Progetto DPC-ReLUIS 2022-2024 WP 13

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

Task 4 – Riduzione della vulnerabilità sismica di edifici esistenti
Task 5 – Influenza della durabilità sulle prestazioni delle costruzioni in legno

UR: UNINA – Responsabile scientifico: Prof. Beatrice Faggiano
Componenti di Unità di ricerca: PhD Eng. Giacomo Iovane, Dante Marranzini

TASK 4
Development of the steel collar connection for composite timber-concrete floors

Objectives and achievements

Goals of the research
- Evaluation of the mechanical behaviour of the connection;
- Design criteria proposal.

Methodology
- Analytical approach;
- Monotonic numerical analysis.

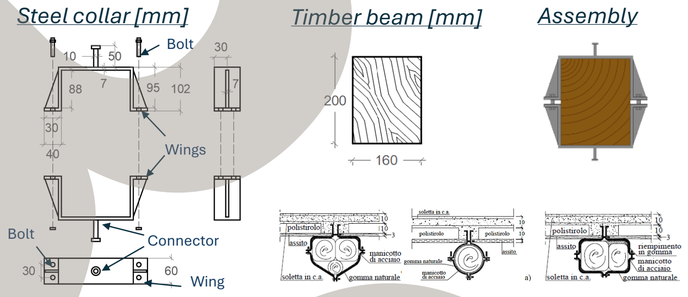
Main issues
- Suitability of steel collar for composite timber-concrete system.

General future improvements
- Extension of the numerical analysis;
- Cyclic experimental test;
- Improvement of the collar system detail;
- Robustness design.

The Collar System Concept

Faggiano et al, 2021

Steel collar [mm] *Timber beam [mm]* *Assembly*



Application at the Royal Palace (Naples)

PROHITECH 2004-2009

Reference Experimental Campaign

DECIVIL - LISBON

Push-out test
2004-2005
Rectangular specimen, single collar *(new pine)*

Push-out test
2004-2005
Circular specimen with single collar *(antique chestnut)*

Push-out test
2006
Rectangular specimen, double collar *(new pine)*

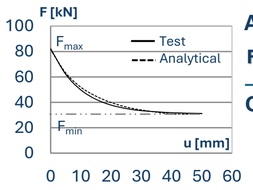
Bending test
2010
Timber concrete composed floor with circular section beams *(ancient chestnut)*

Bending test
2007
Timber concrete composed beam with rectangular section *(new pine)*

DIST - NAPLES

Design criteria

Iovane et al, 2024



Analytical friction law

$F(s) = F_{min} + (F_{max} - F_{min})e^{-ds}$

s: *sliding*
d: *coefficient to calibrate*

Capacity design

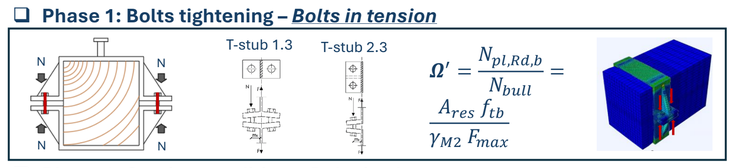
Overstrenght factor

$\Omega_{max} = \Omega'' ; \Omega'$

Design forces

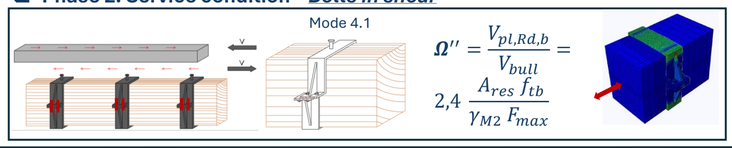
$S_{Ed,\Omega} = S_{Ed}\ \gamma'_{Rd}\ \gamma_{Rd}\ \Omega_{max}$

❑ **Phase 1: Bolts tightening – *Bolts in tension***



$\Omega' = \frac{N_{pl,Rd,b}}{N_{bull}} = \frac{A_{res}\, f_{tb}}{\gamma_{M2}\, F_{max}}$

❑ **Phase 2: Service condition – *Bolts in shear***



$\Omega'' = \frac{V_{pl,Rd,b}}{V_{bull}} = 2{,}4\ \frac{A_{res}\, f_{tb}}{\gamma_{M2}\, F_{max}}$

Objectives and achievements

Goals of the research
- Definition of timber-based systems for the structural and energetic retrofitting of existing constructions;
- Evaluation of overall integrated systems performance;
- Design criteria proposal.

Methodology
- Numerical analysis.

Main issues
- Suitability of timber-based systems for retrofitting of existing structures.

General future improvements
- Extension of numerical investigations;
- Experimental tests;
- Guidelines for the design of timber-based system for retrofitting of existing buildings.

Integrated Retrofit Strategy

Iovane et al, 2022

Timber-based structures

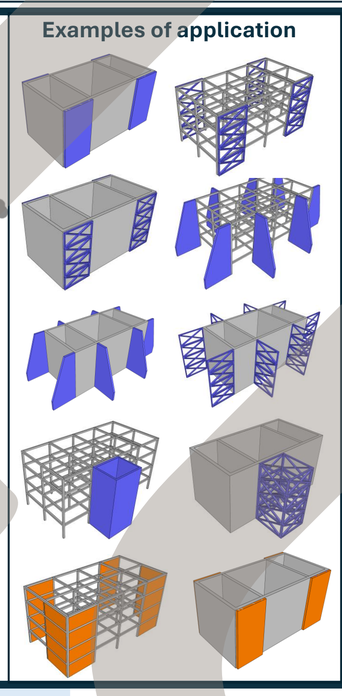
Wooden-based fiber-reinforced mortars (WBF)

Structural-plus-energy retrofitting solutions

Timber-based systems

- Timber-based structures
  - Endoskeleton
    - 2D//
    - 2D⊥
  - Esoskeleton
    - 2D
    - 3D
      - $3D_{Partial}$
      - $3D_{Spatial}$
- Wooden-based fiber-reinforced mortars (WBF)
  - Endoskeleton
  - Esoskeleton
  - Local intervention

Examples of application



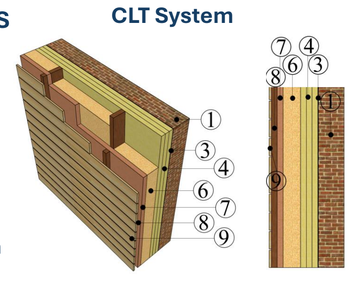
TASK 4
Timber-based systems for retrofitting of existing structures

Technological Details

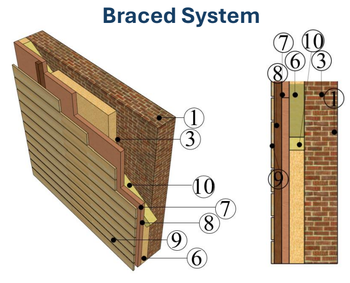
Legend

1. Masonry structure;
2. Vapor control / airtightness membrane;
3. CLT panels;
4. Light frame structure or braced frame;
5. Flexible wood fibre insulation between timber-joints;
6. Insulating wood fibre sheathing;
7. Drained and ventilated cavity;
8. Horizontal weatherboarding fixed to battens;
9. Timber braces;
10. Wooden-based fiber-reinforced mortar layer
11. Joint restoration with wooden-based fiber-reinforced mortar

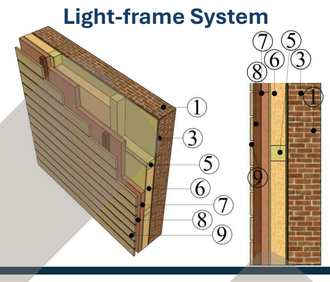
CLT System



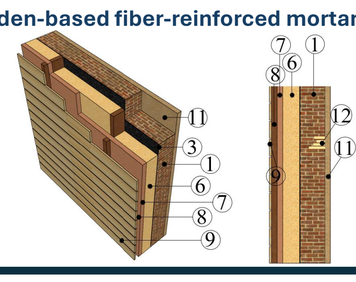
Braced System



Light-frame System



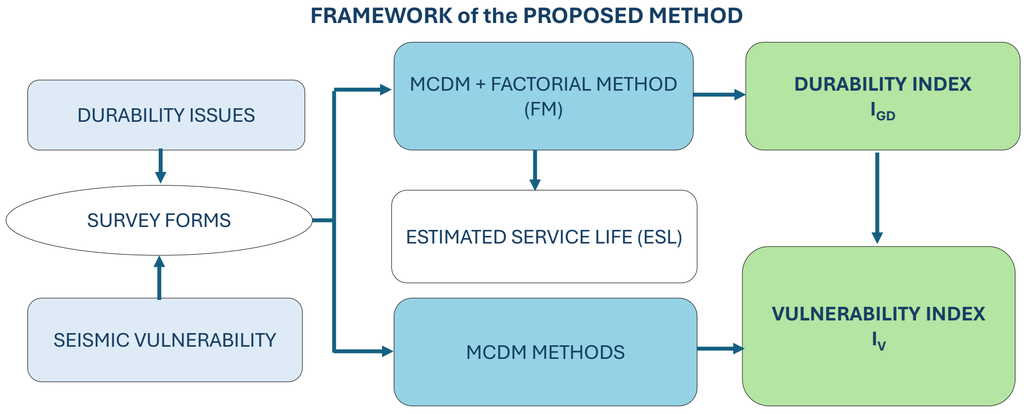
Wooden-based fiber-reinforced mortar



TASK 5
Influence of durability on the performance of timber constructions

Structural Vulnerability Assessment for Seismic and Environmental Actions

FRAMEWORK of the PROPOSED METHOD



Marranzini et al, 2021, 2022, 2023

Quick level method for seismic vulnerability assessment

Framework of the method

Criteria	C1	C2	C3
S1	0.074	0.044	0.039
S2	0.074	0.041	0.039
S3	0.074	0.039	0.039
....	....	....	....
S9	0.056	0.023	0.039
S10	0.044	0.019	0.039
S11	0.041	0.018	0.039

I_V

A. Definition of **vulnerability criteria** for Large-span timber buildings based on CARTIS

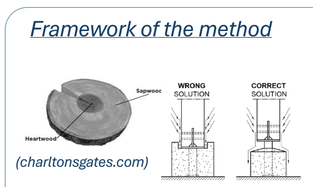
B. Quantification and ranking of **vulnerability criteria**

C. On-site **data acquisition** through **CARTIS form** *(Faggiano et al., 2021)*

D. Estimation of the **seismic vulnerability index I_V**

Method for estimated service life (ESL) and durability index (I_{GD}) assessment

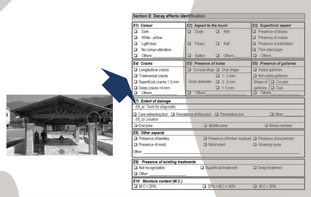
Framework of the method

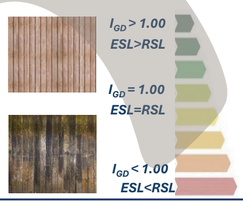


(charltonsgates.com)

(modified from Piazza et al., 2005)

Criteria	Qualitative value	Quantitative value
A1	Heavy timber	1
	Timbe-based product	3
	Sapowood	1
	Sapowood in higher percentage	2
A2	Not-differiented	3
	Hardwood in higher percentage	4
	Hardwood	5





A. Qualitative definition of **durability sub-factors (criteria)** for timber structures

B. Quantitative evaluation and **ranking of durability sub-factors** for timber structures

C. On-site data acquisition through **SHA-TS form**

D. Estimation of the I_{GD} and **Estimated Service Life ESL=RSL· I_{GD}**

Main references

- B. Faggiano, G. Iovane, A. Marzo, M. Grippa, L. Calado, F.M. Mazzolani (2021). Reinforcement of ancient floors by timber-concrete composite systems with collar connector. In: proceedings of the Institution of Civil Engineers (ICE): Structures and Buildings, ISSN 0965-0911, Special Issue "Role of structural timber in the earthquake protection of masonry buildings" ICE Publishing, Champions: Maurizio Piazza, Jason Ingham and Ivan Giongo, vol 174, Issue 6, pp 491–503, June 2021. https://doi.org/10.1680/jstbu.19.00105.
- B. Faggiano, M. Nicolella, G. Iovane, D. Marranzini (2022). A survey form for the structural health assessment of timber constructions. In: 6th International Conference on Structural Health Assessment of Timber Constructions (SHATIS22), 7-9 September 2022, Prague, Czech Republic.
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- D. Marranzini, G. Iovane, F. Cozzolino, B. Faggiano (2022). In situ assessment of mechanical properties of timber using the drilling resistance method. In: 6th International Conference on Structural Health Assessment of Timber Constructions (SHATIS22), 7-9 September 2022, Prague, Czech Republic.
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- G. Iovane, B. Faggiano, M. Lombardi, P. Carbone, R. Landolfo, F.M. Mazzolani (2024). Design of steel collar connectors for timber concrete composite floors. In: 11th International Conference on Behaviour of Steel Structures in Seismic Areas (STESSA 2024), 8-10 July, 2024, Salerno, Italy.

Development of a survey form and manual to support the diagnosis of timber decay phenomena

Faggiano et al, 2022
Marranzini et al, 2021, 2022, 2023

Description of the survey-form: Section E

Section E: Decay effects identification

E1) Colour	E2) Aspect to the touch	E3) Superficial aspect
❑ Dark	❑ Dusty ❑ Wet	❑ Presence of stripes
❑ White - yellow		❑ Presence of cracks
❑ Ligth blue	❑ Floury ❑ Soft	❑ Presence of exfoliation
❑ No colour alteration		❑ Thin intact layer
❑ Others _____	❑ Buttery ❑ Others_____	❑ Others_____

E4) Cracks	E5) Presence of holes	E6) Presence of galleries
❑ Longitudinal cracks	❑ Circural shape ❑ Oval shape	❑ Visible galleries
❑ Trasnversal cracks	❑ 1 - 2 mm	❑ Not visible galleries
❑ Superficial cracks 1-3 mm	Holes diameter ❑ 3 - 5 mm	Shape of ❑ Circular
❑ Deep cracks >4 mm	❑ > 5 mm	galleries ❑ Oval
❑ Others_____	❑ Others_____	❑ Others_____

E7) Extent of damage

E8_a) Tools for diagnostic

❑ Core extracting tool ❑ Resistance drilling tool ❑ Penetration tool ❑ Other:_____

E8_b) Location

❍ End zone ❍ Middle zone ❍ Whole member

E8) Other aspects

❑ Presence of beetles ❑ Presence of timber residuals ❑ Presence of excrement
❑ Presence of mold ❑ Mold smell ❑ Gnawing noise
Other: _____

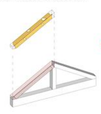
E9) Presence of existing treatments

❑ Not recognizable ❑ Superficial treatment ❑ Deep treatment
❑ Other: _____

E10 Moisture content (M.C.)

❑ M.C.< 20% ❑ 20% < M.C.< 30% ❑ M.C.> 30%

E) Decay effects identifcation

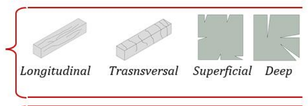


E1) Colour

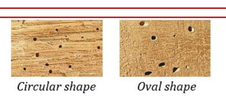
E2) Aspect to the touch

E3) Superficial aspect

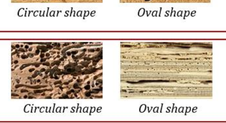
E4) Cracks



E5) Holes



E6) Galleries



Convegno ReLUIS - Napoli, 17-18 ottobre 2024