

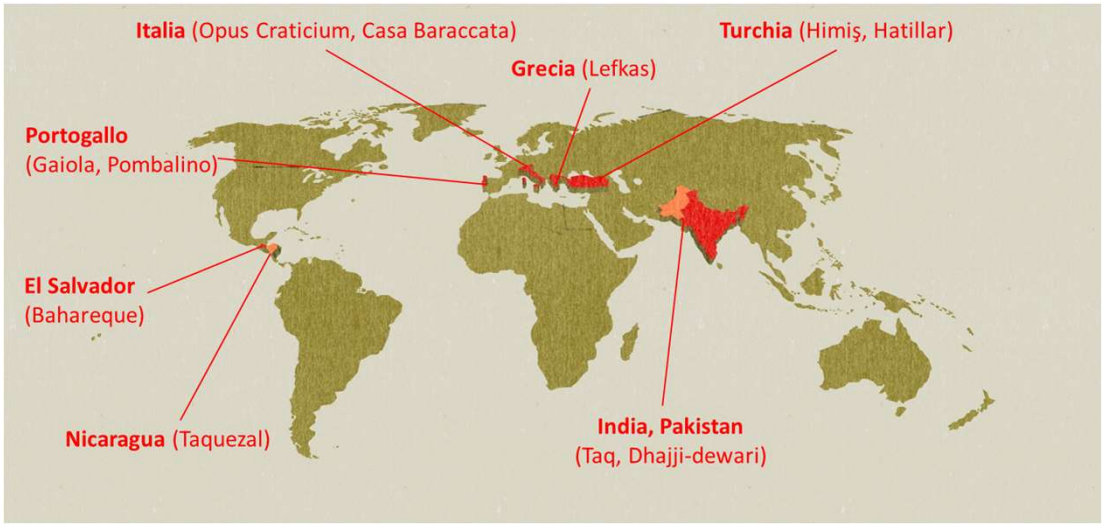
ADEGUAMENTO SISMICO DI STRUTTURE ESISTENTI CON IL LEGNO: STATO DELL'ARTE E SVILUPPI FUTURI

Prof. Ing. Ivan Giongo
Università degli Studi di Trento
DICAM | Dipartimento di Ingegneria Civile, Ambientale e Meccanica

TIMBER AND STRUCTURAL REHABILITATION RESEARCH GROUP

E' POSSIBILE ADEGUARE (MIGLIORARE) SISMICAMENTE UN EDIFICIO ESISTENTE UTILIZZANDO IL LEGNO?

"ADEGUARE SISMICAMENTE" CON IL LEGNO



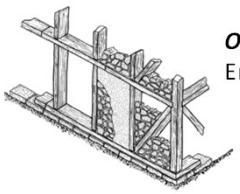
IVAN GIONGO ROMA, 24 MAGGIO 2024

LEGNO E «MIGLIORAMENTO SISMICO» | ESEMPI DI SUCCESSO


Immagine da archivio web

III sec a.C

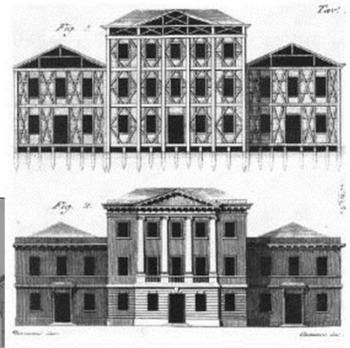
1783

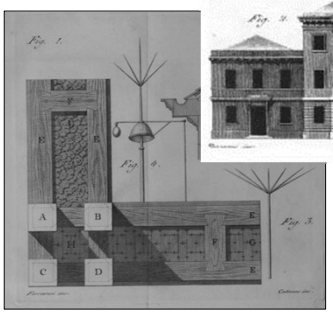


Opus Craticium
Ercolano, Italia

Casa Baraccata

Primo regolamento antisismico d'Italia
Calabria, Italia







Terremoto di Reggio e Messina [Mw stimata **6,9**]
[Vivenzio 1787]

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Gaiola (Pombalino)
Lisbona, Portogallo

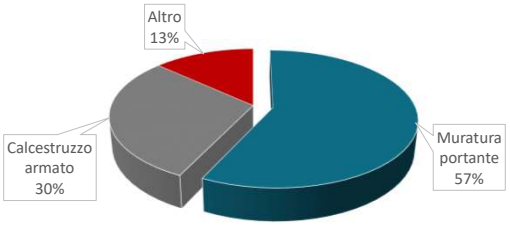
Terremoto di Lisbona nel 1755
[Mw stimata: **8,5-9**]



IVAN GIONGO ROMA, 24 MAGGIO 2024

QUAL É LA SITUAZIONE OGGI IN ITALIA?

Edifici residenziali per tipo di materiale (ISTAT)



- 25.9% degli edifici residenziali costruito < 1945
- 86.2% degli edifici residenziali costruito < 1990



Collasso fuori piano di porzioni murarie
(Meccanismi di I modo)

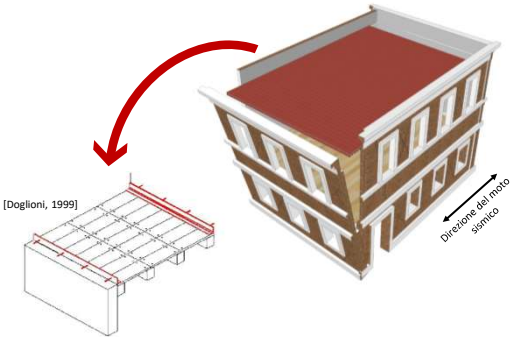
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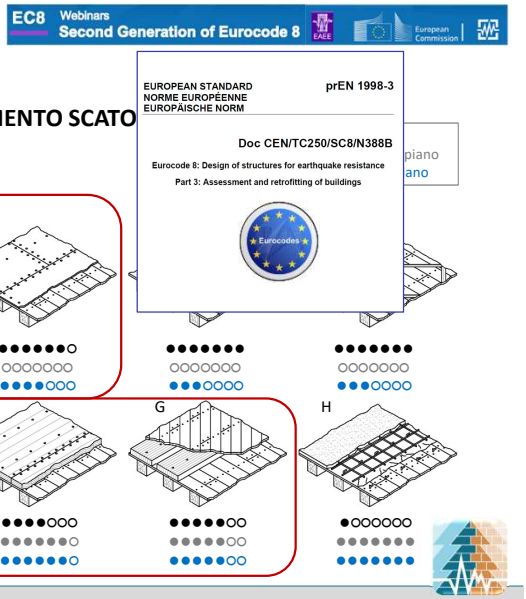
COSA POSSIAMO FARE OGGI?

Il primo passo è assicurarsi che vi siano:

- collegamenti efficaci tra orizzontamenti e pareti
- Solai e copertura dotati di sufficiente rigidezza di piano

COMPORTAMENTO SCATO





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MIGLIORAMENTO SISMICO DI EDIFICI IN MURATURA ATTRAVERSO L'USO DI ELEMENTI LIGNEI

Rinforzo del comportamento fuori-piano con «contrafforti/costolature» in legno

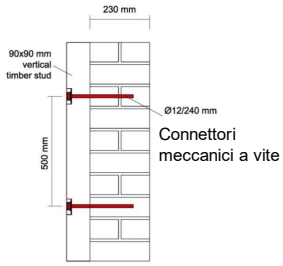


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COSTOLATURE LIGNEE «STRONG-BACKS»



Costolature di rinforzo con collegamenti puntuali diffusi



Connettori meccanici a vite



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NEW ZEALAND
Te Whare Wānanga o Tāmaki Makaurau

UNIVERSITÀ DEGLI STUDI DI TRENTO
Dipartimento di Ingegneria Civile e Ambientale

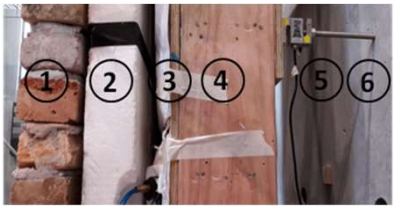
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COSTOLATURE LIGNEE «STRONG-BACKS»

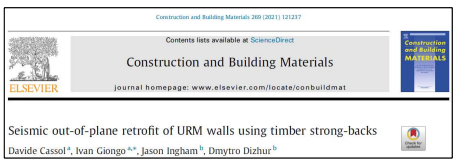
CAMPAGNA SPERIMENTALE

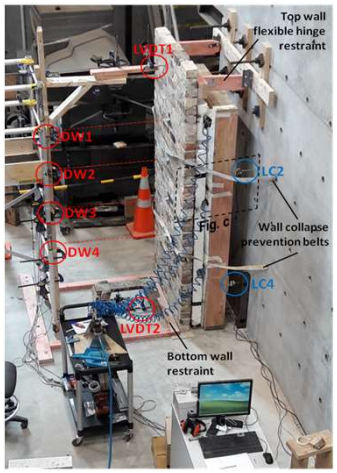
THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

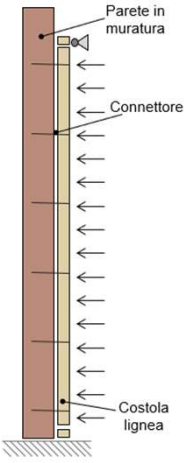
TEST SET-UP



1) Campione
2) Strato polistirene
3) Airbag
4) Pannello di contrasto
5) Cella di carico
6) Parete di reazione


Construction and Building Materials 269 (2021) 121237
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ELSEVIER
Seismic out-of-plane retrofit of URM walls using timber strong-backs
Davide Cassol [a], Ivan Giongo [a,*], Jason Ingham [b], Dmytro Dizhur [b]






Configurazione iniziale


Parete deformata

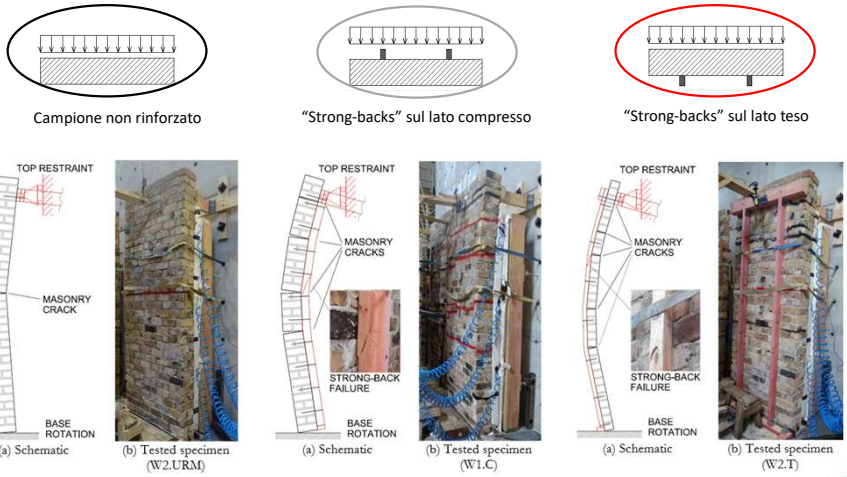
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COSTOLATURE LIGNEE «STRONG-BACKS»

5 CAMPIONI



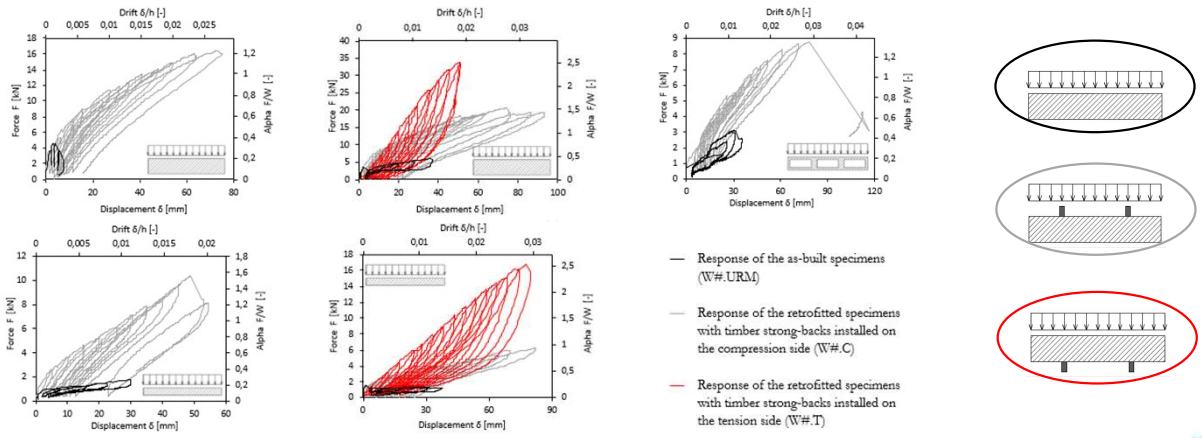
3 CONDIZIONI TESTATE



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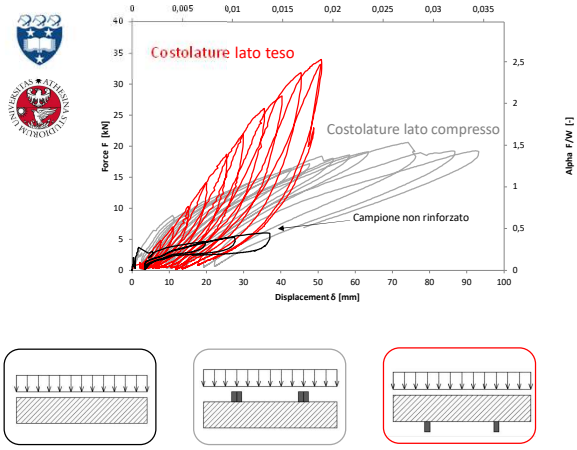
COSTOLATURE LIGNEE «STRONG-BACKS» | RISULTATI

NOVETVOLE AUMENTO DELLA CAPACITÀ PORTANTE!



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COSTOLATURE LIGNEE «STRONG-BACKS» | CONFRONTO RISULTATI

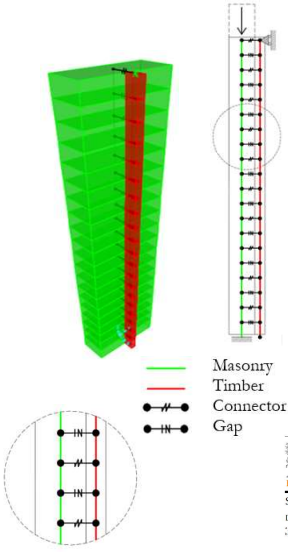


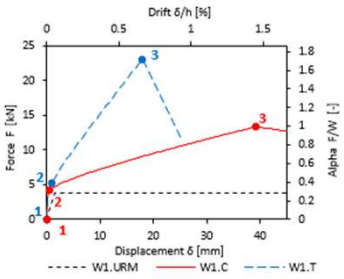
ID muro	Peso W (kN)	Forza orizzontale F (kN)	Alpha	Spostamento	Drift δ/h** (%)	Incremento capacità (%) ***
W1.URM	13.44	4.63			0. 15	-
W1.C	13.44	16.41			2.78	254
W2.URM	13.44	6.03			1.37	-
W2.C	13.44	20.61			2.78	242
W2.T	13.44	33.95			1.89	463
W3.URM	6.50	3.14			1.07	-
W3.C	6.50	8.77			2.89	179
W4.URM	6.65	1.73			1.11	-
W4.C	6.65	10.39			1.70	501
W5.URM	6.65	1.51			1.40	-
W5.C	6.65	6.26			3.04	315
W5.T	6.65	16.73			2.81	1008

Note: *spostamento misurato in corrispondenza del carico max.; **h = quota vincolo (2700 mm per tutti i campioni); *** incremento rispetto al campione non rinf. (W#.URM).

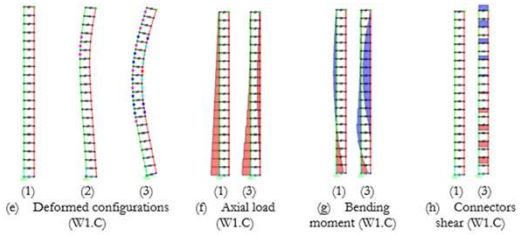
IVAN GIONGO ROMA, 24 MAGGIO 2024

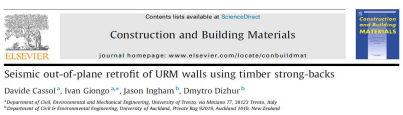
COSTOLATURE LIGNEE «STRONG-BACKS» | MODELLI DI CALCOLO NUMERICO E ANALITICO





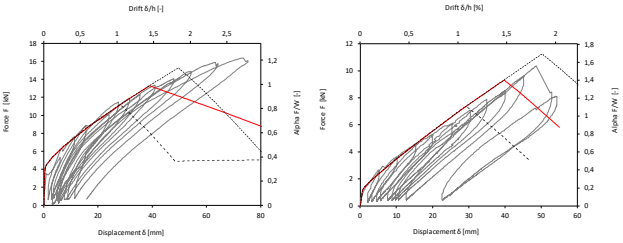
(a) Model results of W1.URM, W1.C and W1.T




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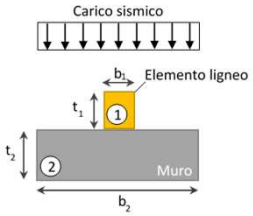
Seismic out-of-plane retrofit of URM walls using timber strong-backs

Davide Cassol [a], Ivan Giongo [a,*], Jason Ingham [b], Dmytro Dizhur [b]
[a] Department of Civil, Environmental and Mechanical Engineering, University of Trento, via Mesiano 77, 38123 Trento, Italy
[b] Department of Civil & Environmental Engineering, University of Auckland, Private Bag 92019, Auckland 1010, New Zealand

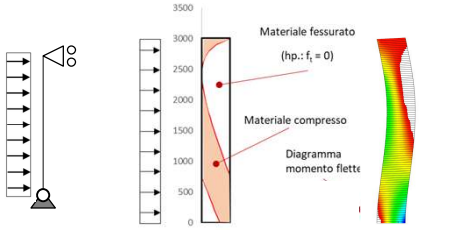


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COSTOLATURE LIGNEE «STRONG-BACKS» | MODELLI DI CALCOLO NUMERICO E ANALITICO



Parete composta Muratura-Legno	"Costole" in legno
$\alpha_{max} = \alpha_{peak} \cdot q = \frac{2q}{W} \cdot \frac{EJ_{eff}}{E_2 J_2} \left(\frac{\pi}{\hat{h}}\right) M_R(\bar{x})$	$M_{1,max} = \frac{E_1 J_1}{EJ_{eff}} \frac{\alpha_{peak} W}{2} \left(\frac{\hat{h}}{\pi}\right)$
$w_{max} = \frac{\alpha W}{2} \left(\frac{\hat{h}}{\pi}\right)^3 \frac{1}{EJ_{eff}} \mu$	$N_{1,max} = \frac{EA_0^* a}{EJ_{eff}} \frac{\alpha_{peak} W}{2} \left(\frac{\hat{h}}{\pi}\right)$
Connessioni	
$S_{fs} = \frac{\alpha_{peak} W}{2} \cdot \frac{EA_0^* a \cdot sp}{EJ_{eff}}$	$V_{1,max} = \frac{\alpha_{peak} W}{2} \beta$
$T_{fs} = \frac{\alpha_{peak} W \cdot sp}{2} \cdot \left(\frac{\pi}{\hat{h}}\right) \cdot \beta$	



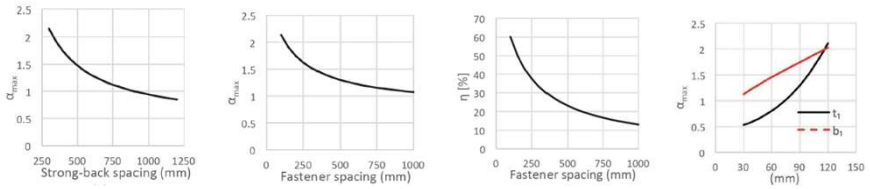
FESSURAZIONE

Si determina uno spessore ridotto equivalente

SESOC Journal

SEISMIC RETROFIT OF MASONRY WALLS USING TIMBER STRONG-BACKS

Dmytro Y. Dizhur[1], Marta Giaretton[2], Ivan Giongo[3] and Jason M. Ingham[4]



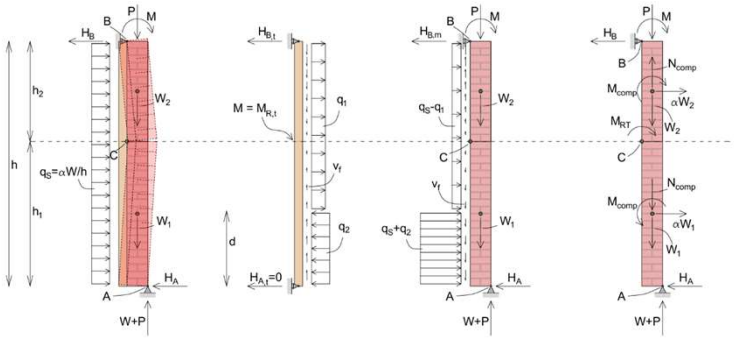
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COSTOLATURE LIGNEE «STRONG-BACKS» | MODELLI DI CALCOLO NUMERICO E ANALITICO

APPROCCIO IN CONDIZIONI LIMITE

- ☐ **Ipotesi di Heyman**
  No scorrimento nei giunti di malta, resistenza muratura a compressione infinita e resistenza a trazione nulla
- ☐ **No deformazione elastica della muratura** Trascurabile
- ☐ **Sezione critica alla quota h_1**
  Apertura lesione nella muratura e crisi lato legno
- ☐ **Azione assiale sui connettori costante**
  Azione assiale q_1

SCHEMATIZZAZIONE ADOTTATA PER LA RISOLUZIONE DEL PROBLEMA

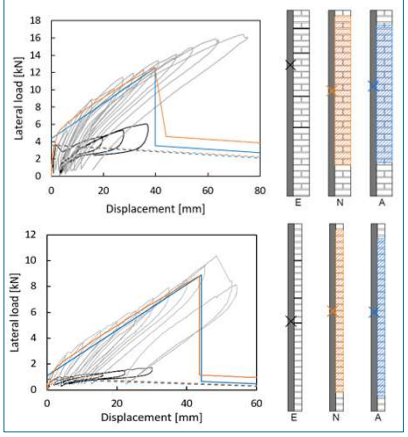


Load distribution retrofitted wall | Load distribution timber strong-back | Load distribution masonry wall | Schematic retrofitted wall

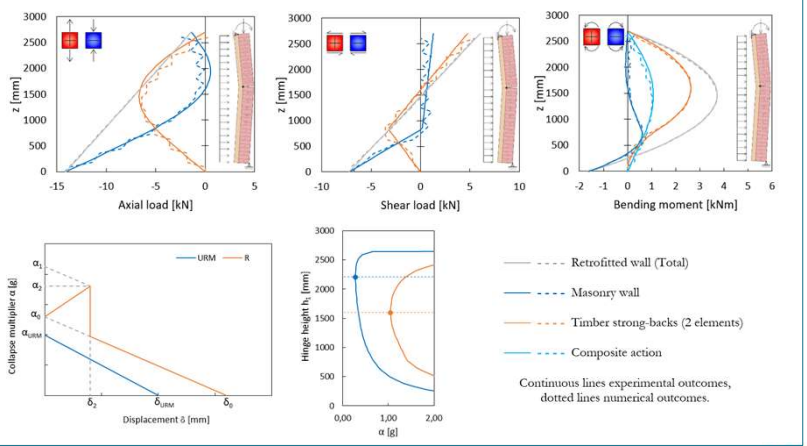
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COSTOLATURE LIGNEE «STRONG-BACKS» | MODELLI DI CALCOLO NUMERICO E ANALITICO

CURVE CARICO LATERALE - SPOSTAMENTO



AZIONI INTERNE E DEFORMAZIONI



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COSTOLATURE LIGNEE SU TAMPONAMENTI



- ☐ Aumento della capacità portante fuori piano
- ☐ Evitare qualsiasi crollo e caduta di detriti

SOLUZIONE DI RINFORZO APPLICABILE DALL'ESTERNO DELL'EDIFICIO



RINFORZO ACCOPPIATO CON PARETE VENTILATA

↓

INTERVENTO INTEGRATO

↓

MIGLIORAMENTO DELLE PRESTAZIONI TERMO-FISICHE E DELL'ASPETTO ESTETICO

ESEMPI DI CROLLI DI TAMPONAMENTI


[Archivio Reluis 2016]


[Archivio Reluis 2016]

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COSTOLATURE LIGNEE SU TAMPONAMENTI | PROGETTO AV-X

SISTEMA DI RINFORZO INTEGRATO

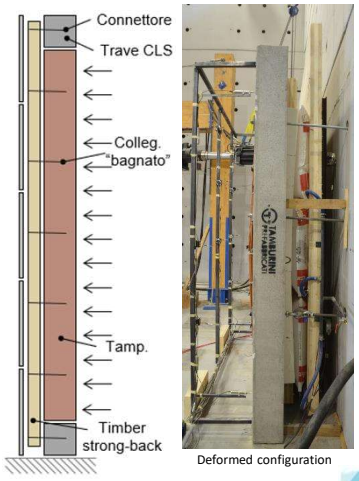
XLAM DOLOMITI The wood building r-evolution | AVANTGARDE r-evolution technical wall

TEST SET-UP



(1) Campione
(2) Strato di polistirene espanso
(3) Airbag
(4) Pannello di contrasto in XLAM
(5) Celle di carico





Deformed configuration

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COSTOLATURE LIGNEE SU TAMPONAMENTI | PROGETTO AV-X | CAMPAGNA SPERIMENTALE

10 CAMPIONI



3 TIPI DI TAMPONAMENTO



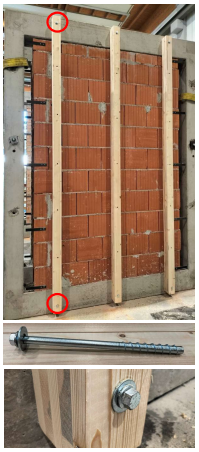
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COSTOLATURE LIGNEE SU TAMPONAMENTI | PROGETTO AV-X | CAMPAGNA SPERIMENTALE

1 Strong-backs in XLAM



2 Connettori a “secco”



3 Collegamenti “bagnati”



4 Pannelli isolanti



5 Struttura di supporto



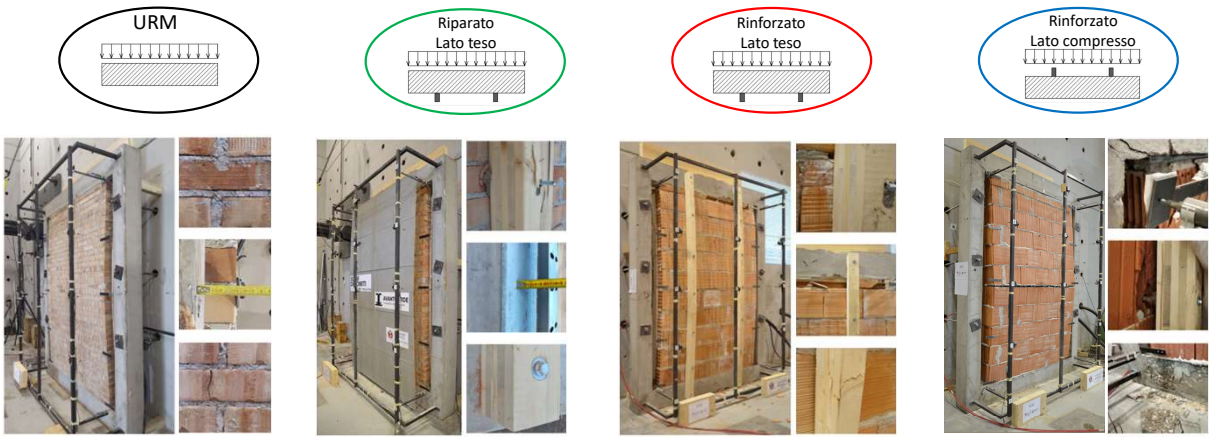
6 Rivestimento parete ventilata



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COSTOLATURE LIGNEE SU TAMPONAMENTI | PROGETTO AV-X | CAMPAGNA SPERIMENTALE

4 TIPOLOGIE DI TEST



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COSTOLATURE LIGNEE SU TAMPONAMENTI | PROGETTO AV-X

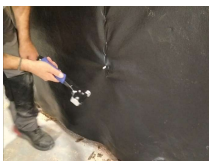
Lana di roccia e membrana traspirante

PANNELLI 100 x 600 x 1000 mm
(DIMENSIONI COMPATIBILI CON SPAZIATURA E SPESSORE MONTANTI)











IVAN GIONGO ROMA, 24 MAGGIO 2024

COSTOLATURE LIGNEE SU TAMPONAMENTI | PROGETTO AV-X

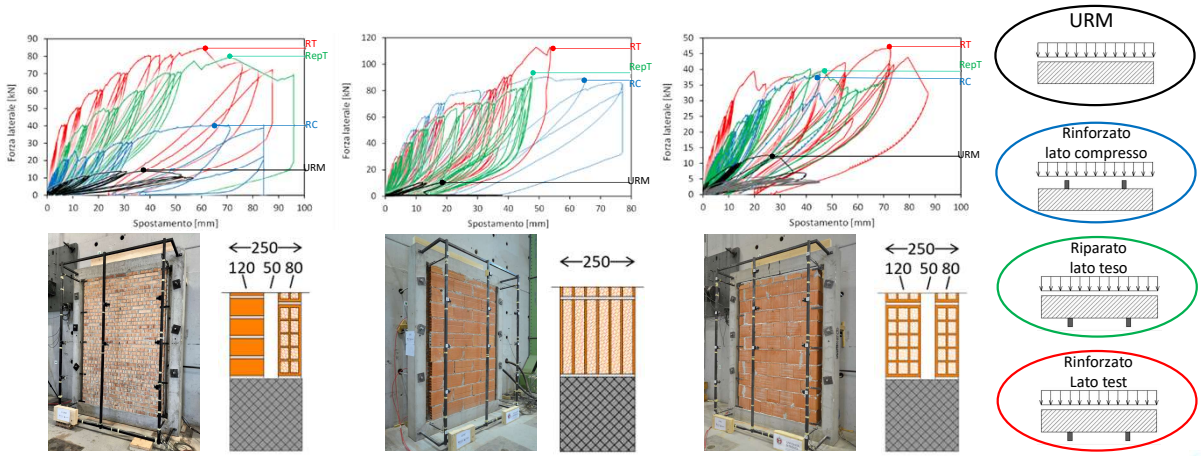
Campioni rinforzati






COSTOLATURE LIGNEE SU TAMPONAMENTI | PROGETTO AV-X | CAMPAGNA SPERIMENTALE

AUMENTO DELLA CAPACITÀ PORTANTE → 190% ÷ 900%

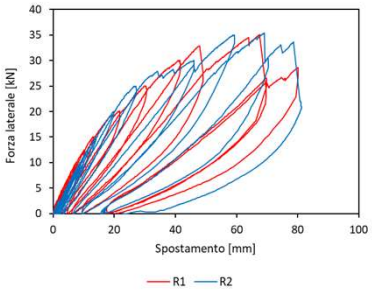


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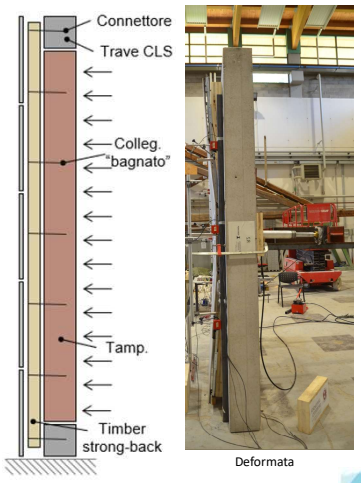
COSTOLATURE LIGNEE SU TAMPONAMENTI | PROGETTO AV-X | CAMPAGNA SPERIMENTALE

CAPACITÀ DI DEFORMAZIONE DEL SISTEMA DI RIVESTIMENTO > 60 mm

Test aggiuntivi per stimare la capacità di deformazione del sistema di rinforzo/rivestimento



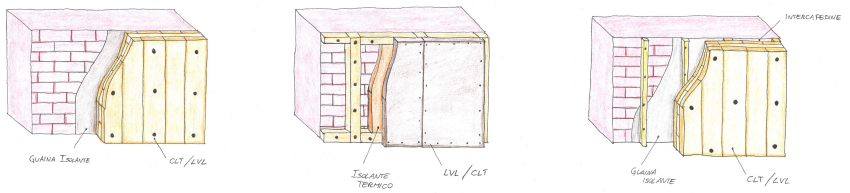




Deformata

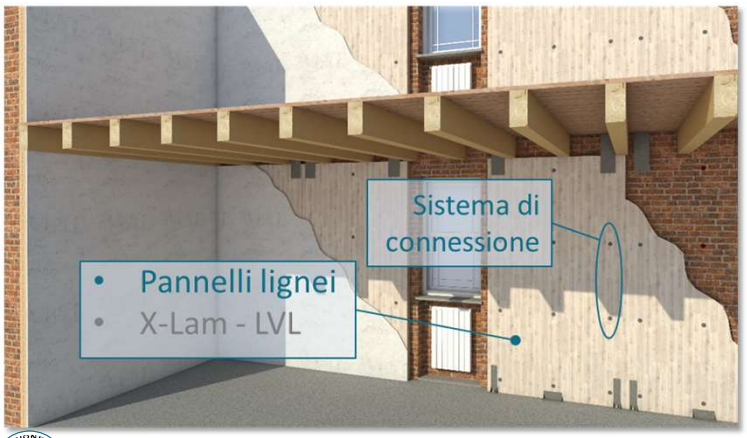
MIGLIORAMENTO SISMICO DI EDIFICI IN MURATURA CON PANNELLI LIGNEI

Fase 1- Individuazione soluzione di rinforzo e studio di fattibilità



IVAN GIONGO ROMA, 24 MAGGIO 2024

RINFORZO DI MURATURE MEDIANTE PANNELLI X-LAM



- ✓ Intervento reversibile
- ✓ Lavorazioni a secco
- ✓ Aumento di massa contenuto
- ✓ Miglioramento efficienza energetica
- ✓ Mantenimento della facciata esterna
- ✓ Durabilità
- ✓ Velocità di esecuzione

- × Interruzione d'uso (limitato)
- × Riduzione del volume interno
- × Impossibilità di realizzare rinforzi di parete continui

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TIMBER AND STRUCTURAL REHABILITATION RESEARCH GROUP

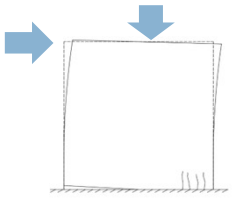
STUDIO DI FATTIBILITÀ ATTRAVERSO MODELLAZIONE NUMERICA

3rd International Conference on
PROTECTION OF HISTORICAL CONSTRUCTIONS
Lisbon, Portugal, 12 – 15 July, 2017

ON THE USE OF TIMBER-BASED PANELS FOR THE SEISMIC RETROFIT OF MASONRY STRUCTURES

Ivan Giongo*, Gianni Schiro* and Maurizio Piazza*

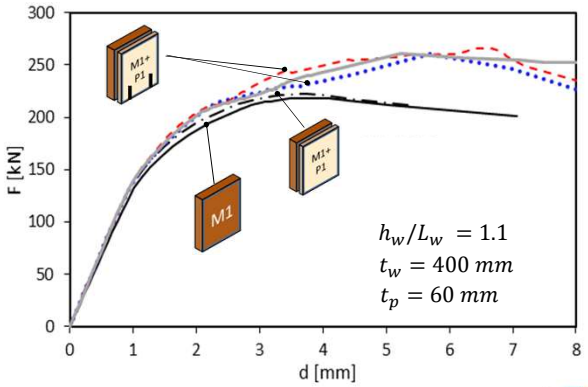
Per maschi murari con comportamento a **"rocking"**, l'efficacia dell'intervento è strettamente legata all'efficacia degli ancoraggi a trazione posti alla base del pannello.



Tuttavia l'influenza della rigidezza dell'ancoraggio appare limitata

- Capacità portante: + 20 – 40 %
- Rigidezza iniziale invariata

Muro originale (no pannelli)
No ancoraggi a trazione
Ancor. Trazione: $K_T = 50\ kN/mm$
Ancor. Trazione : K_T = rigid
Ancor. Trazione : $K_T = 50\ kN/mm$
$L_p = L_w/2$



IVAN GIONGO ROMA, 24 MAGGIO 2024

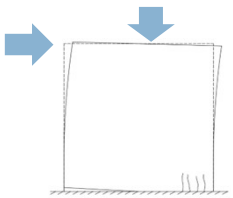
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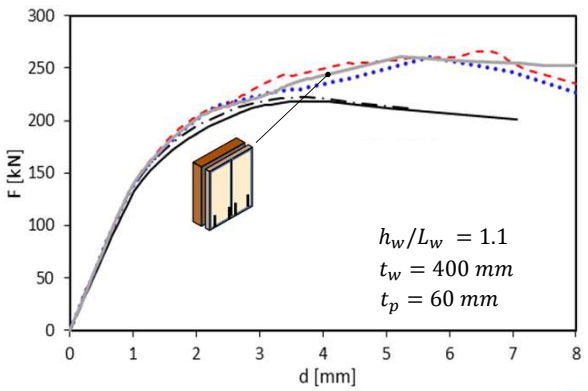
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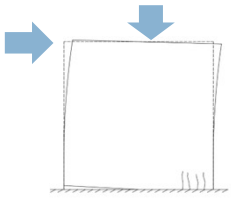
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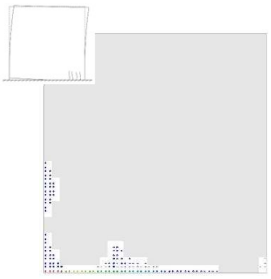
STUDIO DI FATTIBILITÀ ATTRAVERSO MODELLAZIONE NUMERICA

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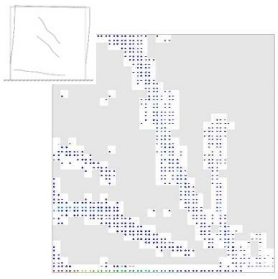


La presenza dei connettori distribuiti blocca la rotazione del maschio e permette di attivarne la resistenza a taglio (diagonale)

Quadro fessurativo in corrispondenza del picco della capacità portante



Muro non rinforzato

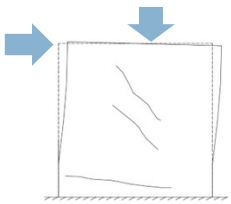


Muro rinforzato

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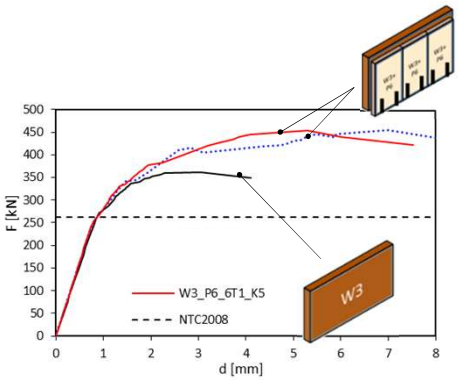
STUDIO DI FATTIBILITÀ ATTRAVERSO MODELLAZIONE NUMERICA

Per maschi murari con comportamento a **"taglio"**, si sono osservati incrementi della capacità portante compresi tra 25% e 50 %.



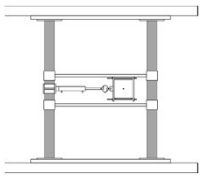
- Capacità portante: + 25 %
- Rigidezza iniziale invariata

——Muro originale (no pannelli)
·····Connettori: $K_c = 20\ kN/mm$
——Connettori: $K_c = 50\ kN/mm$
- - - -NTC



MIGLIORAMENTO SISMICO DI EDIFICI IN MURATURA CON PANNELLI LIGNEI

Fase 2 -Test sperimentali su sistema di connessione



PROVE SPERIMENTALI (IN-SITU): CONNESSIONI A SECCO

CASO STUDIO - GAT | Grande Albergo Terme



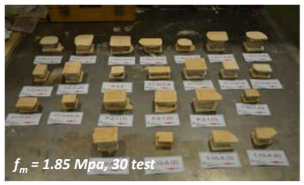


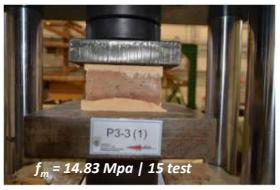
Progetto iniziale 1838-1840

TERME DI COMANO



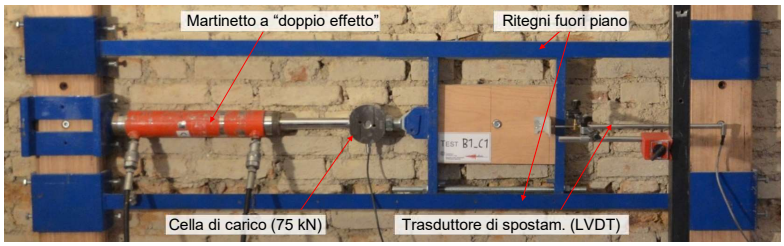
Situazione attuale







PROVE SPERIMENTALI (IN-SITU): CONNESSIONI A SECCO









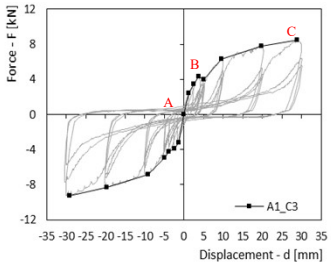


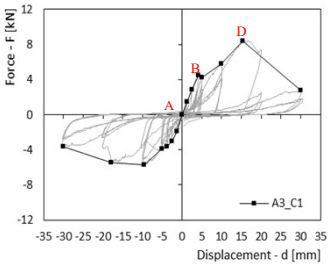
54 test

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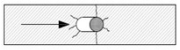
PROVE SPERIMENTALI (IN-SITU): CONNESSIONI A SECCO

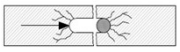
Rappresentazione di due differenti modalità di rottura



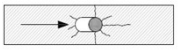


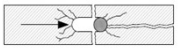

A: Starting load application


B: Tension crack opening


C: Crushing (F_u)


A: Starting load application


B: Tension crack opening


D: Splitting



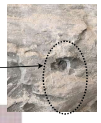




Legno:
- Rifollamento



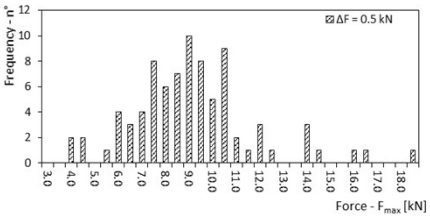
Connettori:
- Cerniere plastiche
- Rottura stelo

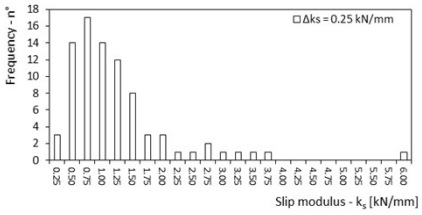


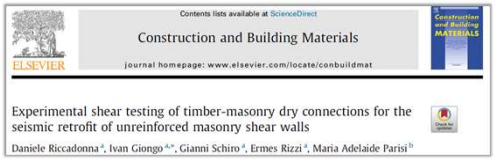




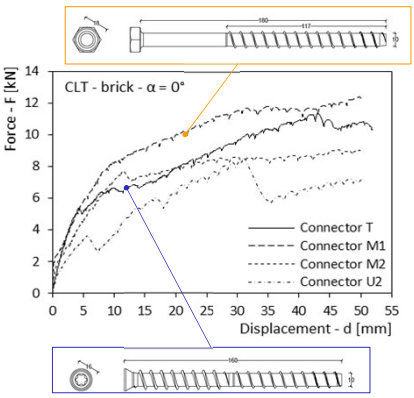
PROVE SPERIMENTALI (IN-SITU): CONNESSIONI A SECCO



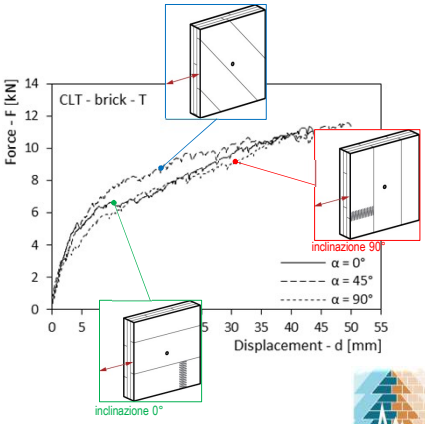




Per differenti tipologie di connettori



Per differenti angoli di applicazione del carico



PROVE SPERIMENTALI (IN-SITU): CONNESSIONI «BAGNATE»

2 tipi di barre:



BARRE FILETTATE 8.8



BARRE D'ARMATURA B450C

2 DIAMETRI: ø14mm; ø20mm

2 tipi di adesivo:



EPOSSIDICA

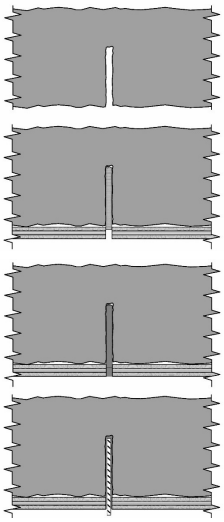


IBRIDA



CALZA METALLICA





TERME DI COMANO RUBNER holzbau fischer



PROVE SPERIMENTALI (IN-SITU): CONNESSIONI «BAGNATE»

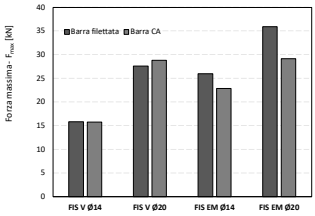

PROHITECH 2020
4th International Conference on
Protection of Historical Constructions
Testing of Irregular Stone Masonry
Strengthened with Cross-Laminated Timber
Ermes Rizzi, Ivan Giongo[(✉)], Daniele Riccadonna, and Maurizio Piazza
Department of Civil, Environmental and Mechanical Engineering, University of Trento, Via Mesiano 77, 38010 Trento, Italy
ivan.giongo@unitn.it

Risultati test semi-ciclici (valori medi)

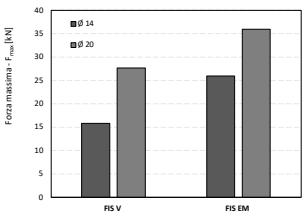
Parametri esaminati:

- Tipologia di resina (epossidica e ibrida vinilestere/epossidica);
- Diametro barra filettata (14 *mm* e 20 *mm*).

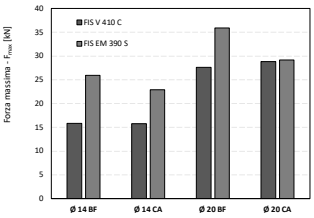
Connessione	F_{max} [kN]	k_1 [kN/mm]
V 14 BF	15.84	3.01
V 20 BF	27.62	4.75
EM 14 BF	25.97	8.97
EM 20 BF	35.90	8.39



Influenza tipologia connettore



Influenza diametro connettore



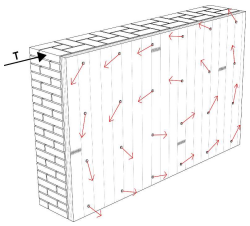
Influenza tipologia ancorante



IVAN GIONGO ROMA, 24 MAGGIO 2024

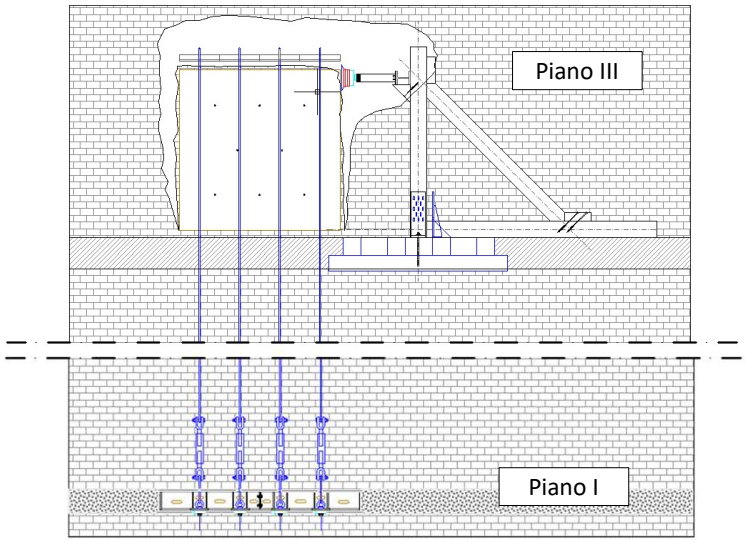
MIGLIORAMENTO SISMICO DI EDIFICI IN MURATURA CON PANNELLI LIGNEI

Fase 3 -Test sperimentali su pareti rinforzate



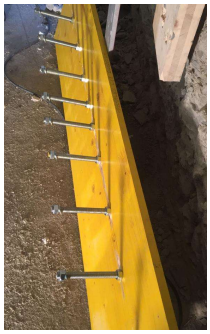
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TIMBER AND STRUCTURAL REHABILITATION RESEARCH GROUP

PROVE IN-SITU SU PARETI RINFORZATE CON PANNELLI CLT



IVAN GIONGO ROMA, 24 MAGGIO 2024

PROVE IN-SITU SU PARETI RINFORZATE CON PANNELLI CLT









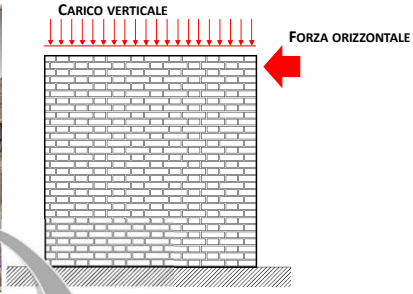


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PROVE IN-SITU SU PARETI RINFORZATE CON PANNELLI CLT



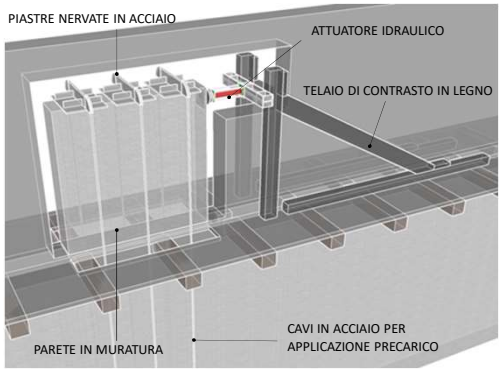






IVAN GIONGO ROMA, 24 MAGGIO 2024

PROVE IN-SITU SU PARETI RINFORZATE CON PANNELLI CLT





Pressione verticale necessaria per impegnare la resistenza a taglio della parete

Incrementi di carico fino a:

$T_{cavi} \approx 23\ kN$

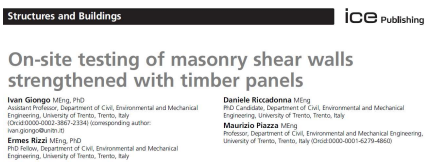
$\sigma_0 \approx 0.22\ MPa$





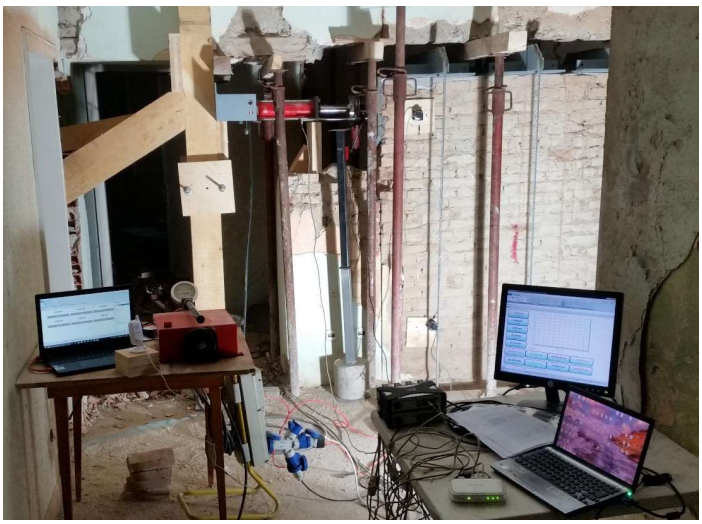
PROVE IN-SITU SU PARETI RINFORZATE CON PANNELLI CLT

PARETE 1	ORIGINALE	RIPARATA
PARETE 2	ORIGINALE	RIPARATA
PARETE 3	RINFORZATA	


Structures and Buildings ice Publishing

On-site testing of masonry shear walls strengthened with timber panels

Ivan Giongo MEng, PhD
Assistant Professor, Department of Civil, Environmental and Mechanical Engineering, University of Trento, Trento, Italy (Orcid:0000-0002-3867-2334) (corresponding author: ivan.giongo@unitn.it)
Ermes Rizzi MEng, PhD
PhD Fellow, Department of Civil, Environmental and Mechanical Engineering, University of Trento, Trento, Italy
Daniele Riccadonna MEng
PhD Candidate, Department of Civil, Environmental and Mechanical Engineering, University of Trento, Trento, Italy
Maurizio Piazza MEng
Professor, Department of Civil, Environmental and Mechanical Engineering, University of Trento, Trento, Italy (Orcid:0000-0001-6279-4866)

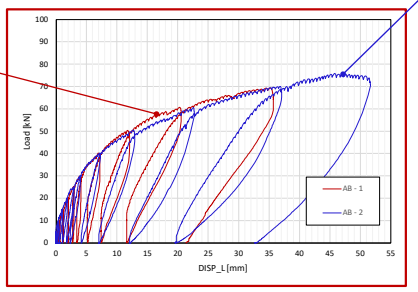


IVAN GIONGO ROMA, 24 MAGGIO 2024

PROVE IN-SITU SU PARETI RINFORZATE CON PANNELLI CLT

PARETE 1	ORIGINALE	RIPARATA
PARETE 2	ORIGINALE	RIPARATA
PARETE 3	RINFORZATA	







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PROVE IN-SITU SU PARETI RINFORZATE CON PANNELLI CLT

PARETE 1 → ORIGINALE → RIPARATA

PARETE 2 → ORIGINALE → RIPARATA

PARETE 3 → RINFORZATA

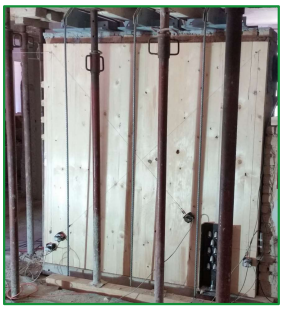


Pannelli CLT (3 strati)

Tipo di connettore		A	B
Lunghezza	[mm]	180	230
Lunghezza filetto	[mm]	100	160
Diametro filetto	[mm]	12.0	10.0
Diametro foro	[mm]	10	8
Resistenza a trazione**	[kN]	25	58

** Valori caratteristici

≈ 5 connettori / m²







CONNETTORE DA CEMENTO + RONDELLA

IVAN GIONGO ROMA, 24 MAGGIO 2024

PROVE IN-SITU SU PARETI RINFORZATE CON PANNELLI CLT

PARETE 1 → ORIGINALE → RIPARATA

PARETE 2 → ORIGINALE → RIPARATA

PARETE 3 → RINFORZATA



Pannelli CLT (3 strati)

Tipo di connettore		A	B
Lunghezza	[mm]	180	230
Lunghezza filetto	[mm]	100	160
Diametro filetto	[mm]	12.0	10.0
Diametro foro	[mm]	10	8
Resistenza a trazione**	[kN]	25	58

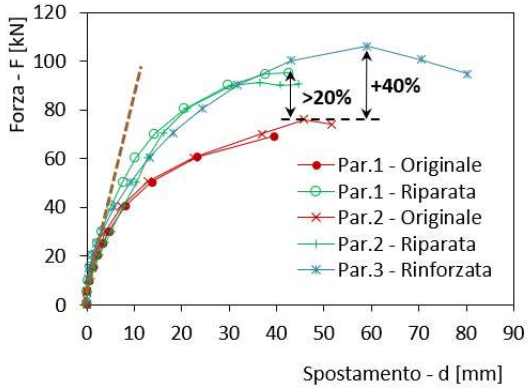
** Valori caratteristici

≈ 8 connettori / m²



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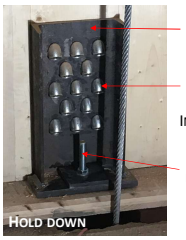
PROVE IN-SITU SU PARETI RINFORZATE CON PANNELLI CLT





PARETE	F_{max} [kN]	$K_{s\ UR}$ [kN/mm]	dr_{max}* [%]	$F_{max\ HD}$ [kN]	K_{HD} [kN/mm]
Par.1 – Orig.	69.3	6.62		--	--
Par.1 – Rip.	95.0	6.53		39.9	4.75
Par.2 – Orig.	75.9	5.94		--	--
Par.2 – Rip.	91.1	4.50	2.5	32.4	3.54
Par.3 – Rinf.	106.0	5.28	4.5	53.0	2.63

* I valori fanno riferimento alla deformazione max. raggiunta durante i test.



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PROVE IN-SITU SU PARETI RINFORZATE CON PANNELLI CLT

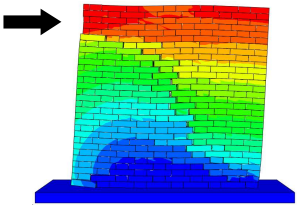


TEST 5 – Campione 3 (rinforzato)

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MIGLIORAMENTO SISMICO DI EDIFICI IN MURATURA CON PANNELLI LIGNEI

Fase 4 – Aggiornamento degli approcci di modellazione e sviluppo di metodi di calcolo



IVAN GIONGO ROMA, 24 MAGGIO 2024

AGGIORNAMENTO MODELLI NUMERICI | NUOVE ANALISI PARAMETRICHE



SISTEMA DI ANCORAGGIO DEL PANNELLO

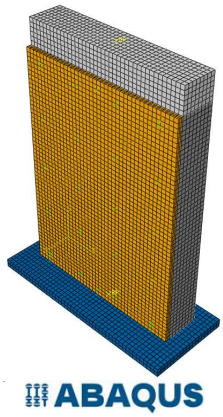
- Sistema di collegamento (CLT-HD-AB-HD+AB)
- Proprietà ancoraggio a trazione (HD1-HD2-HD3-HDR)
- Proprietà ancoraggio a taglio (AB1-AB2-AB3-ABR)

COLLEGAMENTO PANNELLO-MURO

- Proprietà connettore (K1-K2-K3-KR)
- Configurazione connettori (C1-C2-C3-C4-C5-C6-C7)

CARATTERISTICHE MURATURA

- Sforzo verticale (Q1-Q2-Q3-Q4)
- Proprietà meccaniche (M1-M2-M3)
- Spessore muratura (T1-T2-T3)
- Rapporto di forma (L1-L2-L3-L4-L5)

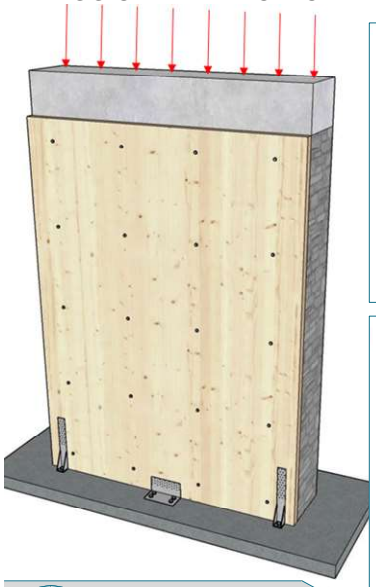


COMPDYN 2021
8th ECCOMAS Thematic Conference on
Computational Methods in Structural Dynamics and Earthquake Engineering
M. Papadrakakis, M. Fragiadakis (eds.)
Streamed from Athens, Greece, 28 - 30 June 2021

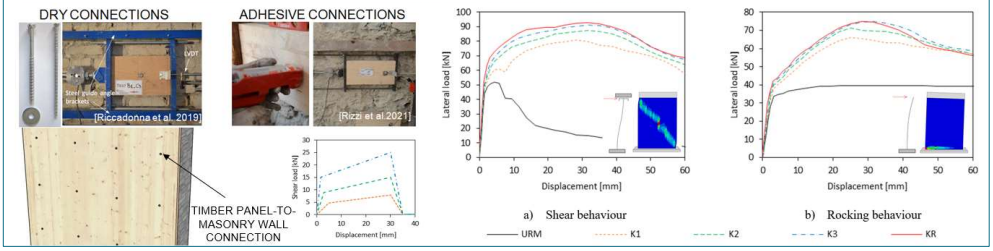
NUMERICAL STUDY ON SEISMIC RETROFIT OF URM WALLS USING TIMBER PANELS

D. Cassol[1], I. Giongo[1], and M. Piazza[1]

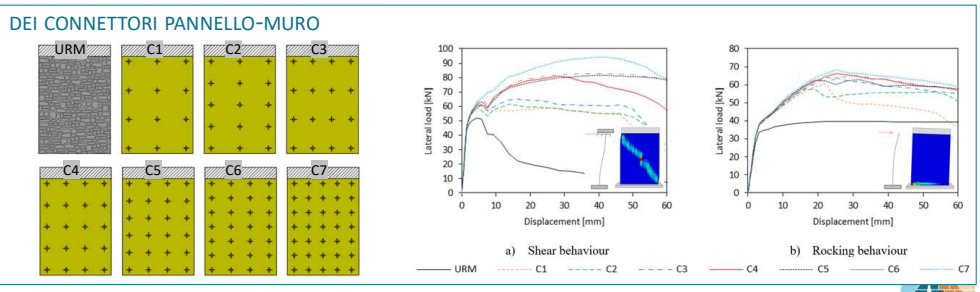
AGGIORNAMENTO MODELLI NUMERICI | NUOVE ANALISI PARAMETRICHE



PROPRIETÀ DEI CONNETTORI PANNELLO-MURO



DEI CONNETTORI PANNELLO-MURO

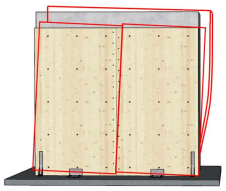


IVAN GIONGO ROMA, 24 MAGGIO 2024

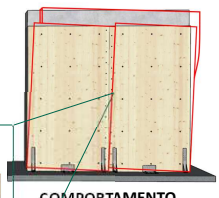
AGGIORNAMENTO MODELLI NUMERICI | NUOVE ANALISI PARAMETRICHE

Connessione pannello-pannello

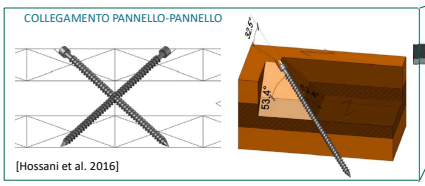
- nessun connettore (J0),
- collegamento pannello-pannello con viti incrociate
- collegamento rigido (JR).



COMPORTAMENTO «MONOLITICO»

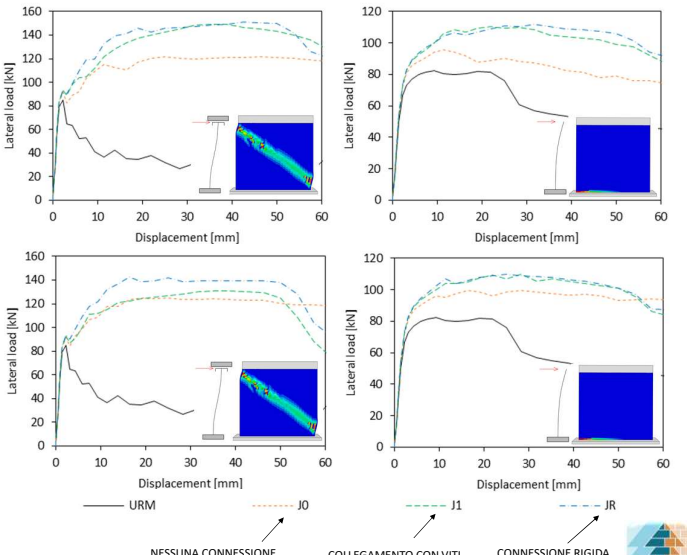


COMPORTAMENTO «MULTI-PANNELLO»



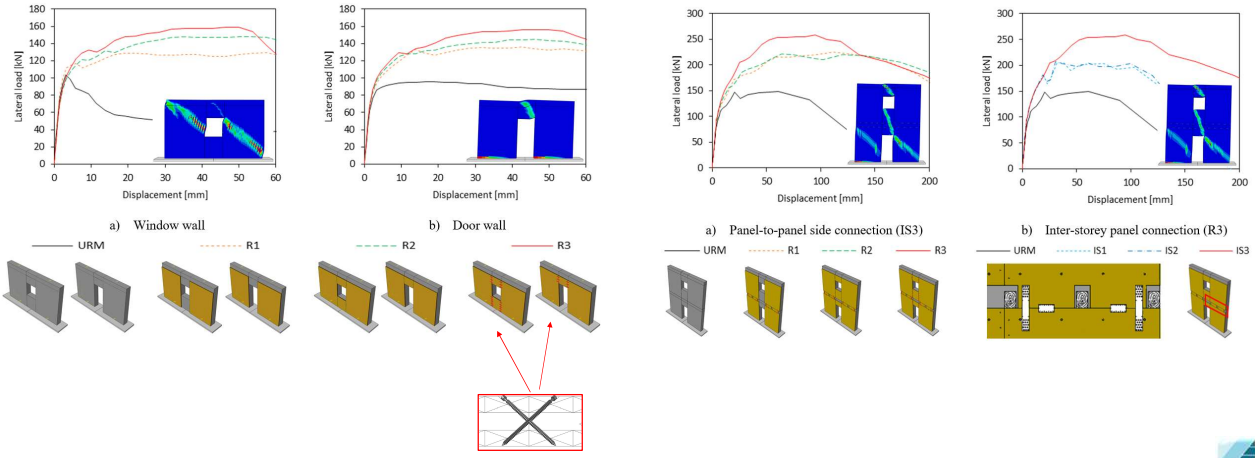
COMPORTAMENTO A TAGLIO

COMPORAMENTO A «ROCKING»



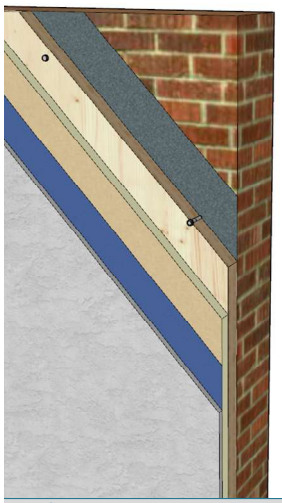
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AGGIORNAMENTO MODELLI NUMERICI | NUOVE ANALISI PARAMETRICHE



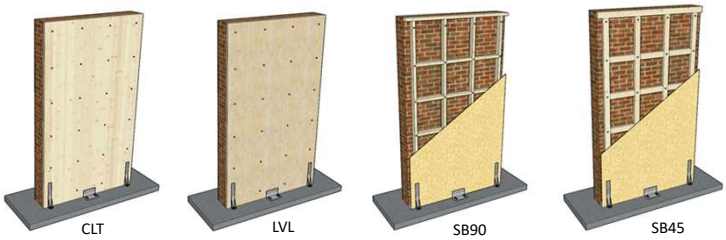
IVAN GIONGO ROMA, 24 MAGGIO 2024

STUDIATE DIVERSE CONFIGURAZIONI DI RINFORZO A «BASE-LEGNO»



PERF. SISMICA

PANNELLI LIGNEI "MASSICCI" | TELAIO & RIVESTIMENTO



PERF. ENERGETICA

DUE SCENARI APPLICATIVI:

- RINFORZO "INTERNO"
- RINFORZO "ESTERNO"

OBIETTIVI:

- Migliorare la prestazione "termo-fisica"
- Assicurare la durabilità
- Limitare la riduzione di volume interno (< 125 mm)

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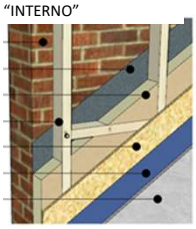
STUDIATE DIVERSE CONFIGURAZIONI DI RINFORZO A «BASE-LEGNO»

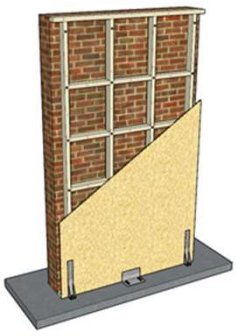
SB90

RINFORZO "INTERNO"

masonry wall
breathable membrane
PIR panel – 90 mm
strong-back 45x90 mm
OSB panel - 15 mm
vapour barrier
plasterboard – 12 mm

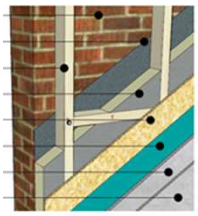






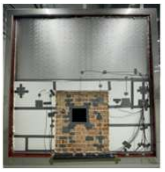
RINFORZO "ESTERNO"

masonry wall
breathable membrane
strong-back 45x90 mm
PIR panel – 90 mm
OSB panel - 15 mm
w., b. and r membrane
f. c. board – 15 mm
skim coating – 10 mm



Valutazione delle proprietà termofisiche delle pareti rinforzate mediante analisi in regime stazionario, periodico e impulsivo





Stato di fatto



Applicazione pannello in CLT



Applicazione isolante in fibra di legno

IVAN GIONGO ROMA, 24 MAGGIO 2024

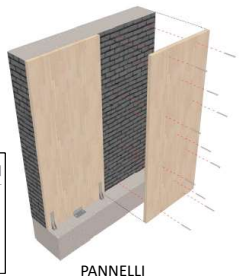
STUDIATE DIVERSE CONFIGURAZIONI DI RINFORZO A «BASE-LEGNO»


sustainability MDPI

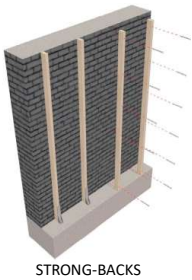
Article

Timber Based Integrated Techniques to Improve Energy Efficiency and Seismic Behaviour of Existing Masonry Buildings

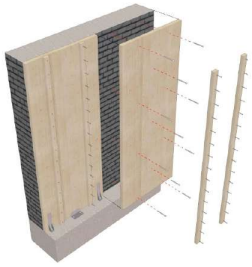
Matteo Busselli, Davide Cassol, Alessandro Prada and Ivan Giongo *

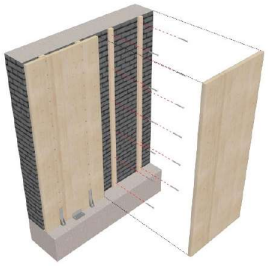


PANNELLI



STRONG-BACKS

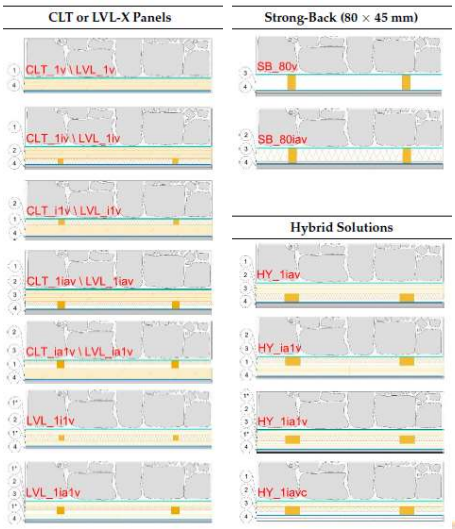






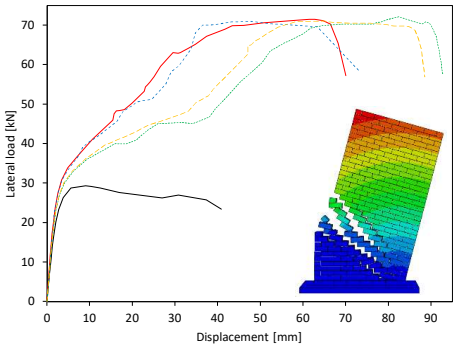
Pannello LVL – 27 mm

SOLUZIONI IBRIDE

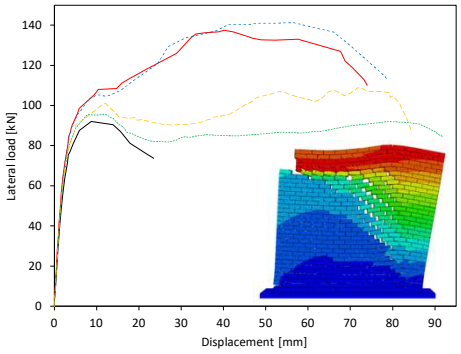


STUDIATE DIVERSE CONFIGURAZIONI DI RINFORZO A «BASE-LEGNO»

COMPORTAMENTO A "ROCKING"



COMPORTAMENTO A TAGLIO



- ✓ Aumento della capacità portante fino al 130%
- ✓ Aumento della capacità di deformazione fino al 220%



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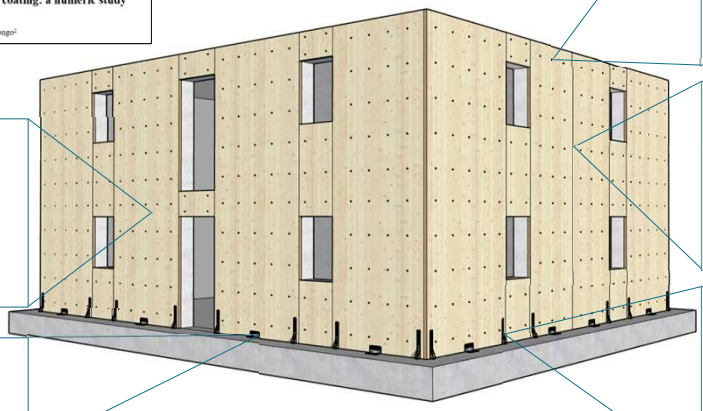
STUDIATE DIVERSE CONFIGURAZIONI DI RINFORZO A «BASE-LEGNO»

SAHC 2023

Seismic retrofit of a URM building with timber-based coating: a numeric study

Davide Cassol[1], Edoardo Nagliati[2] and Ivan Giongo[2]

«CAPPOTTO LIGNEO»



PANNELLO XLAM



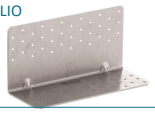
3 strati

spessore 60 mm

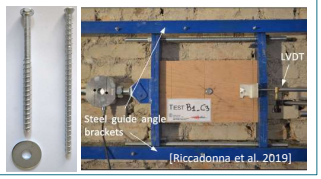
Strati esterni con tavole disposte verticalmente

ANCORAGGIO A TAGLIO

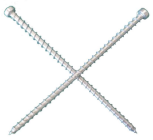
angle bracket



COLLEGAMENTO PANNELLO-MURATURA



CONNESSIONE PANNELLO-PANNELLO



ANCORAGGIO A TRAZIONE

hold-down



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STUDIATE DIVERSE CONFIGURAZIONI DI RINFORZO A «BASE-LEGNO»

ANALISI NON-LINEARE STATICA



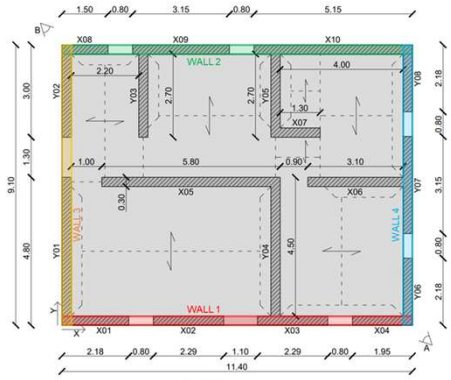
Studio delle singole pareti

Nessun vincolo tra solaio e parete



Comportamento dell'edificio

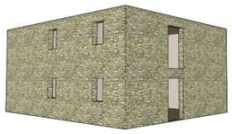
Rinforzo applicato alle sole pareti perimetrali



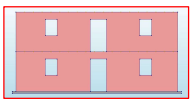
Building plan



3D viewpoint A



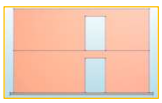
3D viewpoint B



PARETE 1



PARETE 2



PARETE 3

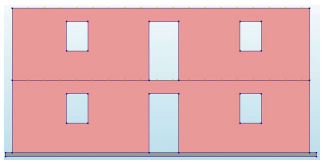


PARETE 4

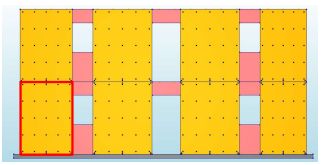
IVAN GIONGO ROMA, 24 MAGGIO 2024

STUDIATE DIVERSE CONFIGURAZIONI DI RINFORZO A «BASE-LEGNO»

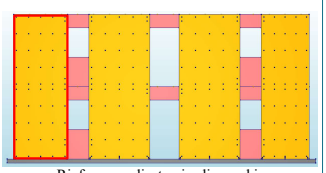
PARETE 1 | CONFIGURAZIONI DI RINFORZO



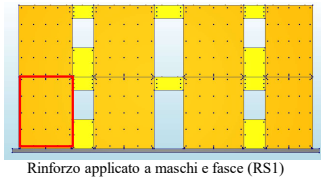
Parete in muratura non rinforzata (URM)



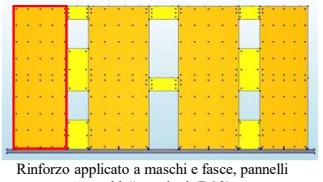
Rinforzo applicato ai soli maschi (RP1)



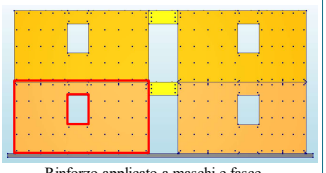
Rinforzo applicato ai soli maschi, pannelli continui (RP2)



Rinforzo applicato a maschi e fasce (RS1)



Rinforzo applicato a maschi e fasce, pannelli "maschio" continui (RS2)



Rinforzo applicato a maschi e fasce, "pareti monolitiche" (RS3)



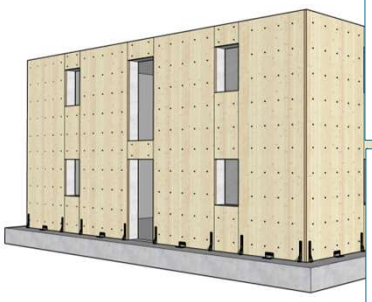
Configurazioni di rinforzo determinate tenendo in considerazione le dimensioni massime trasportabili



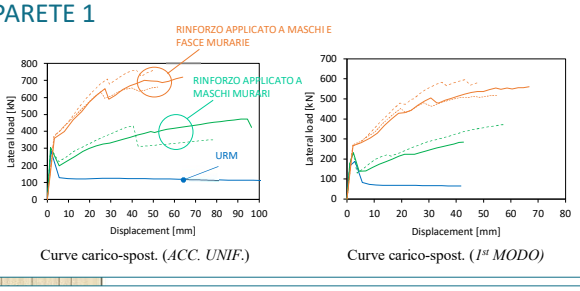


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TIMBER AND STRUCTURAL REHABILITATION RESEARCH GROUP

STUDIATE DIVERSE CONFIGURAZIONI DI RINFORZO A «BASE-LEGNO»

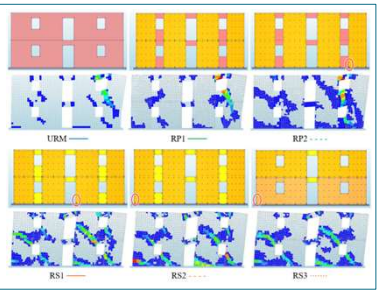


PARETE 1

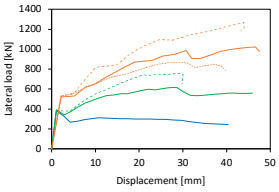


Curve carico-spost. (*ACC. UNIF.*)

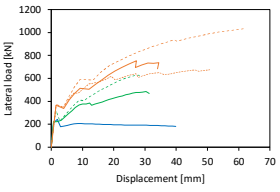
Curve carico-spost. (*1st MODO)*



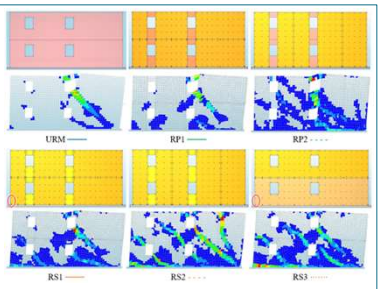
PARETE 2



Curve carico-spost. (*ACC. UNIF .*)

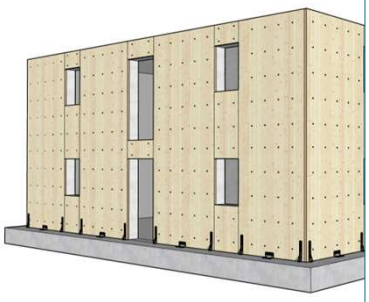


Curve carico-spost. (*1st MODO)*



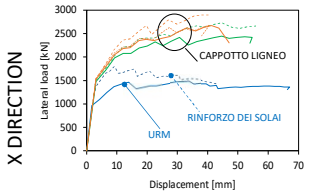
IVAN GIONGO ROMA, 24 MAGGIO 2024

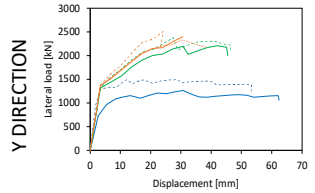
STUDIATE DIVERSE CONFIGURAZIONI DI RINFORZO A «BASE-LEGNO»



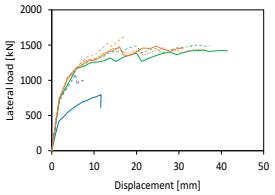
RISPOSTA DELL'INTERO EDIFICIO

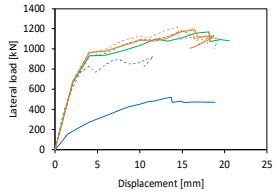
Lat. load – Disp. curves (*UNIF. ACC.)*





Lat. load – Disp. curves (*1st MODE)*





Modal analysis

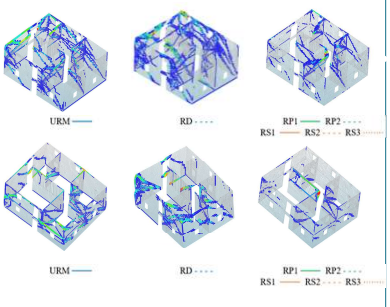
Configuration *URM*

Mode	Period (s)	Frequency (Hz)	UX	UY
1	0.136	7.34	0.3%	32.4%
2	0.111	8.98	45.8%	0.4%
3	0.100	10.03	0.2%	8.8%
4	0.094	10.68	6.3%	8.7%
5	0.086	11.69	0.1%	0.1%

Configurations *RD, RP1, RP2, RS1, RS2 and RS3*

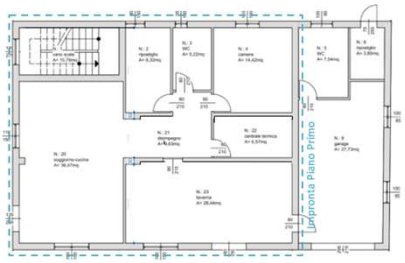
Mode	Period (s)	Frequency (Hz)	UX	UY
1	0.102	9.84	3.9%	60.5%
2	0.092	10.87	61.5%	2.8%
3	0.075	13.33	1.4%	4.6%
4	0.069	14.41	1.6%	0.2%
5	0.054	18.35	0.1%	0.9%

Note: *UX* = Modal mass participation to *X* direction, *UY* = Modal mass participation to *Y* direction.



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CASO STUDIO | ADEGUAMENTO SISMICO DI UN EDIFICIO RESIDENZIALE



Pianta Piano Terra



Adeguamento sismico di edifici esistenti in muratura con pannelli XLAM: un caso studio

Gianni Schiro, PhD, Ingegnere Strutturista - ReWiS Srl; Ivan Giongo, Professore Associato - Università degli Studi di Trento

Ringraziamento a Ing. G. Schiro (ReWIS)

ALCUNI DATI

- ✓ Due piani (pianta 17.6 m x 10.7 m)
- ✓ Muratura piano terra: blocchi forati di calcestruzzo (spessore 30 cm)
- ✓ Muratura primo piano: laterizio semipieno (spessore 33 cm)
- ✓ Secondo solaio fuori terra: latero-cemento senza cappa collaborante, poggia su tramezze di spessore 10 cm
- ✓ Copertura tavelloni in laterizio poggianti su frenelli in laterizio forato

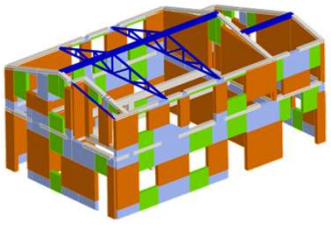
REQUISITI/VINCOLI PROGETTUALI

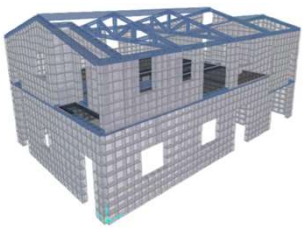
- ✓ Ampliamento volume abitativo a primo piano (adeguamento)
- ✓ Intervento di rinforzo applicabile solo dall'esterno (piano terra abitato)

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CASO STUDIO | ADEGUAMENTO SISMICO DI UN EDIFICIO RESIDENZIALE

STATO DI FATTO


MODELLO A MACROELEMENTI


MODELLO A SHELL

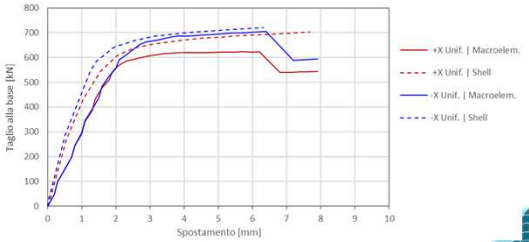
MODELLO A "MACROELEMENTI"

Modo	T [s]	Mx [%]	∑Mx [%]	My [%]	∑My [%]
1°	0.22	14.51	14.51	55.31	55.31
2°	0.18	72.08	86.59	23.44	78.75
3°	0.14	9.30	95.89	16.24	94.99

MODELLO A SHELL

Modo	T [s]	Mx [%]	∑Mx [%]	My [%]	∑My [%]
1°	0.24	16.00	16.00	57.23	57.23
2°	0.21	74.15	90.15	17.52	74.75
5°	0.14	1.75	92.15	14.59	91.82

Analisi Locali:	▪ Stato limite di salvaguardia della vita (SLV): $\zeta_{E,SLV} = 0.95$ ▪ Stato limite di danno (SLD): $\zeta_{E,SLD} = 1.30$
Analisi Globali:	▪ Stato limite di salvaguardia della vita (SLV): $\zeta_{E,SLV} = \mathbf{0.455}$ ▪ Stato limite di danno (SLD): $\zeta_{E,SLD} = 0.652$

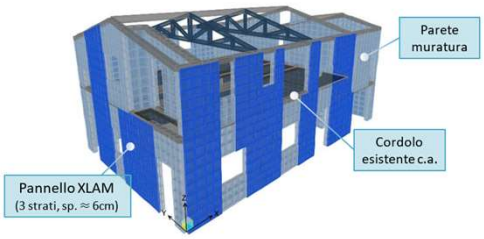


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CASO STUDIO | ADEGUAMENTO SISMICO DI UN EDIFICIO RESIDENZIALE

VALUTAZIONI PRELIMINARI

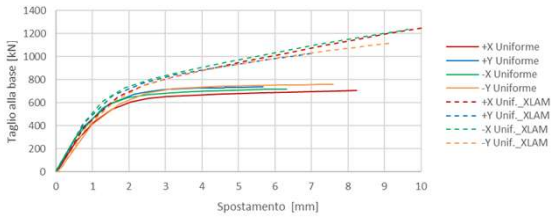
- ✓ sistemi "maschio-fascia" ibridi (accoppiamento dei "maschi" in XLAM garantito dal cordolo in c.a. e dalle fasce murarie)
- ✓ pannelli XLAM «corti» ma continui da terra fino al cordolo (4 m)
- ✓ collegamento XLAM-edificio solo a livello del cordolo (barre in acciaio
- ✓ ancoraggio a terra con piastre metalliche saldate/bullonate al cordolo di base delle pareti e fissate al pannello ligneo tramite viti a tutto-filetto



DIVERSE CONFIGURAZIONI DI RINFORZO



CONFIGURAZIONE A



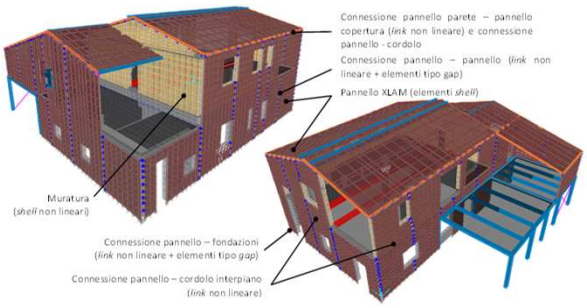
Incremento > 70% del taglio resistente alla base

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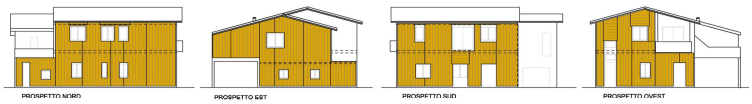
CASO STUDIO | ADEGUAMENTO SISMICO DI UN EDIFICIO RESIDENZIALE

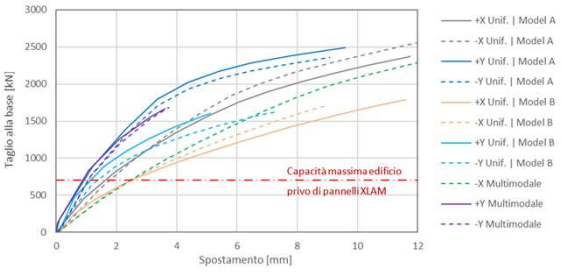
SOLUZIONE FINALE

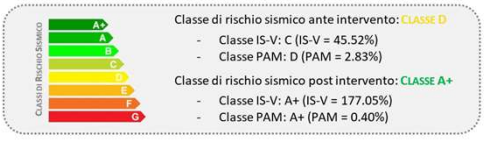
- ✓ Modifiche architettoniche → revisione sostanziale del progetto
- ✓ Nuova terrazza parzialmente coperta in adiacenza (struttura intelaiata in acciaio «tamponata» con pannelli XLAM, soletta in lamiera grecata e getto collaborante)
- ✓ Nuovi modelli numerici
- ✓ Collegamenti in campo elastico



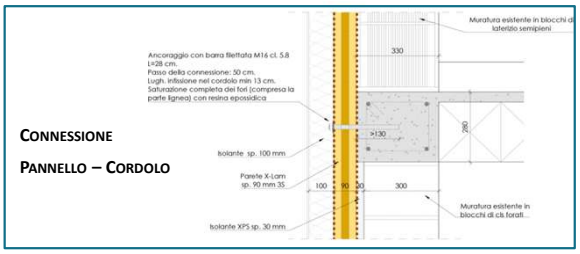
SCHEMA DI TAGLIO DEI PANNELLI





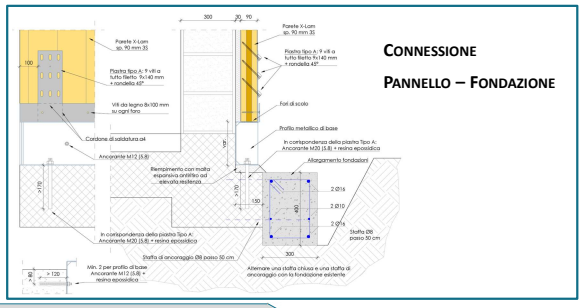


CASO STUDIO | ADEGUAMENTO SISMICO DI UN EDIFICIO RESIDENZIALE



CONNESSIONE

PANNELLO – CORDOLO



CONNESSIONE

PANNELLO – FONDAZIONE









Immagini dell'intervento in fase di realizzazione (cortesia di Ing. Artuso)

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MIGLIORAMENTO SISMICO DI EDIFICI INTELAIATI IN CALCESTRUZZO ATTRAVERSO L'USO DI PANNELLI LIGNEI



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STRUTTURE IN C.A. TAMPONATE | CRITICITÀ

Collasso dei tamponamenti in muratura





Crisi a taglio dei pilastri





Meccanismi di “piano soffice”

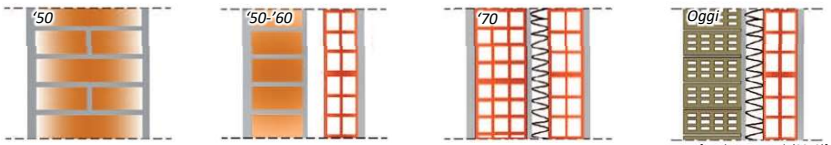




RUOLO DEI TAMPONAMENTI







[Verderame et al. (2012)]

- **Tipicamente non considerati** nei modelli di calcolo (no ruolo strutturale)

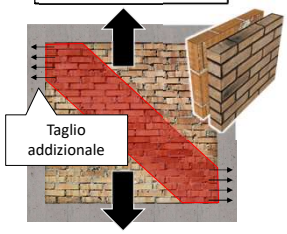




- **Influenzano la risposta** degli edifici
  - *In termini di **resistenza e rigidezza***
  - *Modificano il **periodo fondamentale** della struttura e quindi la domanda sismica*
  - *Trasmettono **azioni taglianti aggiuntive***
  - *Modificano sensibilmente il comportamento sismico e la **modalità di collasso***

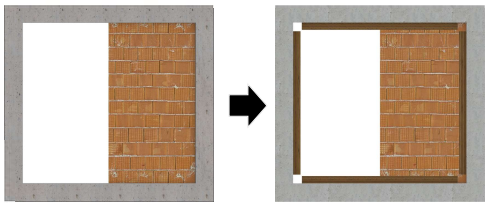
INTERVENTO PROPOSTO

RC-TP
Reinforced Concrete-Timber Panels



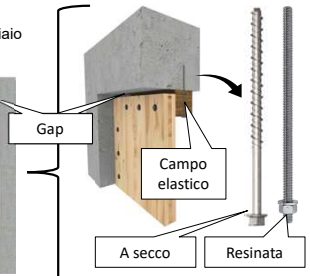
RC-TPext
Reinforced Concrete-external Timber Panels

- Rimozione di uno o più paramenti
- Installazione controtelaio in legno
- Inserimento pannello CLT
- Utilizzo di connettori in acciaio
- *Gap* tra pannello e telaio

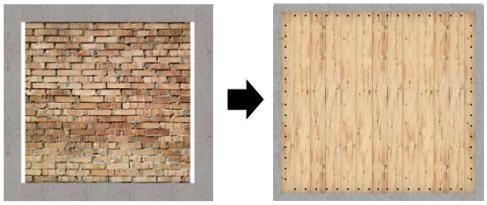


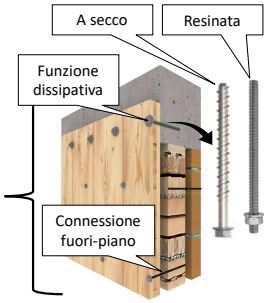
RIDUZIONE SPESSORE E MASSA SISMICA

CONTRIBUTO RESISTENZA AD AZIONI VERTICALI



- Taglio laterale del tamponamento
- Applicazione pannello in CLT dall'esterno
- Utilizzo di connettori in acciaio







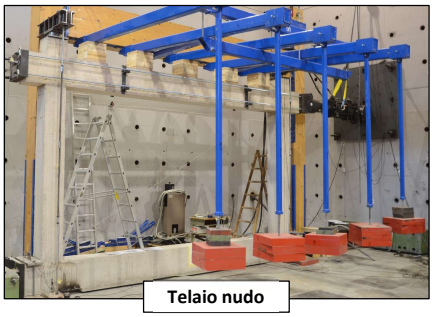
Smiroldo F, Paviani I, Giongo I, Zanon S, Albatici R, Piazza M.: An Integrated Approach to Improve Seismic and Energetic Behaviour of RC Framed Buildings Using Timber Panels. Sust, 2021
Smiroldo F., Kallioras S., Bournas D.A., Piazza M., and Giongo I.: Pannelli XLAM per il miglioramento sismico e energetico di edifici in CA esistenti, Ingenio.it, 2022
Smiroldo F, Giongo I, Piazza M. Use of timber panels to reduce the seismic vulnerability of concrete frame structures. Engineering Structures, 2021

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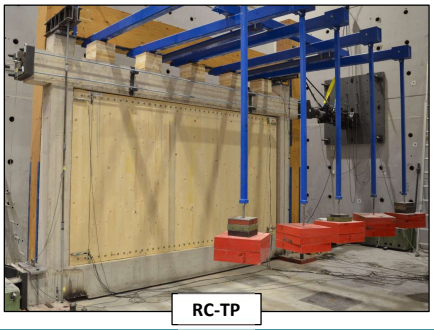
TEST SPERIMENTALI

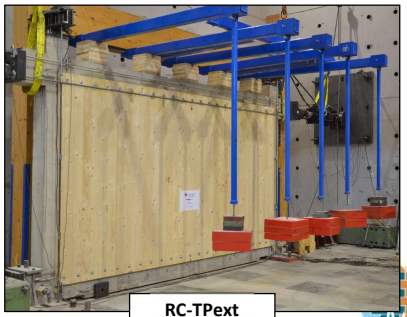
- Quattro telai isolati monopiano a una campata
- Analisi nel piano cicliche quasi statiche
  - *Telaio nudo: campo elastico*
  - *Altre configurazioni: fino a collasso*




Telaio nudo


Tamponato in muratura


RC-TP


RC-TPext

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TEST SPERIMENTALI – CARATTERIZZAZIONE DEI MATERIALI



Calcestruzzo



Acciaio



Muretti in laterizio





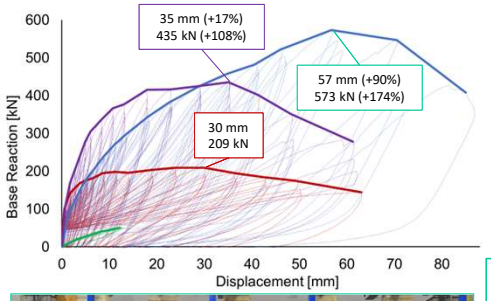


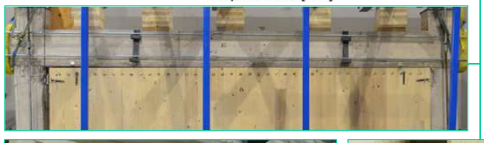
Connessioni

Smiroldo F., Sommacal G., Kallioras S., Bournas D.A., Piazza M., and Giongo I.: Material Characterisation for the Numerical Modelling of a Timber-Based Seismic Retrofit for RC Buildings, Proceedings of the XIX ANIDIS Conference, Seismic Engineering in Italy, Torino, Italy, 2022.

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TEST SPERIMENTALI

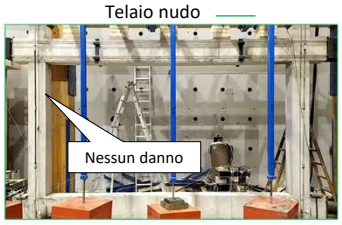




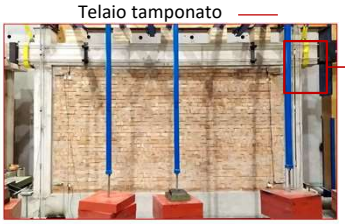




Telaio nudo



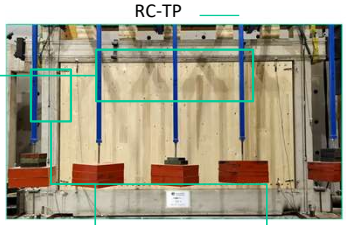
Telaio tamponato



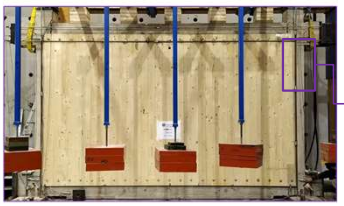


Rottura a taglio

RC-TP



RC-TPext





Danneggiamento flessionale



Danneggiamento flessionale



Danni da contatto dopo chiusura gap

Tamponato



RC-TPext



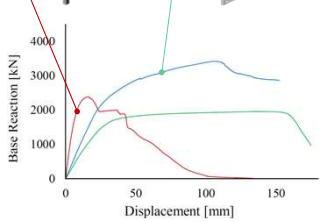


APPLICAZIONE DEL SISTEMA DI RINFORZO A CASI-STUDIO

Edificio Residenzale
Bonefro (BC)
1983

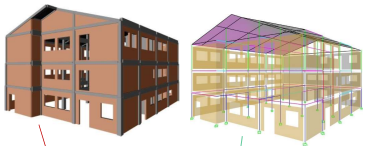


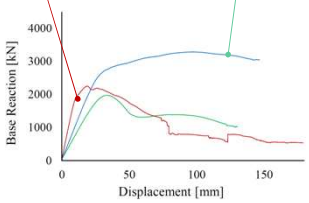




Scuola Primaria "Pietro Santini"
Loro Piceno (MC)
Fine anni '60

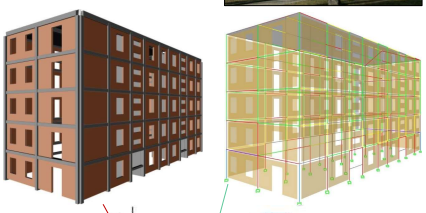


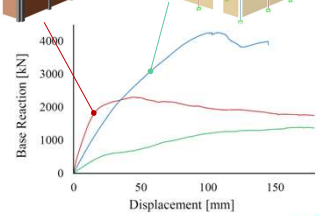




EDIFICIO ex I.A.C.P.
Torino (TO)
1955







CASO STUDIO – INTERVENTO INTEGRATO

Edificio residenziale (ReLUIS)
Torino – 1955

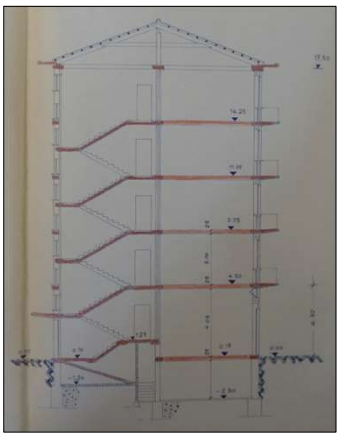
- Alta vulnerabilità sismica
- Scarse performance energetiche

Stato di fatto









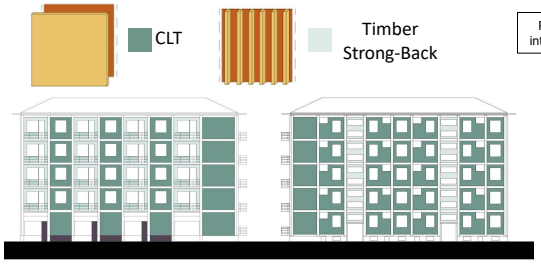


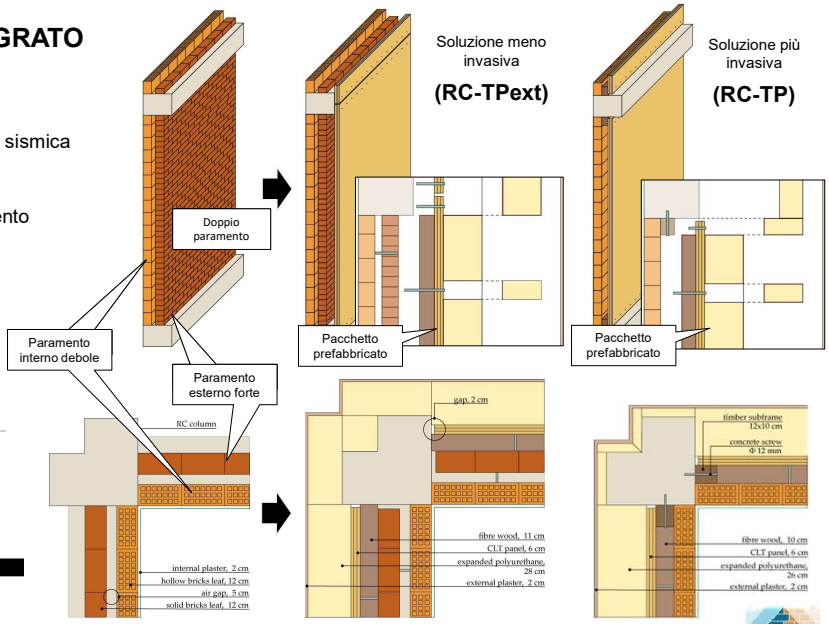


CASO STUDIO – INTERVENTO INTEGRATO

Due strategie di intervento con differente livello di invasività

- Riduzione della vulnerabilità sismica
- Miglioramento energetico
- Prefabbricazione dell'intervento

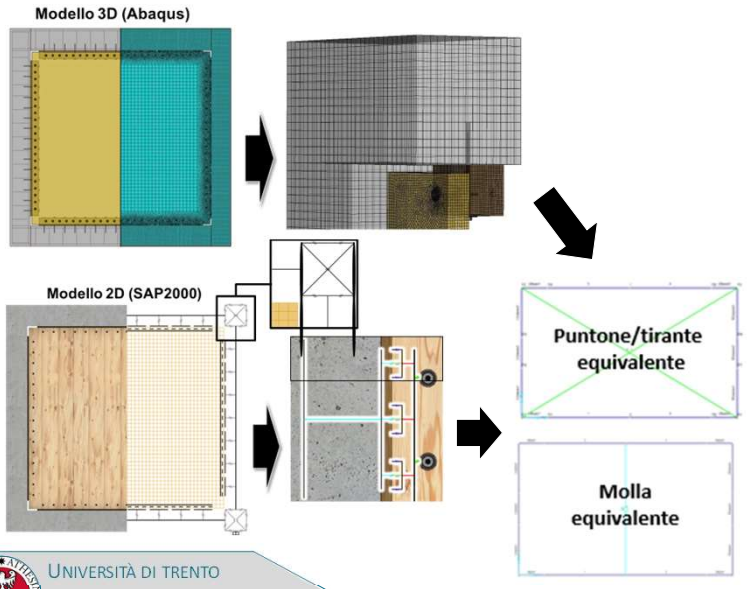


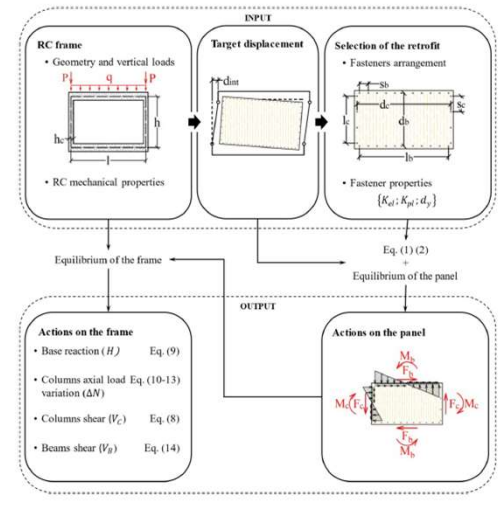


Smiroldo F, Paviani I, Giongo I, Zanon S, Albatici R, Piazza M.: An Integrated Approach to Improve Seismic and Energetic Behaviour of RC Framed Buildings Using Timber Panels. Sust., 2021
Smiroldo F, Bartolotti A, Colombo M, and Giongo I: Timber-based seismic retrofit of a 5-storey RC structure built in 1955, In NZSEE Conference, Auckland, New Zealand, 2023

IVAN GIONGO ROMA, 24 MAGGIO 2024

MODELLI NUMERICI E FORMULAZIONI ANALITICHE







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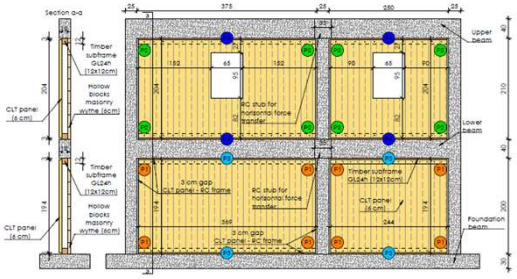
ULTERIORE VALIDAZIONE SPERIMENTALE

ERIES-STRONG

SUSTAINABLE TIMBER RETROFIT OF CONCRETE BUILDINGS

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ERIES ENGINEERING RESEARCH INFRASTRUCTURES FOR EUROPEAN SYNERGIES





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PROGETTO RELUIS-DPC 2022-2024

WP5 | INTERVENTI DI RAPIDA ESECUZIONE A BASSO IMPATTO ED INTEGRATI

Coordinatori: Francesca da Porto e Andrea Prota

Task 5.1 – Interventi integrati e sostenibili per la riqualificazione di edifici esistenti

UR - UNIBG
Coordinatrice: **A. Marini**
Membri UR: J. Zanni, S.Labò, C. Passoni, S. Cademartori, M. Milesi, P. Riva, A. Belleri

UR - UNICT
Coordinatore: **I. Caliò**
Membri UR: F. Cannizzaro, S. Liseni, G. Occhipinti, B. Pantò, V. Cusmano, I. Fiore

UR – UNIPD-b
Coordinatrice: **M.R. Valluzzi**
Membri UR: L. Sbrogiò, M. Salvalaggio

UR - UNIPV
Coordinatore: **F. Graziotti**
Membri UR: A. Penna, N. Damiani, G. Guerrini

UR - UNITN
Coordinatore: **I. Giongo**
Membri UR: M. Piazza, R. Albatici, M. Dalprà, A. Prada, G. Maracchini, F. Smiroldo, D. Cassol, G. Sommacal, A. Bartolotti

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PROGETTO RELUIS-DPC 2022-2024 | WP 5 (Interventi di rapida esecuzione a basso impatto e integrati)

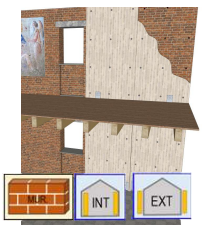
Aspetti che caratterizzano le diverse tipologie di intervento

TIPOLOGIA EDIFICIO	OBIETTIVO RINFORZO	POSIZIONE RINFORZO	TIPOLOGIA RINFORZO
✓ Muratura ✓ C.A.	✓ Nel piano & fuori piano ✓ Fuori piano	✓ Interno ✓ Esterno	✓ Puntuale ✓ Placcaggi {Pannelli / Telai/ibridi} ✓ Esoscheletri/endos.

Valutazione dell'efficacia degli interventi

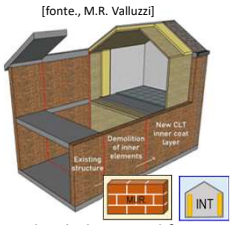
ANALISI DI «COMPONENTI»	ANALISI EDIFICI	INTERVENTI INTEGRATI	INDICAZIONI PROGETTUALI
✓ Sperimentali ✓ Numeriche	✓ Casi studio ✓ Realizzazioni	✓ Eff. energetico ✓ Impatto ✓ Prefabbricazione	✓ Metodi analitici ✓ Modelli numerici semplificati

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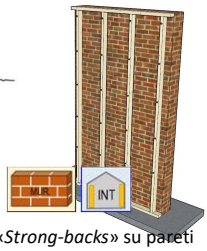


Placcaggi su murature

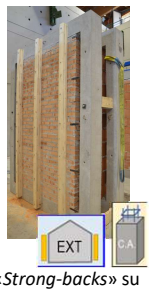
[fonte., M.R. Valluzzi]



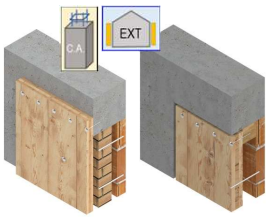
Endoscheletri in edifici in muratura (*nested build.*)



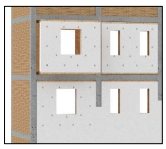
«*Strong-backs*» su pareti in muratura

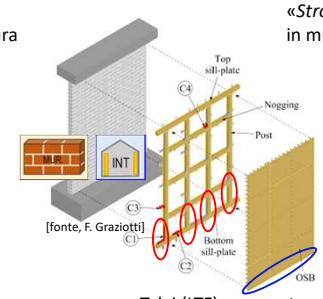


«*Strong-backs*» su tamponamenti

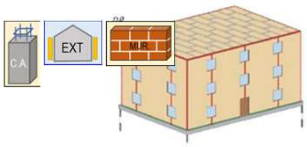


Placcaggi su edifici C.A.



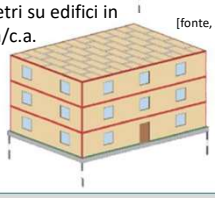


[fonte, F. Graziotti]
Telai (LTF) su murature



Esoscheletri su edifici in muratura/c.a.

[fonte, A. Marinii]



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GRAZIE PER L'ATTENZIONE!

…un grazie particolare a:


SCHIRO GIANNI


RIZZI ERMES


RICCADONNA DANIELE


GASPARI ANDREA


SMIROLDO FRANCESCO


CASSOL DAVIDE


SOMMACAL GIOVANNI


SOFIA GELMETTI


DANIELE SALZANI


GIADA ZAMMATTIO