IMPACT OF RETROFIT OF RC FRAMES BY CLT PANELS AND FRICTION DAMPERS

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Current seismic retrofitting techniques for RC framed buildings

- Increase of seismic capacity
  - RC jacketing
  - Steel jacketing
  - FRP jacketing
  - TRM/FRCM jacketing

- Reduction of seismic demand
  - Addition of new RC shear walls
  - Steel bracing systems
  - Addition of infill walls
  - Seismic isolation
  - Energy dissipation systems
Introduction

Current seismic retrofitting techniques for RC framed buildings

**MAIN LIMITS**

- ECONOMIC
- MANAGEMENT
- TECHNICAL
Seismic upgrading by e-CLT system

**e-CLT SYSTEM**

- Friction damper
- CLT panel

**e-CLT OPERATION**

- In occurrence of moderate ground motions, CLT panels allow the increase of the seismic capacity of the existing structure;

- In occurrence of stronger ground motions, the activation of the dampers after the infill cracking allows the dissipation of part of the input seismic energy.
Seismic upgrading by e-CLT system

e-CLT SYSTEM

Friction damper

CLT panel

FRICTION DAMPER

RC beam

FREE PROFILE

slotted hole

pretensioned high strength bolts

ANCHOR PROFILE

anchor bolts

Energy and Seismic
AFFordable rEnovation solutions
Seismic upgrading by e-CLT system

**e-CLT SYSTEM**

PRE-intervention

POST-intervention
Seismic upgrading by e-CLT system

**e-CLT ADVANTAGES**

- Damper activation defines an upper bond to the force sustained by the CLT panels, thus preventing their failure;
- Quick and easy installation from the building outside;
- Use in combination with energy-efficient solutions in view of an integrated seismic and energy renovation action.
Seismic upgrading by e-CLT system

**e-CLT ADVANTAGES**

- Damper activation defines an upper bond to the force sustained by the CLT panels, thus preventing their failure;

- *Quick and easy installation from the building outside;*

- Use in combination with energy-efficient solutions in view of an integrated seismic and energy renovation action.
Seismic upgrading by e-CLT system

**e-CLT ADVANTAGES**

- Damper activation defines an upper bond to the force sustained by the CLT panels, thus preventing their failure;
- Quick and easy installation from the building outside;
- Use in combination with energy-efficient solutions in view of an integrated seismic and energy renovation action.
Aim and methodology

Analysis of the potential impact of the e-CLT technology on the seismic response of RC framed structures

1. Implementation of a numerical model of a case study frame equipped with the e-CLT system
2. Evaluation on the e-CLT impact on the case study frame in terms of stiffness, strength and energy dissipation capacity improvement.
Case study

One storey, three-bay RC frame designed considering gravity loads only, according to the regulations in force in Italy during the 1970s.

CONCRETE C25/30 - STEEL Feb38K
Case study

One storey, three-bay RC frame designed considering gravity loads only, according to the regulations in force in Italy during the 1970s.

INFILLED CONFIGURATIONS

Config. 1

Config. 2

WALLS MADE OF TWO LEAVES OF HALLOW CLAY BRICKS
(internal leaf: 8-cm thick; external leaf: 12-cm thick)

CONCRETE C25/30 - STEEL Feb38K
Case study

**PRE-intervention**

**POST-intervention**

- **Config. 1**
- **Config. 2**
Numerical modelling in OpenSEEs environment

Single bay of the case study at post-intervention state

Numerical model schema
Numerical modelling in OpenSEEs environment

RC FRAME:
- Columns → “beamWithHinges Element”
- Beams → “nonlinearBeamColumn Element”
  “elasticBeamColumn Element”

 Numerial model schema

“Concrete04” uniaxial material (concrete)
“Steel02” uniaxial material (rebars)
Numerical modelling in OpenSEES environment

CLT PANEL → “ShellMITC4 elements” → elastic orthotropic and homogenized material (3-ply CLT panel made of C24 spruce wood)
Numerical modelling in OpenSEES environment

**FRICTION DAMPER:**

- Steel profiles (8-mm thick) → "ShellMITC4 Element / Truss Element" → elastic material ($E_s = 210.000$ Mpa)

**Numerical model schema**
Numerical modelling in OpenSEEs environment

FRICITION DAMPER:

- Friction connection $\rightarrow$ "zeroLength Element" $\rightarrow$ elasto-plastic material ($F_y = 30 \text{kN}$)
- N° 2 friction bolts $\rightarrow$ "zeroLength Element" $\rightarrow$ elastic material (large stiffness)
- N° 30 screws $\rightarrow$ "Two Node Link Element" $\rightarrow$ elastic material (stiffness in accordance with EC5)
**Numerical modelling in OpenSEEs environment**

**FRICITION DAMPER:**
- Friction connection $\rightarrow$ “zeroLength Element” $\rightarrow$ elasto-plastic material ($F_y = 30$ kN)
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- N$^{\circ}$ 30 screws $\rightarrow$ “Two Node Link Element” $\rightarrow$ elastic material (stiffness in accordance with EC5)
Numerical modelling in OpenSEEs environment

INFILL WALLS → “Truss Elements” → “Hysteretic” uniaxial material ($E_w=4130$ MPa, $G_w=1240$ MPa, $\tau_{cr}=0.28$ Mpa)
Pushover analyses

- Vertical loads on each column and beam, resulting from those used to design the frame
- Monotonic and cyclic pushover analyses at displacement control
- Ultimate top horizontal displacement corresponding to the near collapse limit state of the bare frame (du= 80 mm).
- 5-step incremental loading protocol, where the maximum amplitude is equal to the top displacement.
Results

Hysteretic responses of the BARE frame at pre- and post-intervention state

- **Lateral strength:** 165.6 kN
- **Stiffness:** 21231 kN/m
- **Energy dissipation:** 41.8 kNm
Results

Hysteretic responses of the **BARE** frame at pre- and post-intervention state

PRE-intervention

**SEISMIC CAPACITY**

- Lateral strength: **165.6 kN**
- Stiffness: **21231 kN/m**
- Energy dissipation: **41.8 kN*m**
Results

Hysteretic responses of the **BARE** frame at pre- and post-intervention state

**PRE-intervention**

**SEISMIC CAPACITY**

- Lateral strength: **165.6 kN**
- Elastic stiffness: **2123 kN/m**
- Energy dissipation: **41.8 kNm**
Results

Hysteretic responses of the BARE frame at pre- and post-intervention state

PRE-intervention

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<tr>
<th>PRE-intervention</th>
<th>SEISMIC CAPACITY</th>
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<tbody>
<tr>
<td></td>
<td>- Lateral strenght: 165.6 kN</td>
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<td></td>
<td>- Elastic stiffness: 21231 kN/m</td>
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<td>- Energy dissipation: 41.8 kNm</td>
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</table>
Results

Hysteretic responses of the BARE frame at pre- and post-intervention state

**POST-intervention - Configuration 1**

**POST-intervention - Configuration 2**

**SEISMIC CAPACITY IMPROVEMENT**

- Lateral strength: +40%
- Elastic stiffness: +93%
- Energy dissipation: +128%

- Lateral strength: +82%
- Elastic stiffness: +170%
- Energy dissipation: +275%
Results

Hysteretic responses of the **INFILLED** frame at pre- and post-intervention state

<table>
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<th>Configuration 1</th>
<th>Configuration 2</th>
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<td><strong>POST</strong>-intervention</td>
<td><strong>POST</strong>-intervention</td>
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</table>

**SEISMIC CAPACITY IMPROVEMENT**

- Lateral strength: + 10%
- Stiffness: ---
- Energy dissipation: + 82%
- Lateral residual strength: + 38%

- Lateral strength: + 17%
- Stiffness: ---
- Energy dissipation: + 146%
- Lateral residual strength: + 76%
Results

Seismic capacity improvement of the INFILLED frame at post-intervention state

- **Lateral strength**
- **Lateral residual strength**
- **Energy dissipation**

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<th>Percentage Increase [%]</th>
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<td>Medium</td>
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<td>Weak</td>
<td>15.8%</td>
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<td>Bare</td>
<td>39.7%</td>
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<td>Weak</td>
<td>182.6%</td>
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<tr>
<td>Bare</td>
<td>275.9%</td>
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COMPDYN 2021

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Conclusions and future developments

• The e-CLT system appears high potential for seismic upgrading of RC framed buildings.

• The effectiveness of the e-CLT system could be great in fulfilling the objective of Near Collapse performance.

• The effectiveness of the-CLT system could be limited if applied to infilled frames, when the improvement of seismic performance is mainly related to the increase of lateral stiffness.
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• The e-CLT system appears high potential for seismic upgrading of RC framed buildings.

• The effectiveness of the e-CLT system could be great in fulfilling the objective of Near Collapse performance.

• The effectiveness of the-CLT system could be limited if applied to infilled frames, when the improvement of seismic performance is mainly related to the increase of lateral stiffness.

• Calibration of the numerical model of the damper, according to its mechanical characterization.
• Investigation of the effectiveness of the e-CLT system on multi-storey numerical models
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