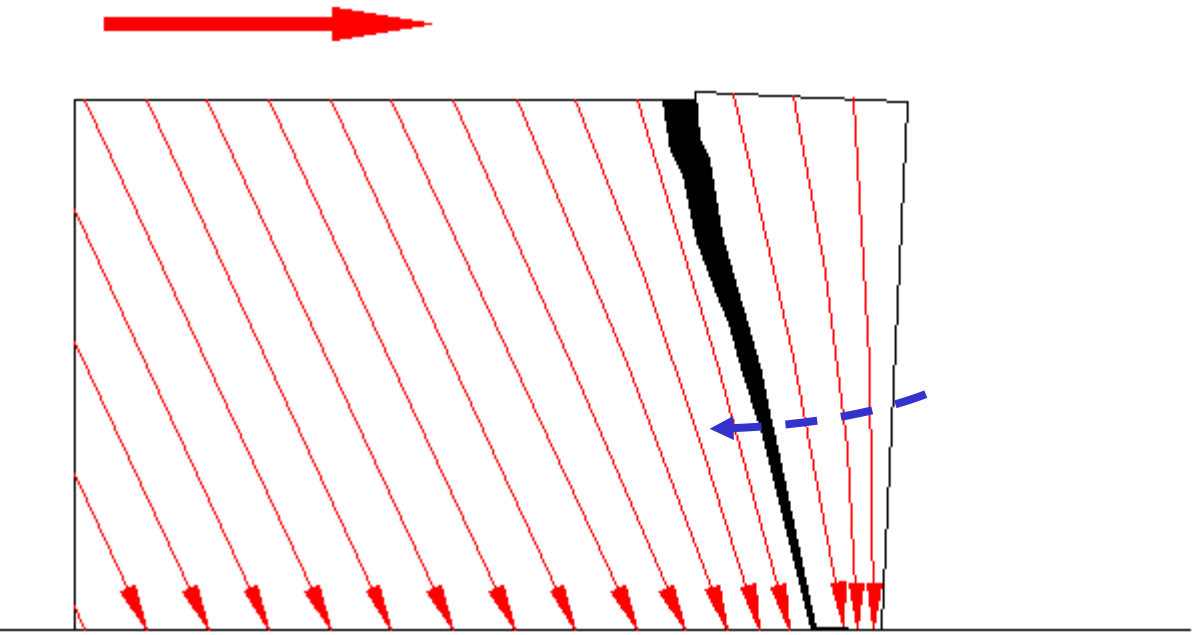


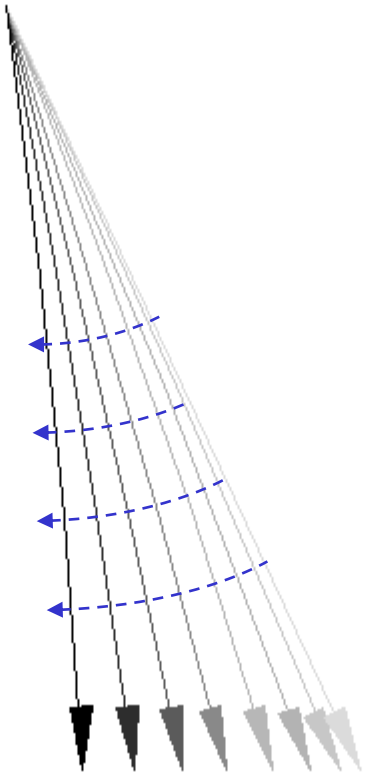
Rappresentazione spaziale di un quadro fessurativo con manifestazione di cedimento fondale



Cinematismi elementari


CAMPIONE DI LEGNAME
RICRVDI E STAGIONATI
MESSANA
COPPO
MANELLA
MATTO
QVADRVCCIO





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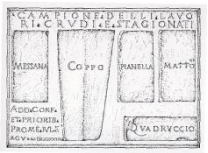
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RICRVDI E STAGIONATI
MESSANA
COPPO
MANELLA
MATTO
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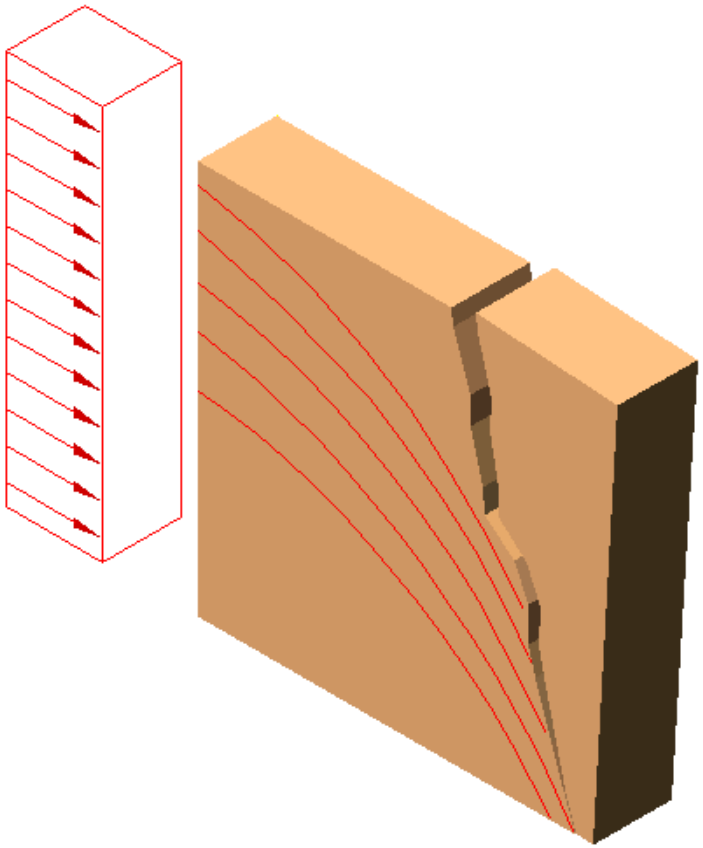

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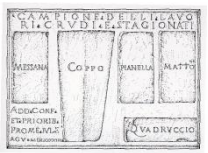
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RICRVDI E STAGIONATI
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COPPO
MANELLA
MATTO
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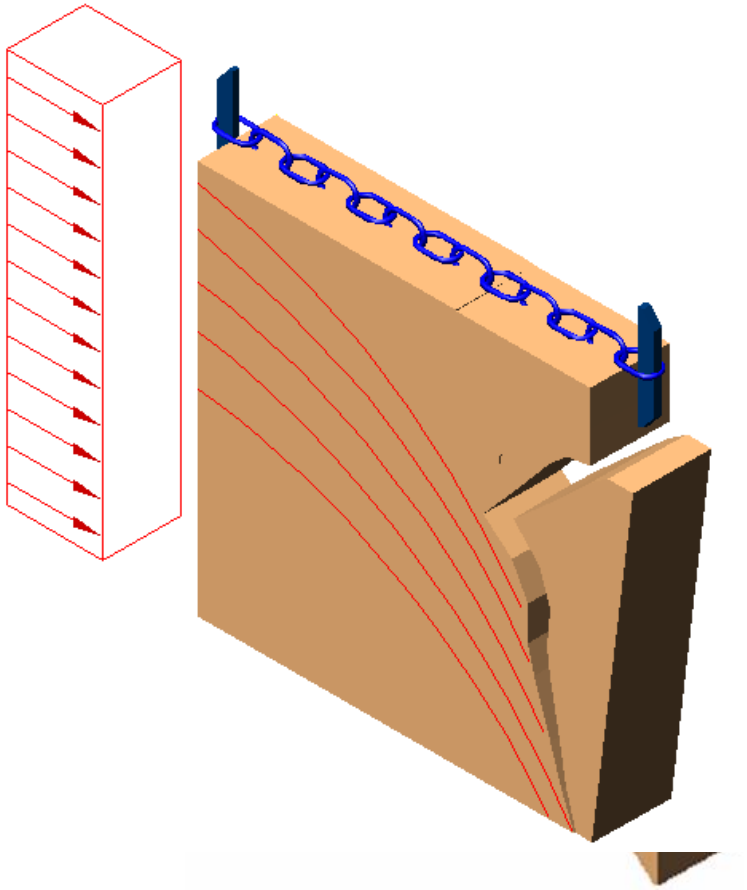

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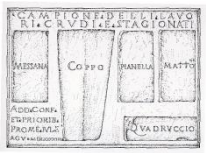
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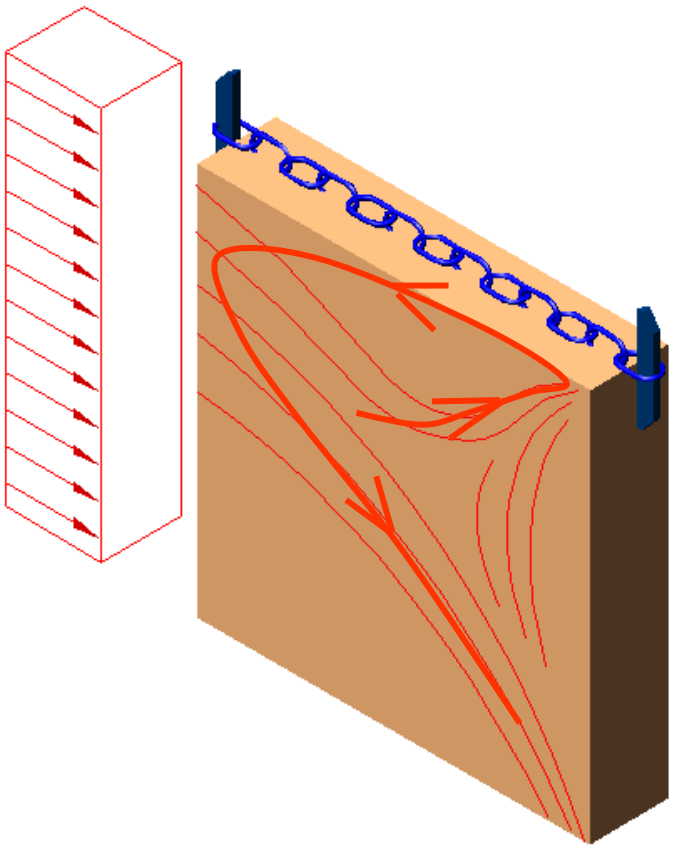

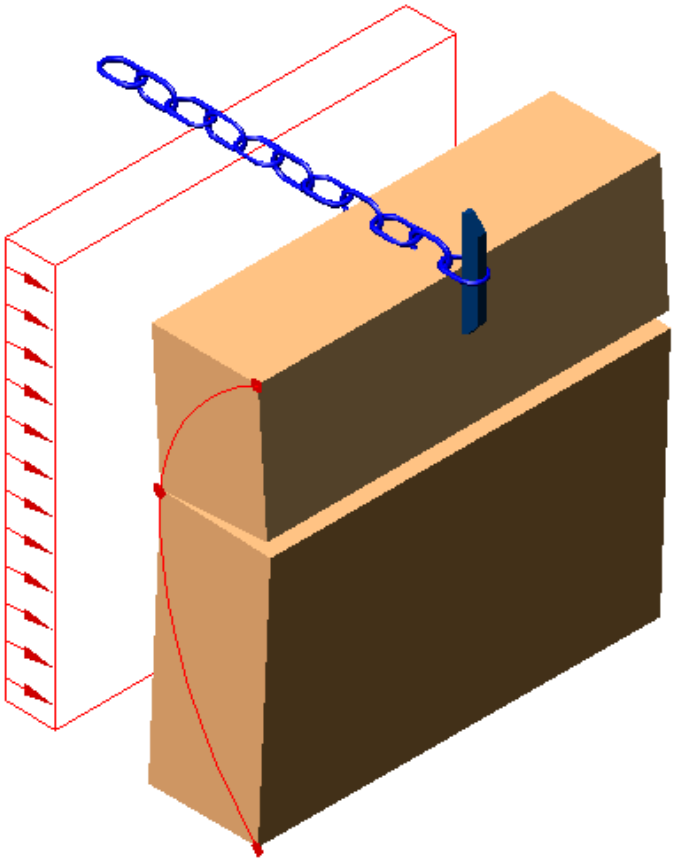

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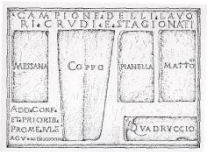
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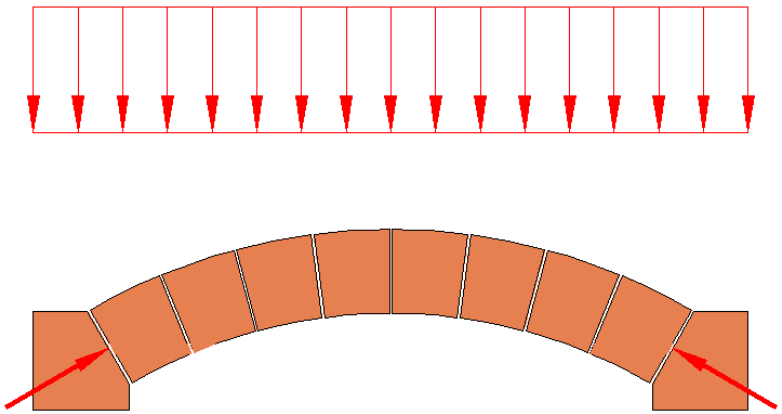
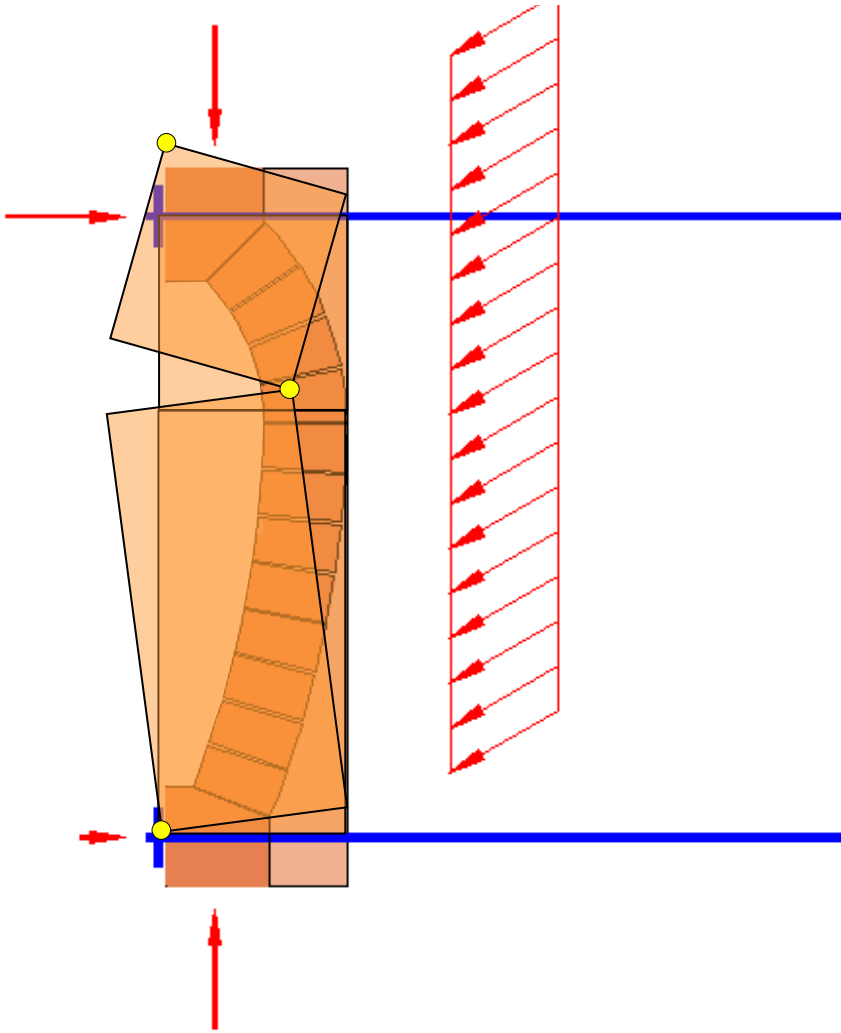
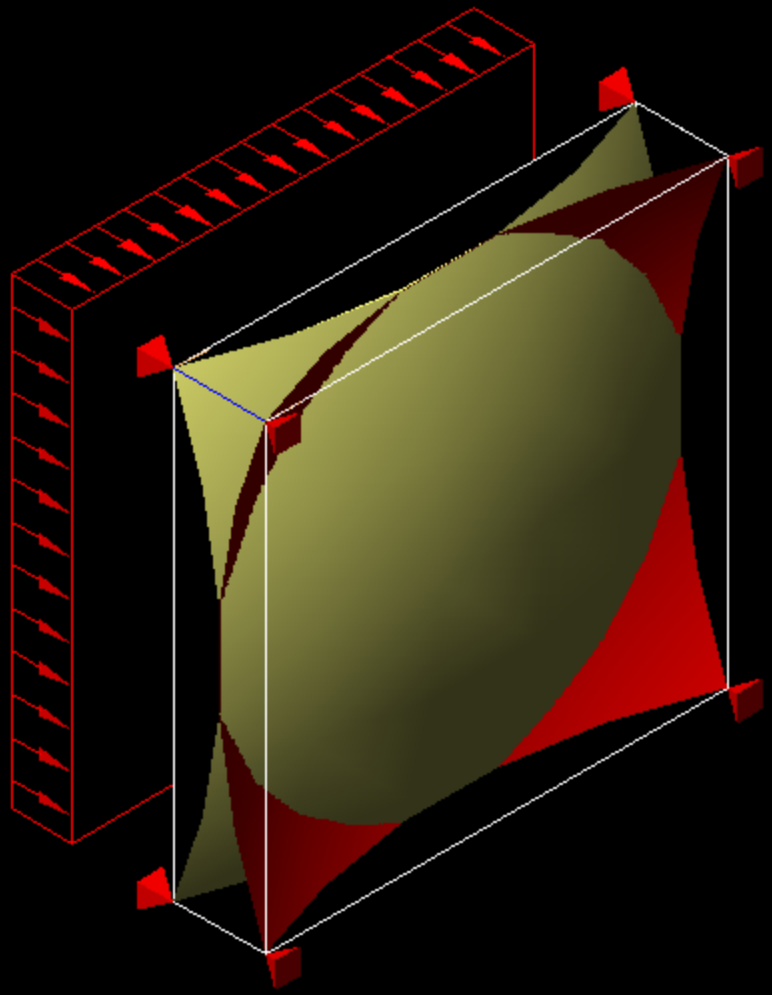




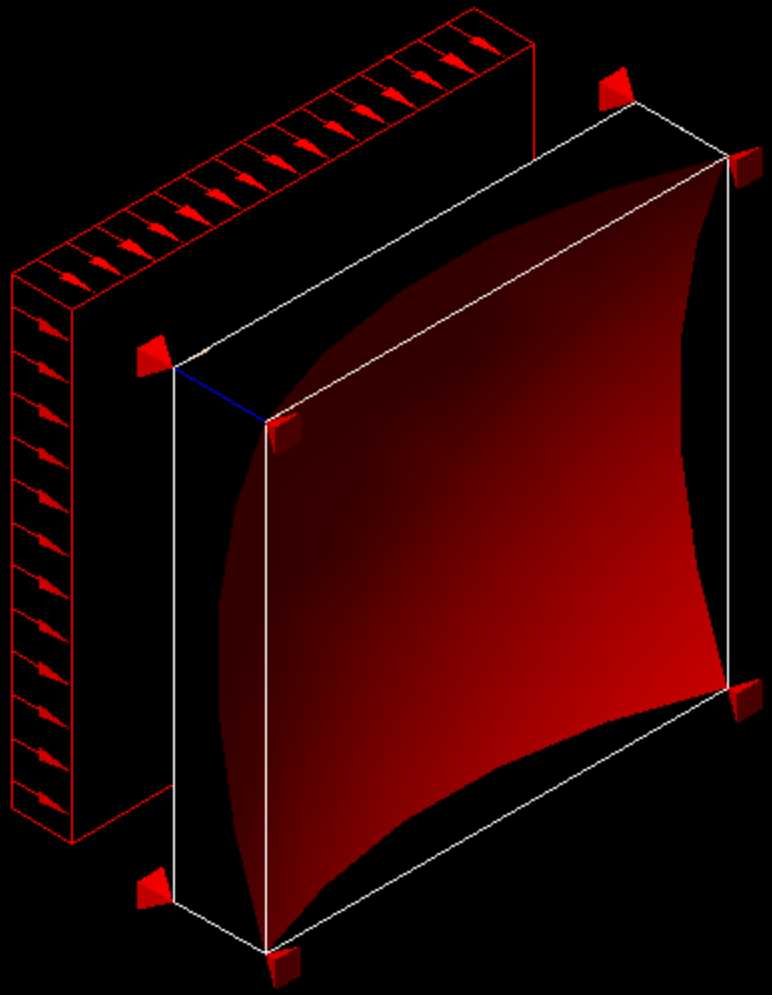
G. Cangi


CAMPIONE DI LEGNAME
RICRVDI E STAGIONATI
MEZZANA
COPPO
MANELLA
MATTO
QVADRVCCIO



G. Cangi


CAMPIONE DI LEGNAME
RICRVDI E STAGIONATI
MEZZANA
COPPO
MANELLA
MATTO
QVADRVCCIO



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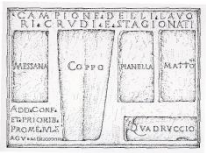
CAMPIONE DI LATERIZIO
RICRVDI E STAGIONATI
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COPPO
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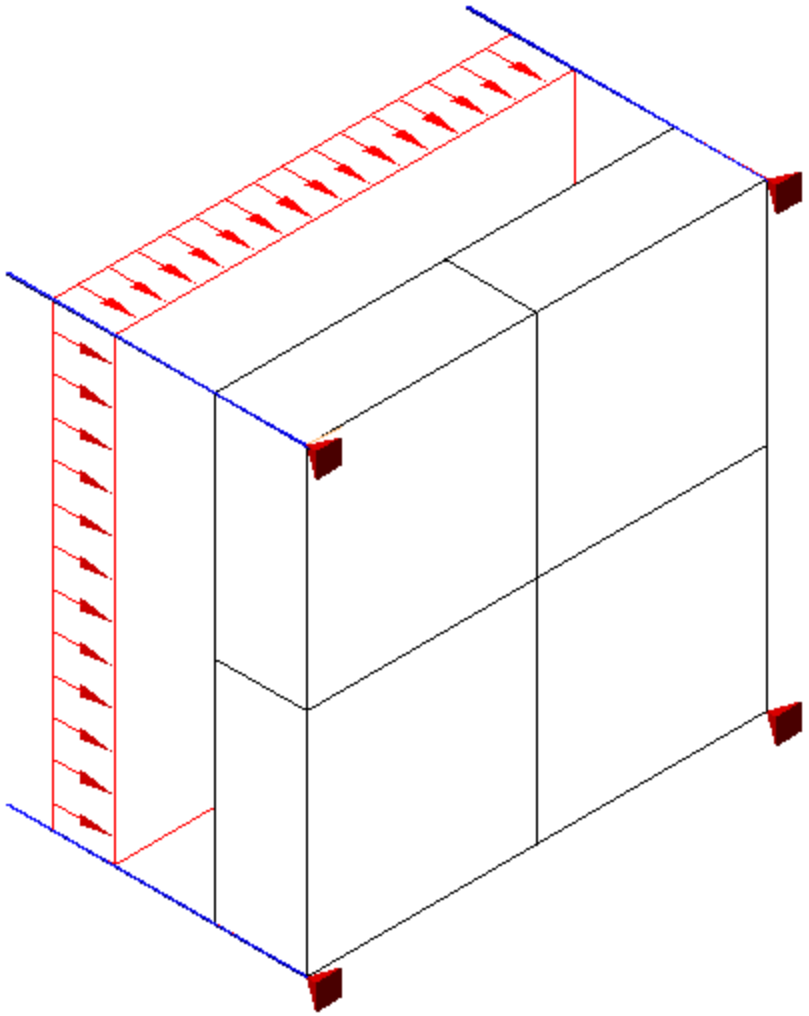

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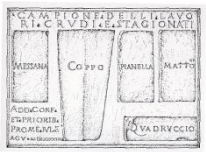
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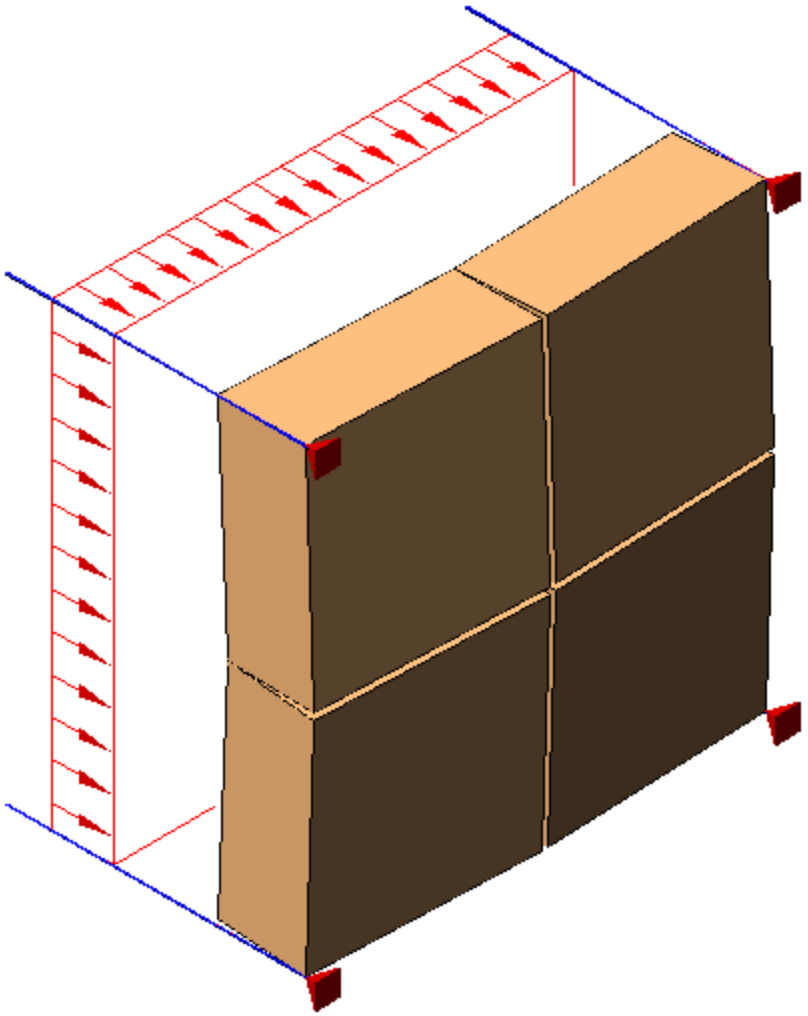

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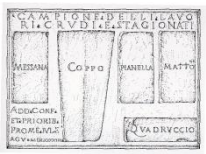
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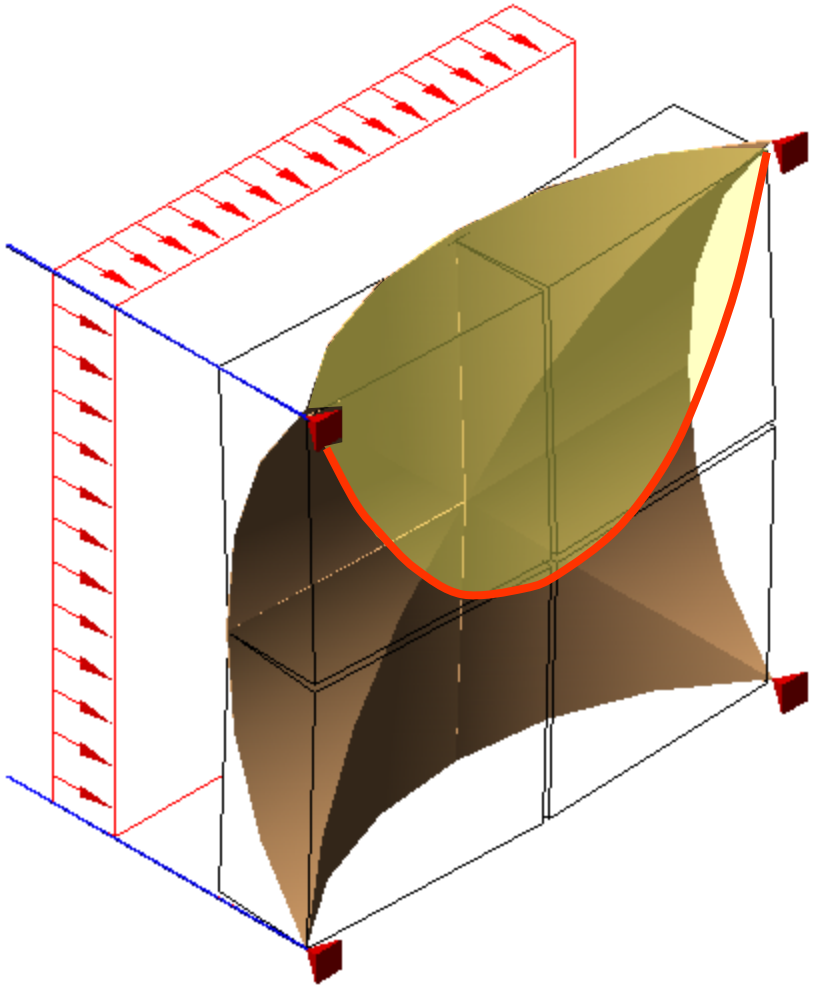

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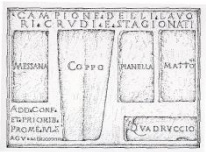
CAMPIONE DI LEGNO CAVO
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MESSANA
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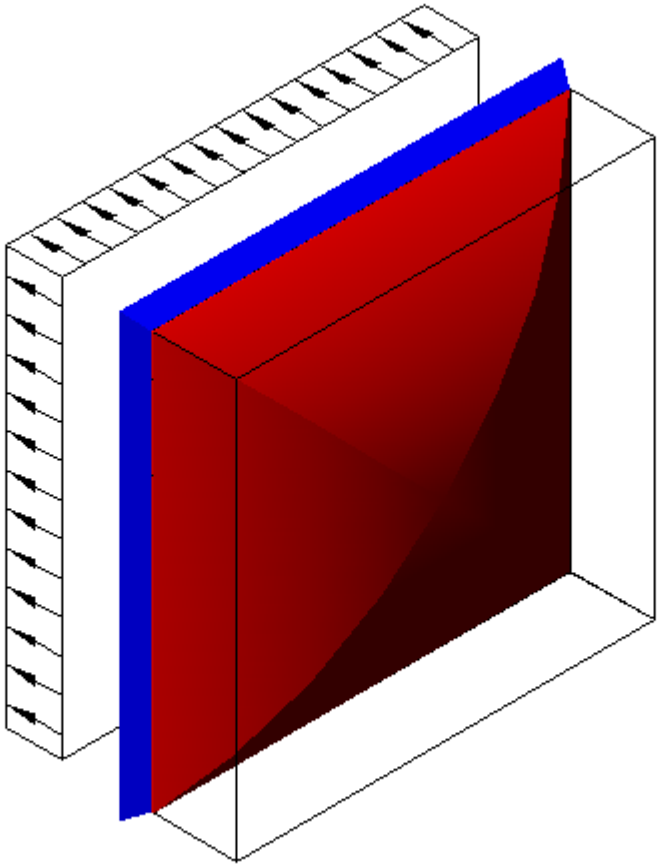

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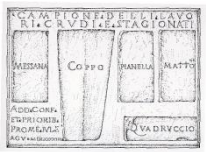
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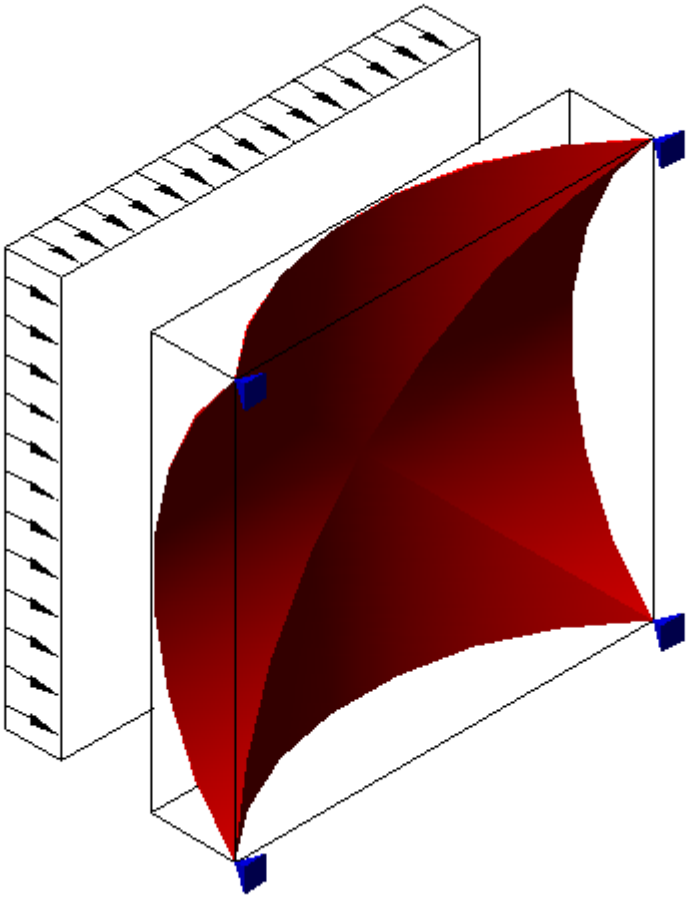

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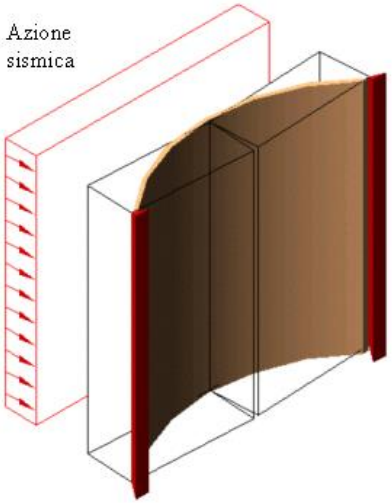
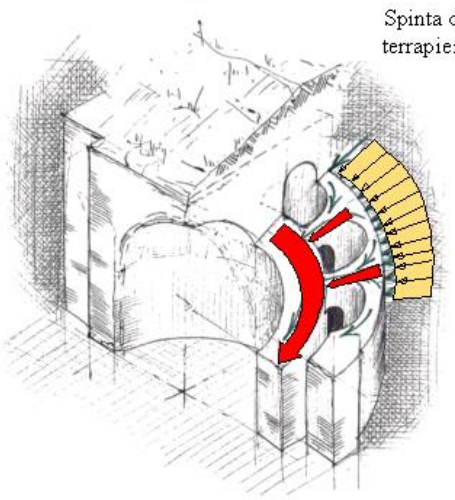
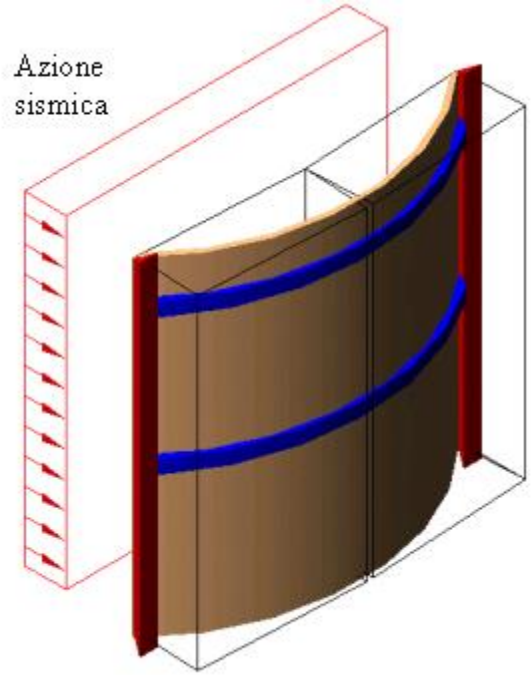


L'Aquila - Chiesa delle Anime Sante

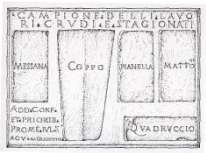


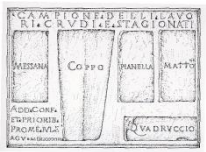
Roma – Podio del Tempio di Claudio al Celio

Nicchioni lungo Via Claudia

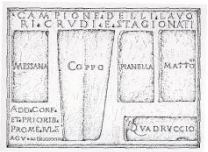


Chiesa dell'Immacolata a Paganica


CAMPIONE DI LEGNAME
RICRVDI E STAGIONATI
MESSANA
COPPO
MANELLA
MATTO
QVADRVCCIO


CAMPIONE DEL CAVO
RICRVDI E STAGIONATI
MESSANA
COPPO
MANELLA
MATTO
QVADRVCCIO

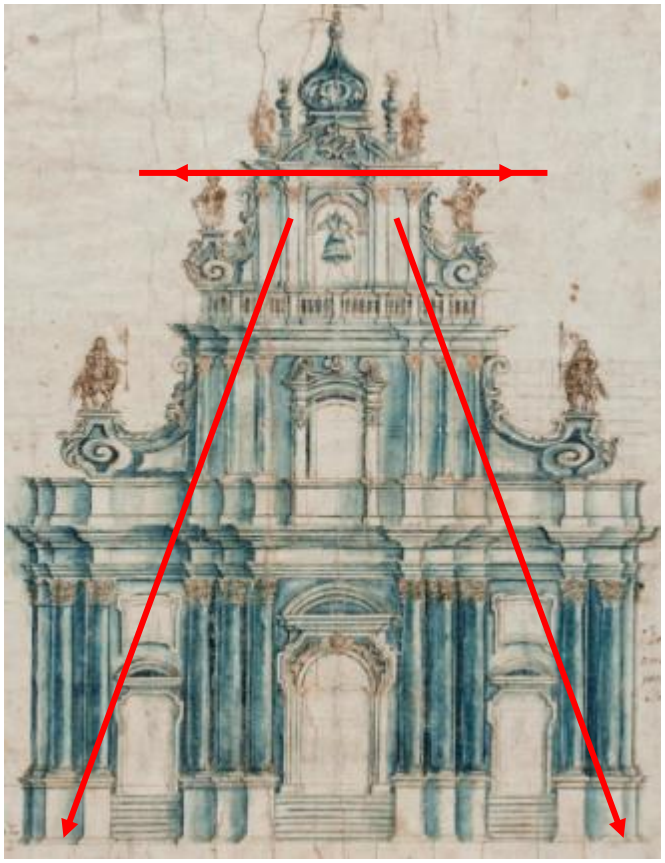
G. Cangi

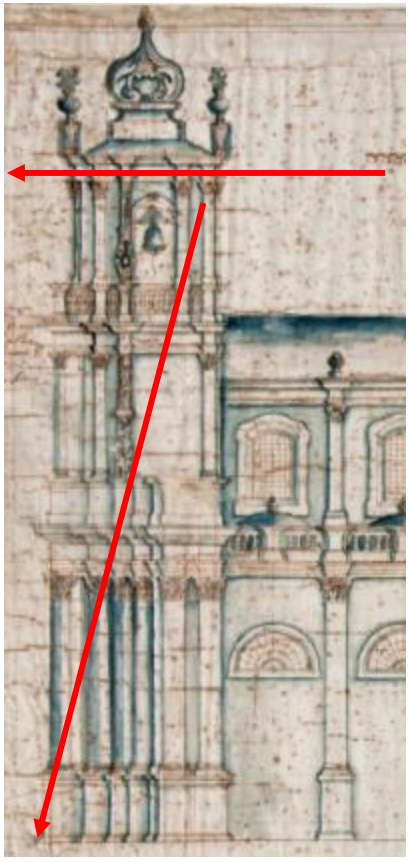


Trarre esperienza dall'osservazione: un esempio indicativo

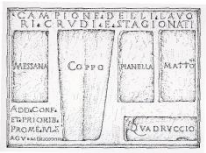
Architettura barocca Siciliana (Scicli)

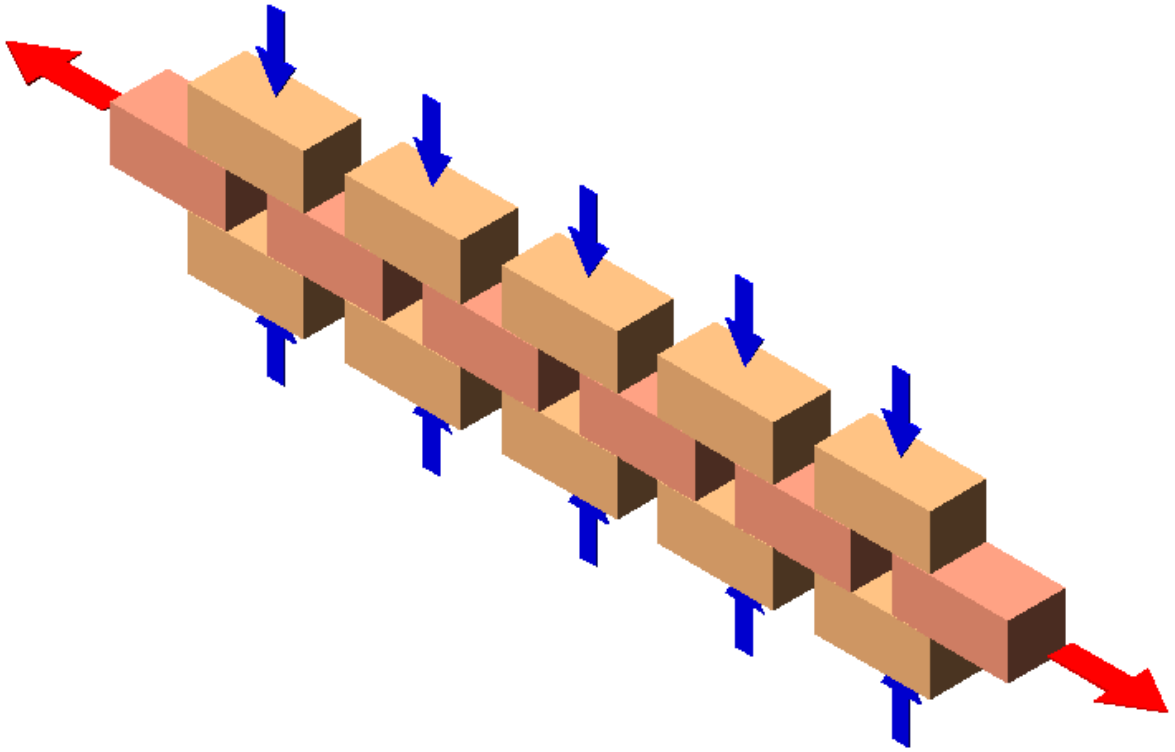
Chiesa paleocristiana presso le Terme di Vespasiano a Cotilia (Rieti)



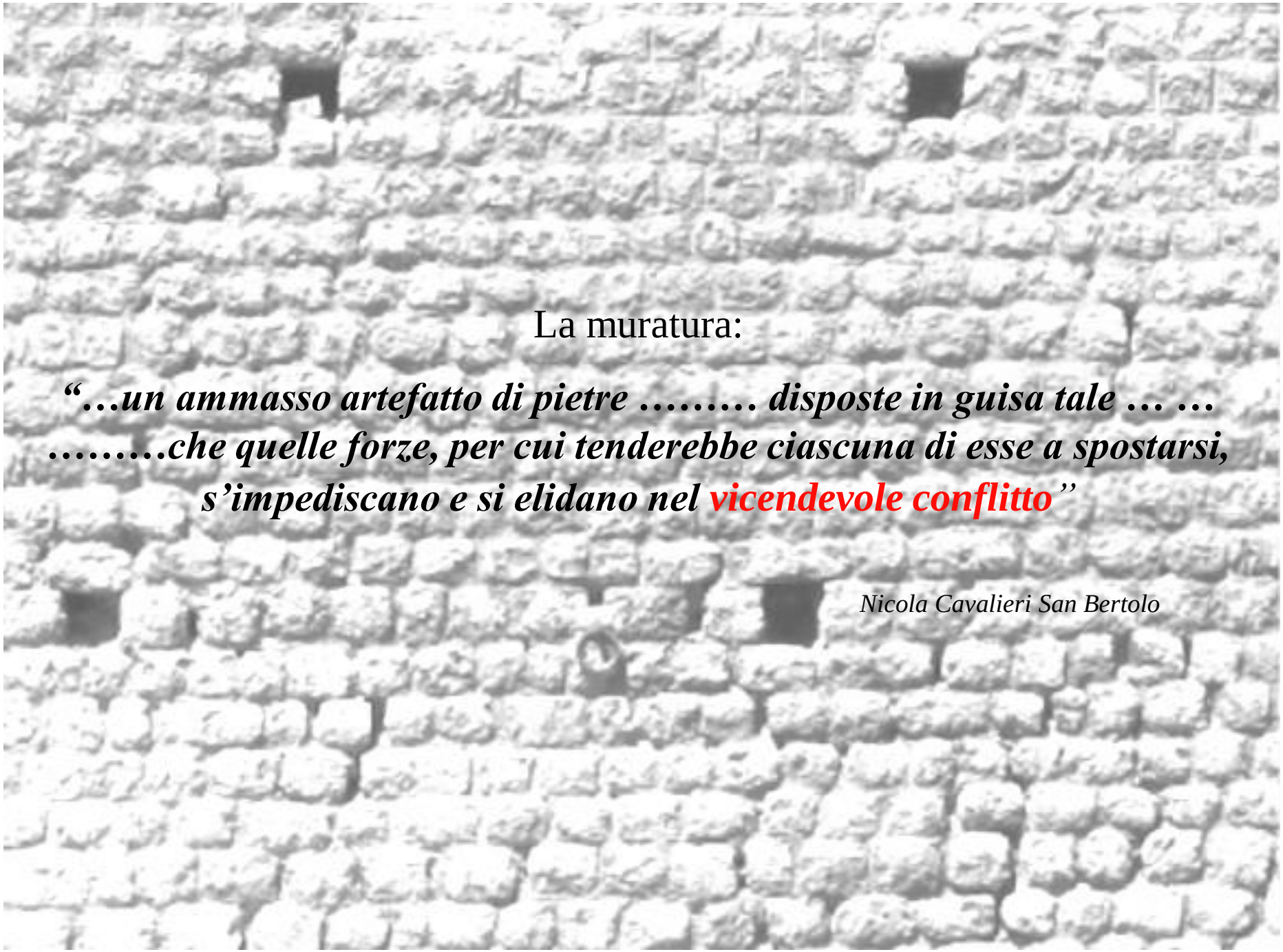


Architettura barocca Siciliana
(Ragusa – Ibla, Chiesa di San Giorgio, 1744)





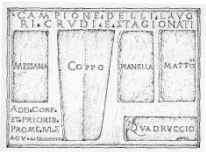
Effetto catena nelle murature incatenate, garantito dall'attrito sulle superfici di contatto fra gli elementi e dalla coesione della malta

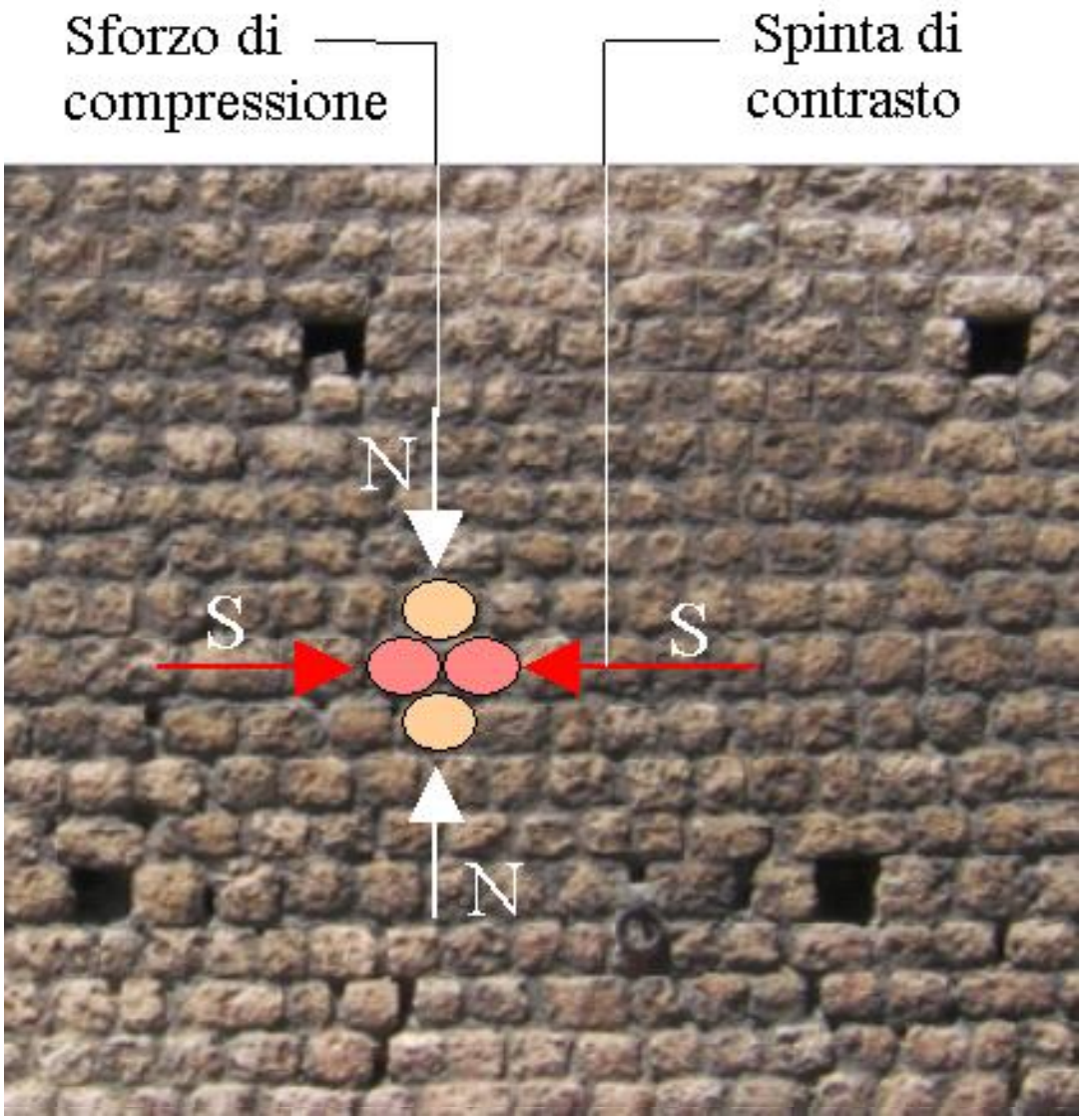


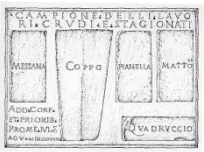
La muratura:

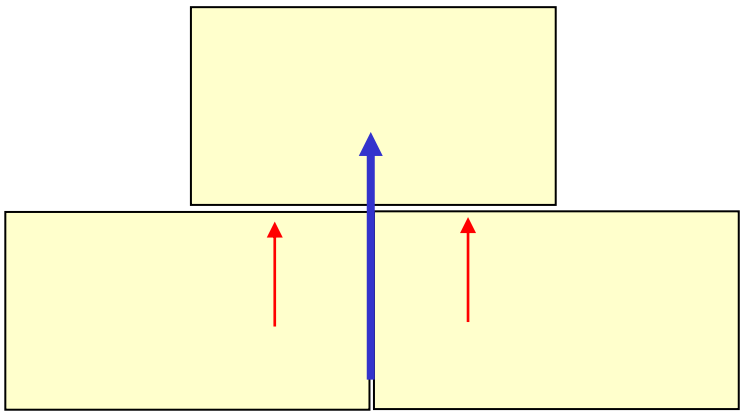
"…un ammasso artefatto di pietre ……. disposte in guisa tale … … ……..che quelle forze, per cui tenderebbe ciascuna di esse a spostarsi, s'impediscano e si elidano nel vicendevole conflitto"

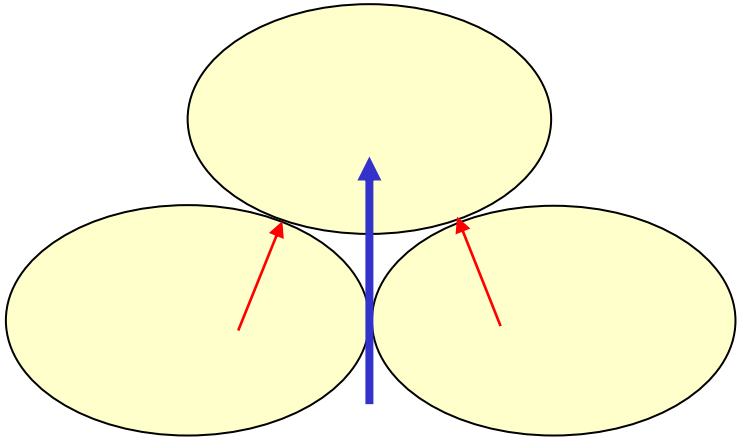
Nicola Cavalieri San Bertolo



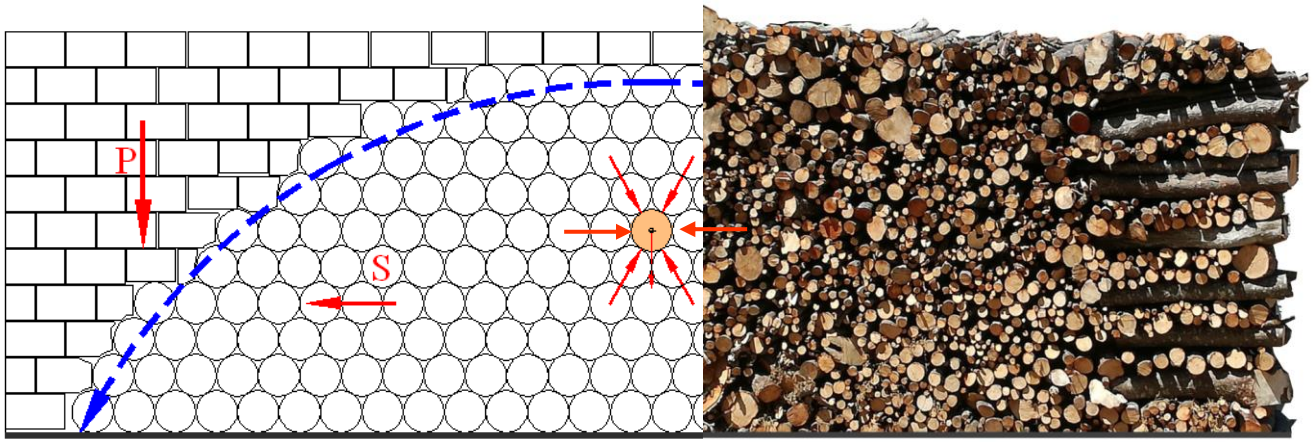

Sforzo di compressione
Spinta di contrasto
N
S
S
N


CAMPIONE DI FERRO AVO
RICRVDI E STAGIONATI
MESSANA
COPPO
MANELLA
MATTO
QVADRVCCIO



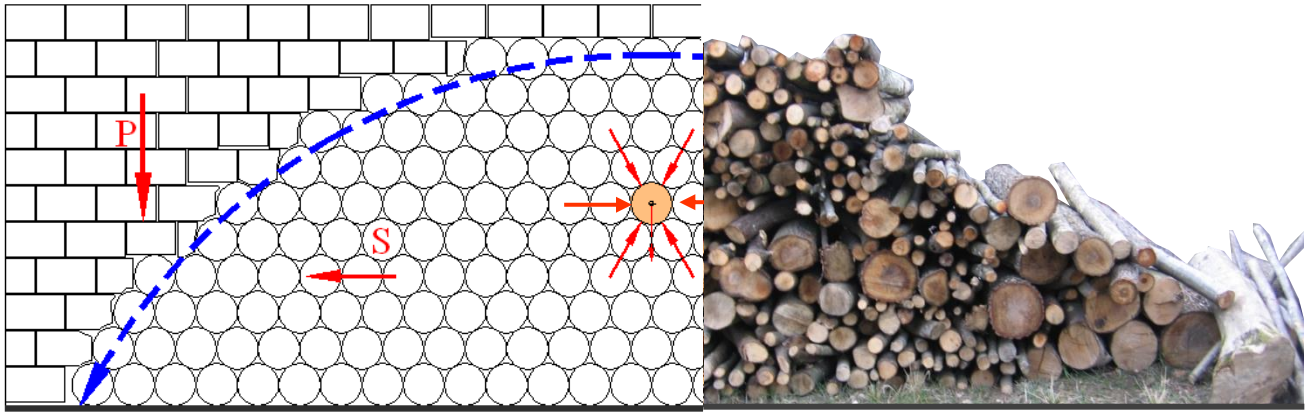


G. Cangi



Modello di parete muraria con stato di “precompressione orizzontale” e testate di contrasto in blocchi squadrati

G. Cangi

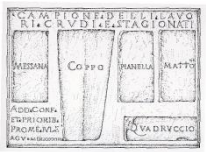


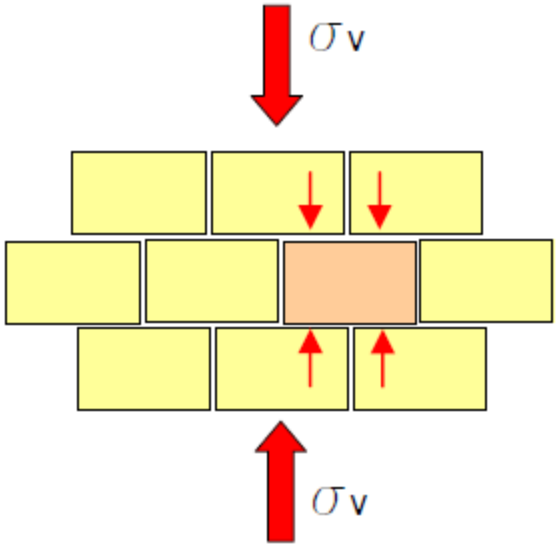
Modello di parete muraria con stato di “precompressione orizzontale” e testate di contrasto in blocchi squadrati

G. Cangi

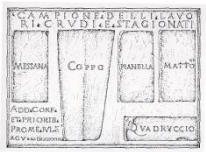
Palmira (Siria) – Rovine del tempio di Bel, con paramento costituito da rocchi di colonne riusate.
Foto: F.Giovanetti

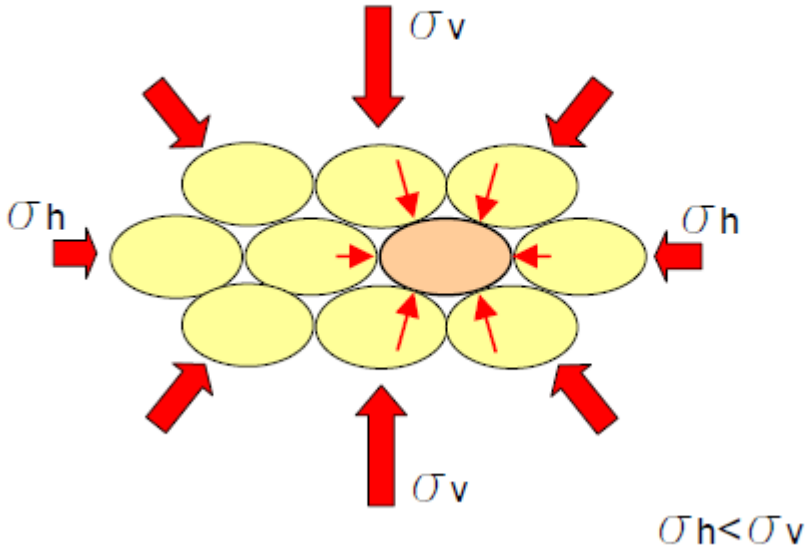
G. Cangi


CAMPIONE DI LATERIZIO
RICRVDI E STAGIONATI
MESSANA
COPPO
MANELLA
MATTO
QVADRVCCIO

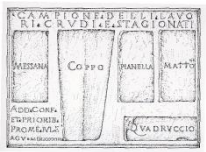

σv
σv

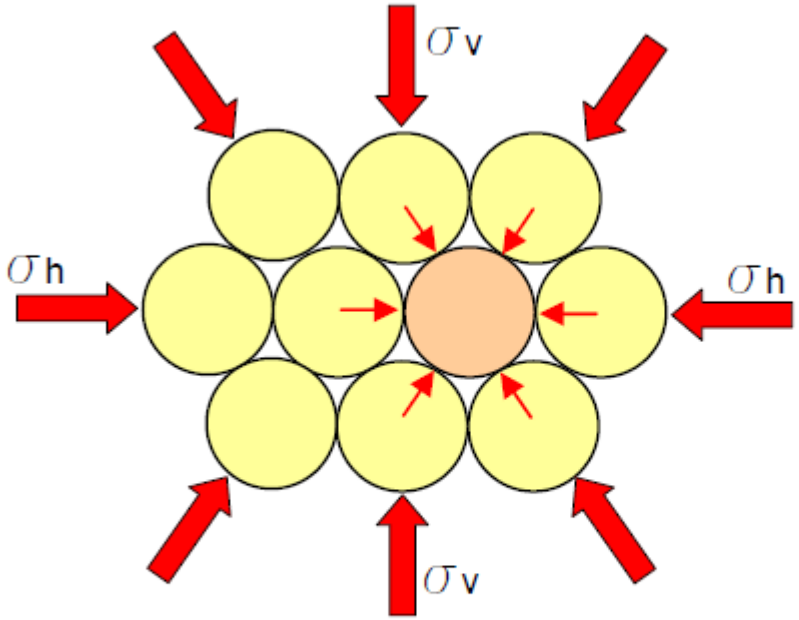
$\sigma_h = 0$


CAMPIONE DI LATERIZIO
RICRVDI E STAGIONATI
MEZZANA
COPPO
MANELLA
MATTO
QVADRVCCIO

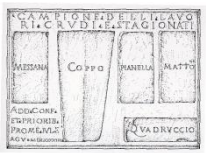

σv
σh
σh
σv
σh<σv

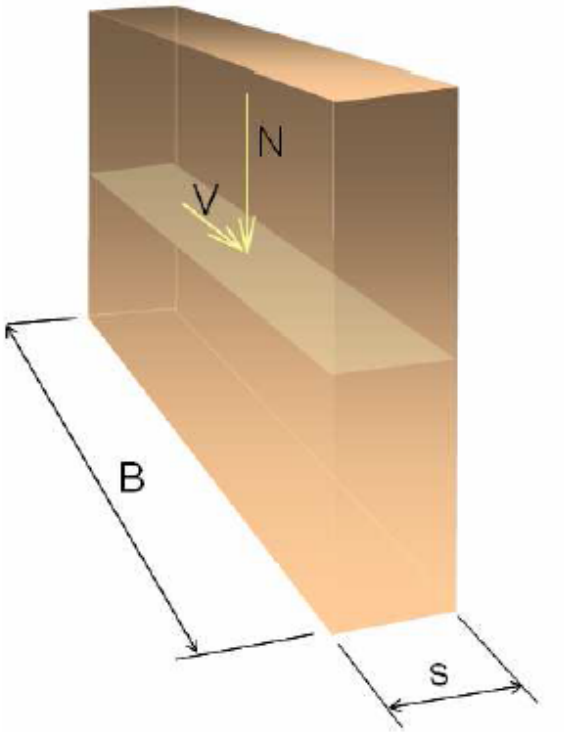
G. Cangi





$\sigma h = \sigma v$





Caratteristiche geometriche:

s= 0,40 ml

B= 1,80 ml

Sollecitazioni:

N= 30000 daN

σ_v= 4,17 daN/cmq

α = σ_h/σ_v= 0,20

σ_h= 0,83 daN/cmq

Resistenza a taglio:

τ_o= 0,40 daN/cmq

$$\tau_u = \tau_o \sqrt{1 + \frac{\sigma_v}{1{,}5\tau_o}}$$ = 1,13 daN/cmq

se α=0 *Formula di Turnsek - Cacovic*

τ_u= 2/3* $\sqrt{[(\sigma v+\sigma h)/2+1{,}5*\tau o]^2-((\sigma v-\sigma h)/2)^2}$ = 1,74 daN/cmq

α	τ_u (daN/cmq)	rapporto +	Taglio ultimo $V_u = B*s*\tau_u$	
0	1,13	**1,00**	8.118	daN
0,1	1,47	**1,30**	10.567	daN
0,2	1,74	**1,55**	12.546	daN
0,3	1,98	**1,76**	14.254	daN
0,4	2,19	**1,94**	15.778	daN
0,5	2,38	**2,11**	17.167	daN
0,6	2,56	**2,27**	18.451	daN
0,7	2,73	**2,42**	19.652	daN
0,8	2,89	**2,56**	20.784	daN
0,9	3,04	**2,69**	21.857	daN
1	3,18	**2,82**	22.880	daN

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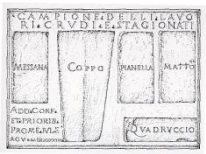
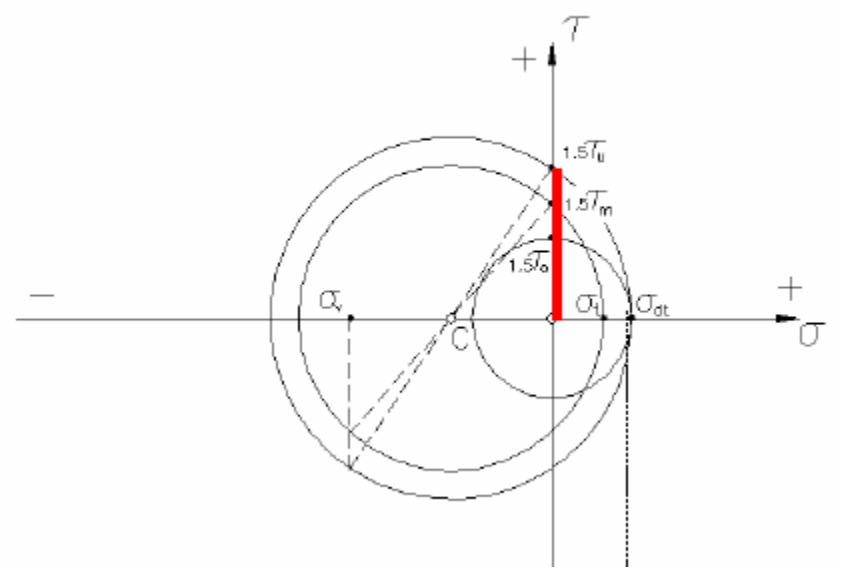
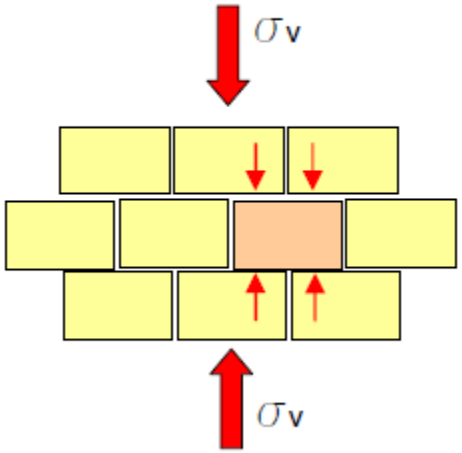




A)



$\sigma_h = 0$

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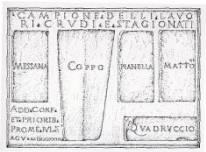
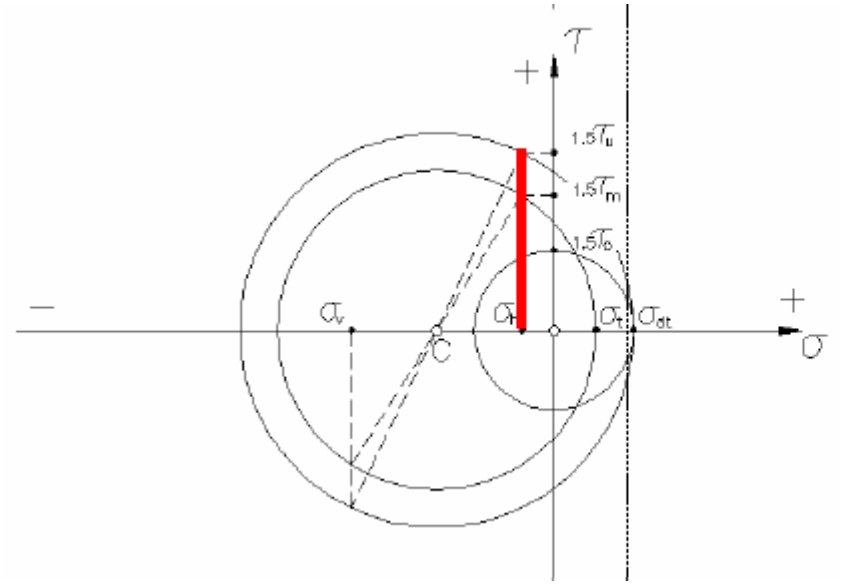
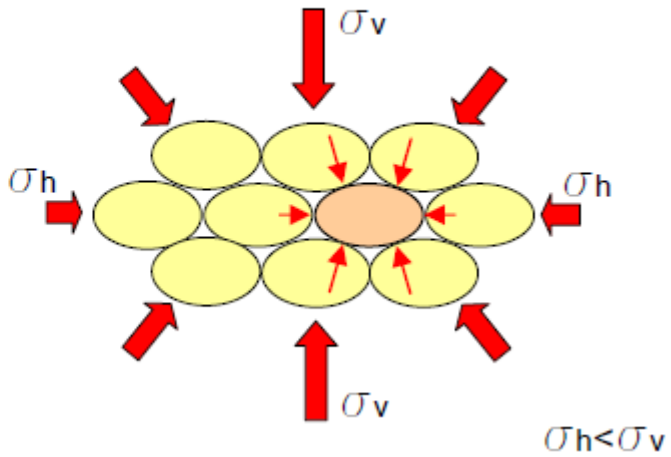
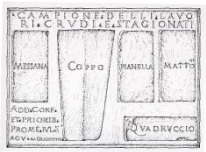

CAMPIONE DI LEGNO
RICRUDI STAGIONATI
MESSANA
COPPO
MANELLA
MATTO
QUADRUCCIO

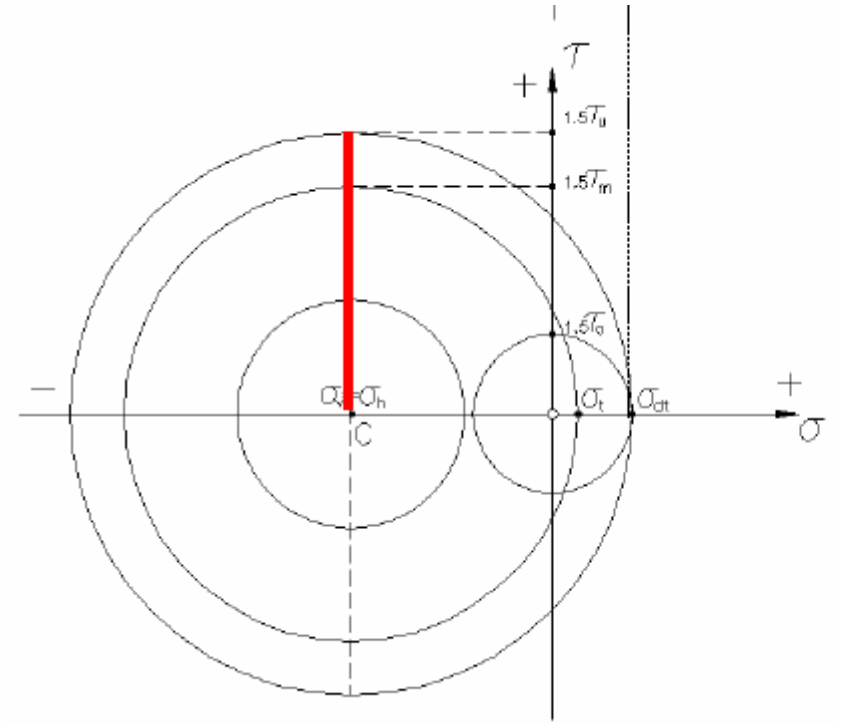

T
+
1.5τu
1.5τm
1.5τo
−
σv
σh
C
σt
σdt
+
σ

B)

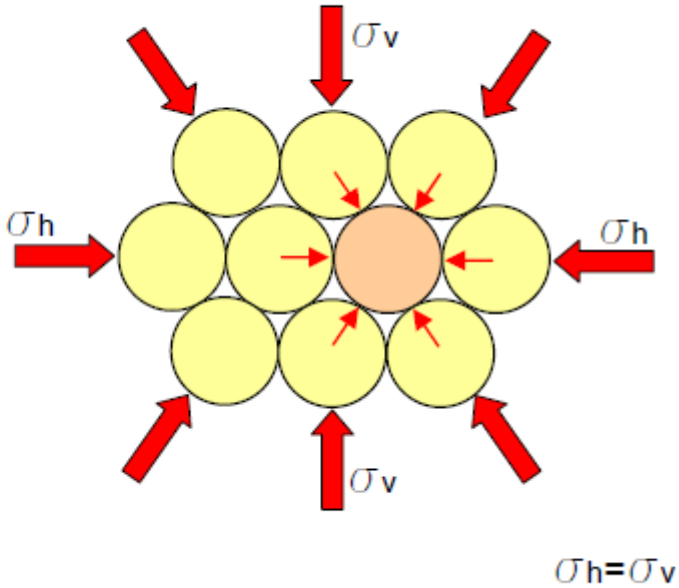

σv
σh
σh
σv
σh<σv

G. Cangi





C)



$\sigma_h = \sigma_v$

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Caratterizzazione meccanica dei materiali

- Valutazione delle caratteristiche meccaniche e livello di degrado dei materiali tramite:

. verifiche visive in situ

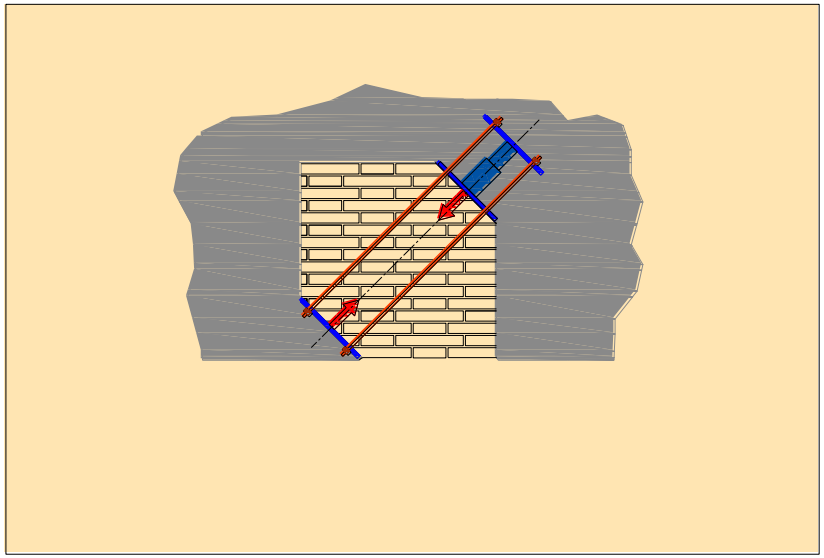
. analisi dati già disponibili

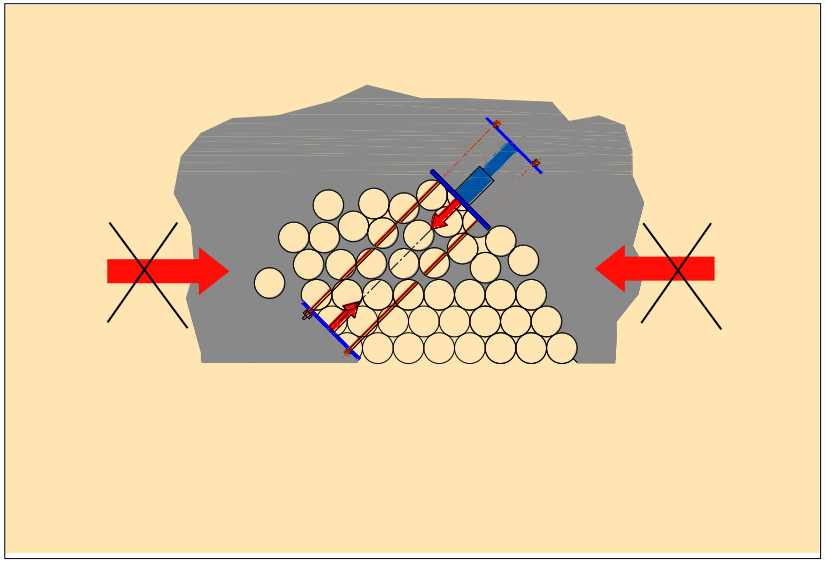
. prove sperimentali

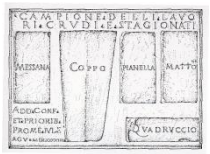
Livelli di conoscenza

(LC1, LC2 e LC3)

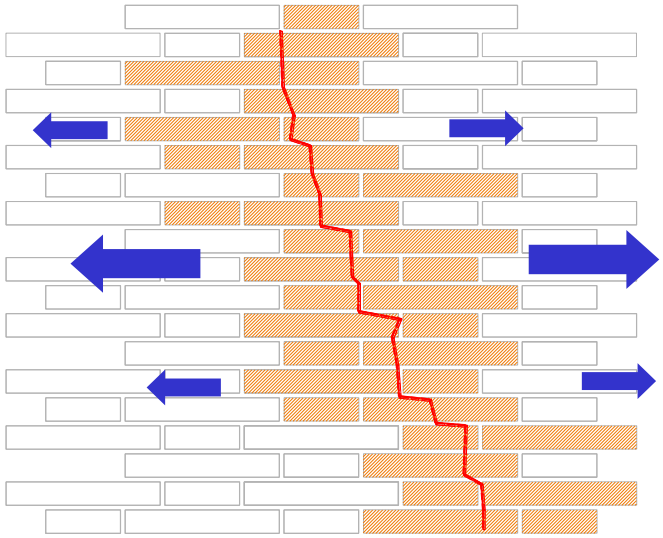
Indagini limitate, estese, esaustive



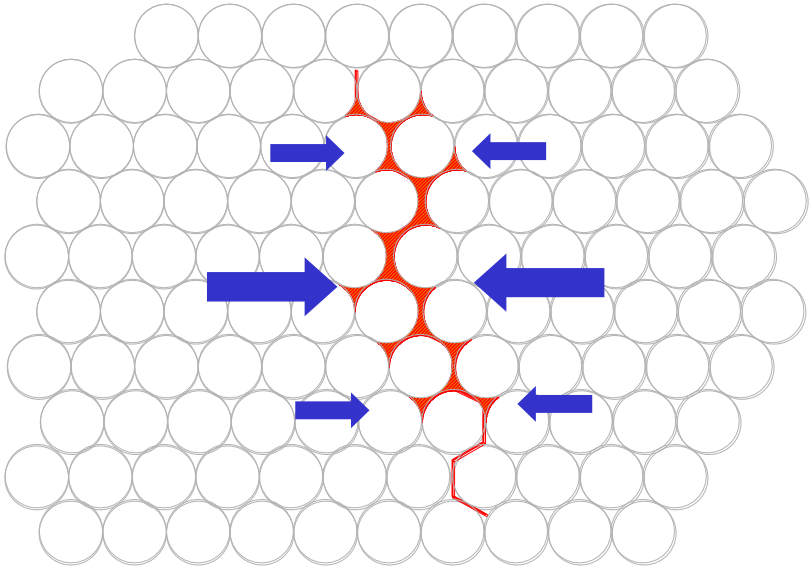




Interventi di cuci-scuci



Ripristino dell'ingranamento e della resistenza a trazione equivalente per attrito e coesione



Ripristino dell'azione di contrasto e dello stato di precompressione

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Analisi del danno e delle lesioni sugli edifici storici, casistiche e approccio alla lettura del quadro fessurativo

Ing. Giovanni Cangi – libero professionista