Session on: Sustainability of Concrete Structures: An Italian Perspective

THE ITALIAN CHALLENGE FOR THE SUSTAINABILITY OF EXISTING CONCRETE CONSTRUCTION

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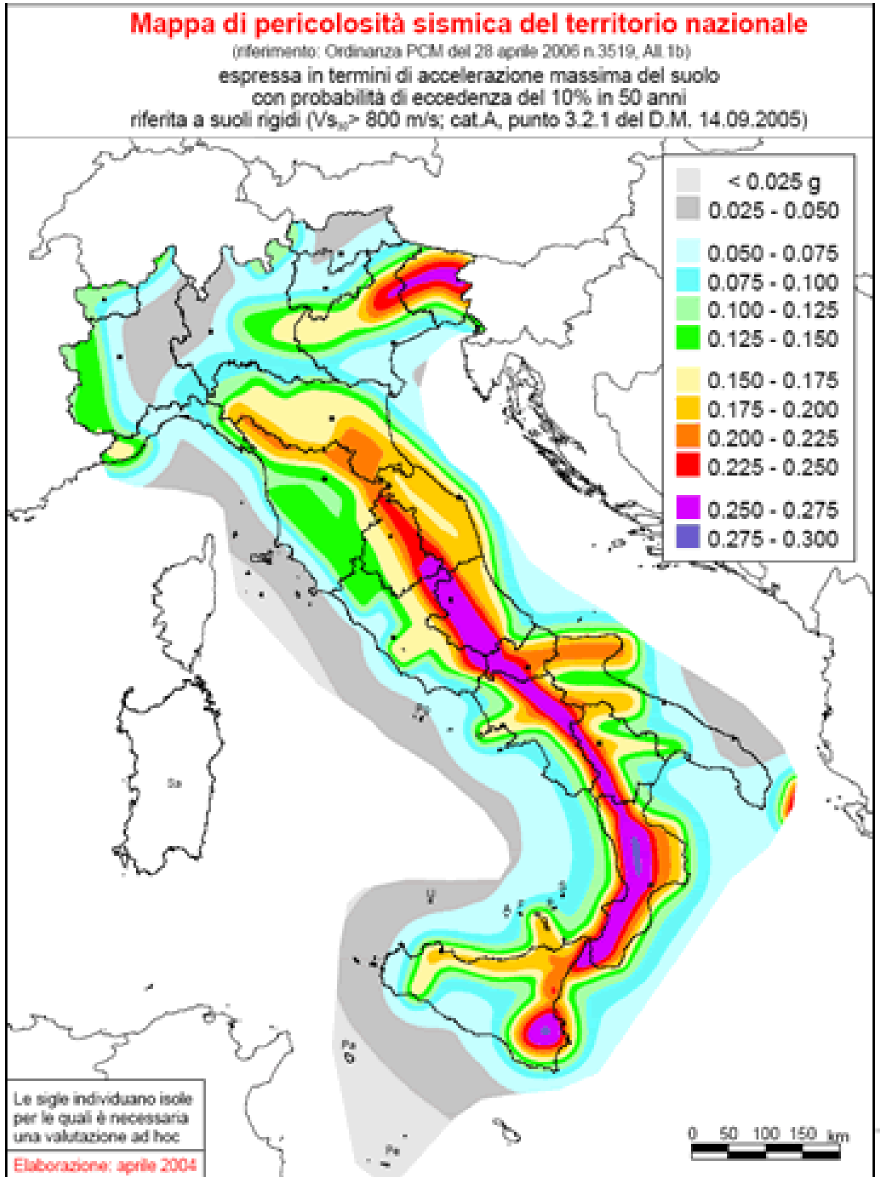
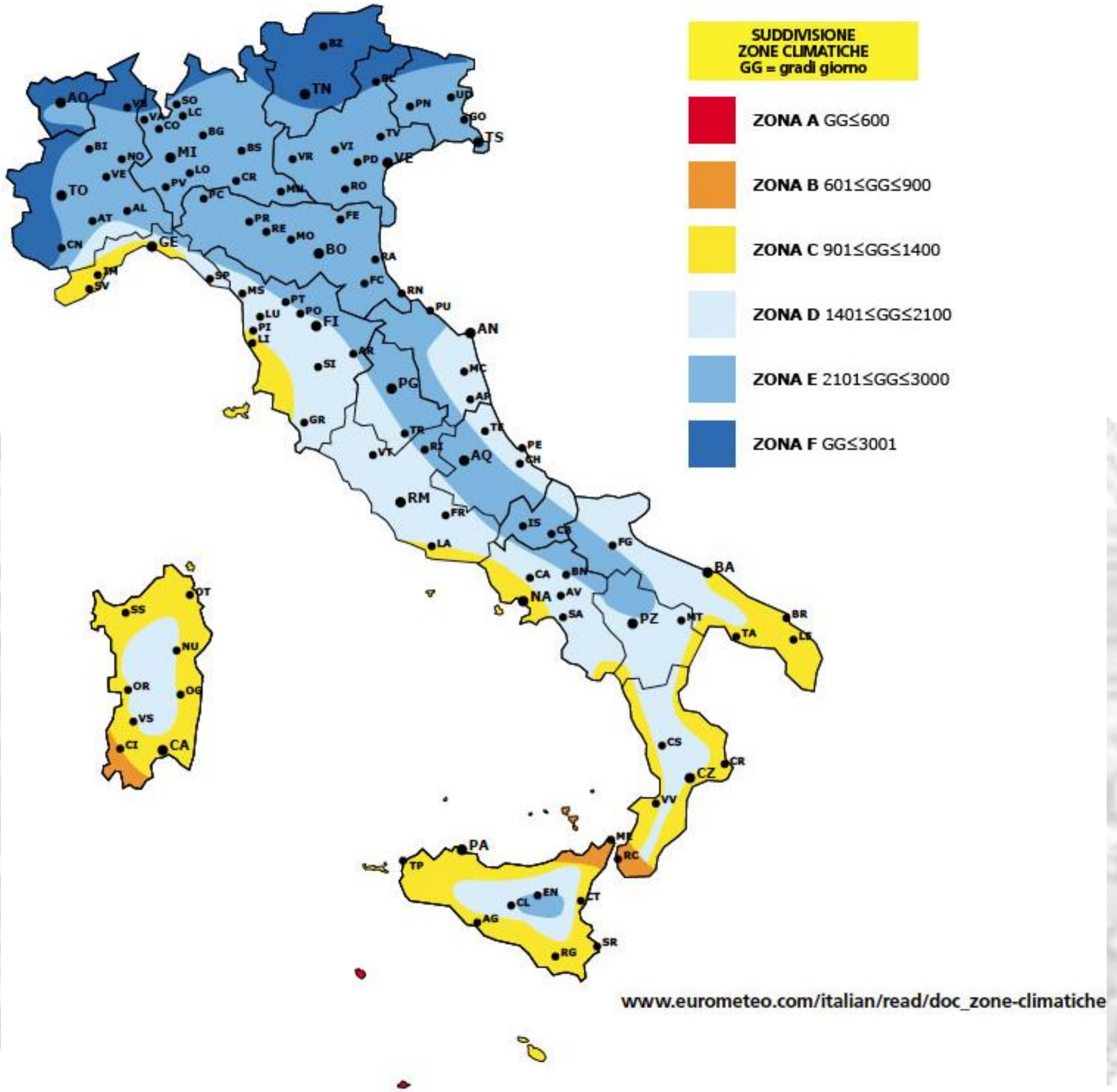
Seismic and Energy issues: Italian perspective

Seismic Risk



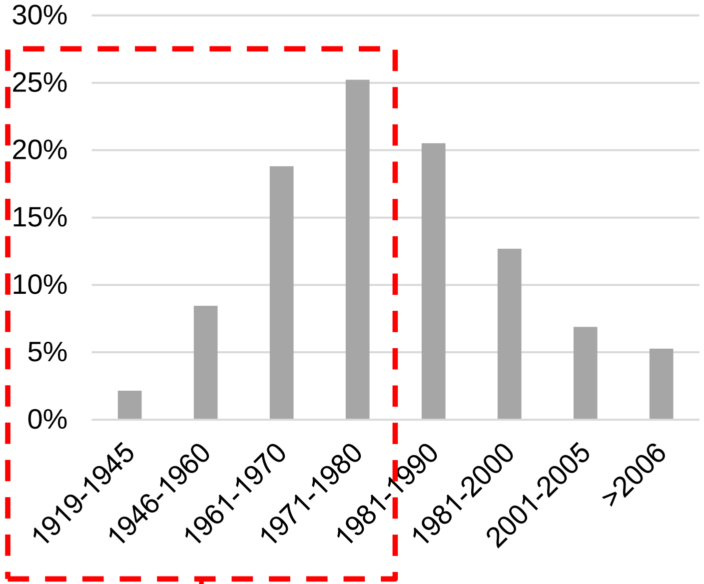
Energy Demand



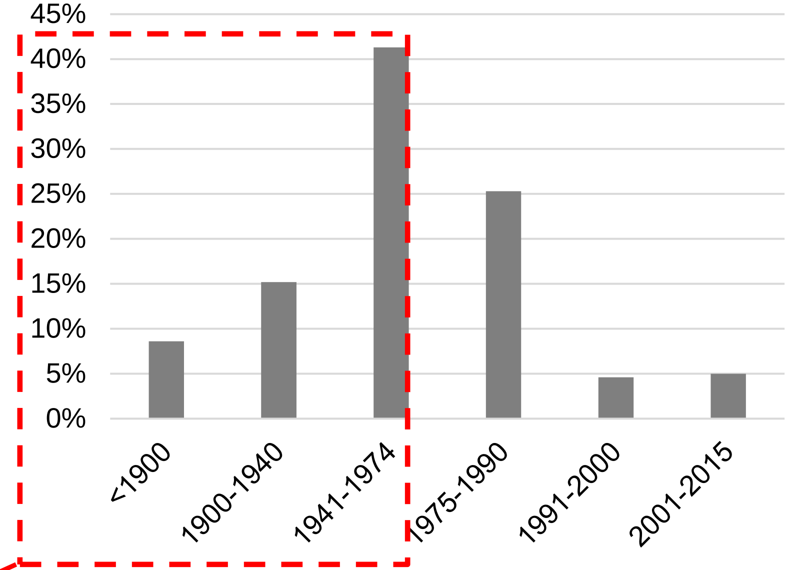
Seismic and Energy issues: Italian perspective

Reinforced concrete buildings are old (structural and energy performance)

Residential buildings (ISTAT 2011)



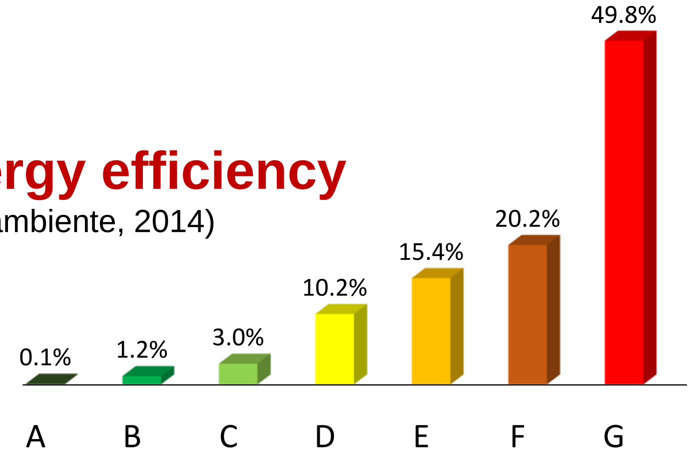
School buildings (Legambiente 2014)



More than 50% have been built before ’80s

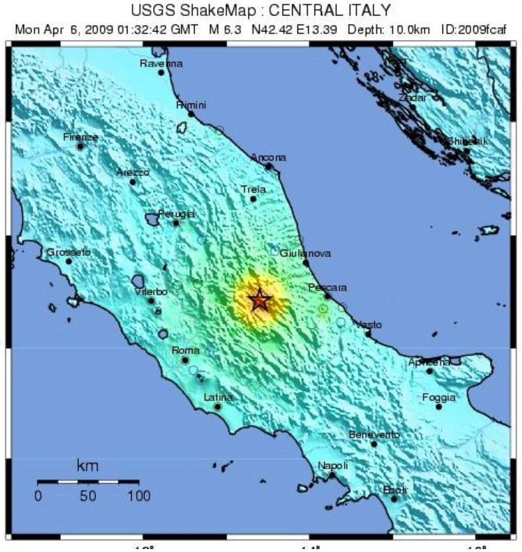
Low energy efficiency

(Legambiente, 2014)



LEARNING FROM EARTHQUAKES

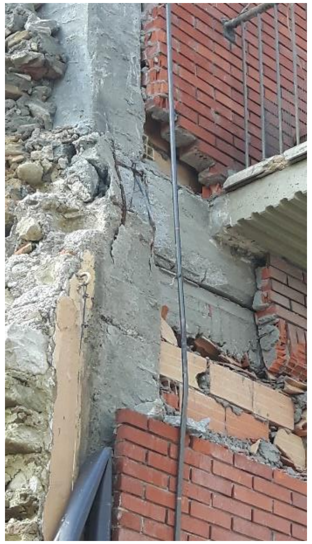
Recent earthquakes in Italy, damage to RC structures



- ➢ L’ Aquila Earthquake – 3:32 a.m, April 6, 2009 (Mw=6,3)



- ➢ Central Italy Earthquake – 3:36 a.m, August 24, 2016 (Mw=6,0-6,2)

Seismic and Energy issues in Italy

Many cases of buildings recently retrofitted only in terms of energy consumption, no care to structural capacity

August 2016 Central Italy earthquake

August 2016 Central Italy earthquake

Recent earthquakes confirmed the need for a concurrent approach that combine and optimize seismic and energy consumption upgrade

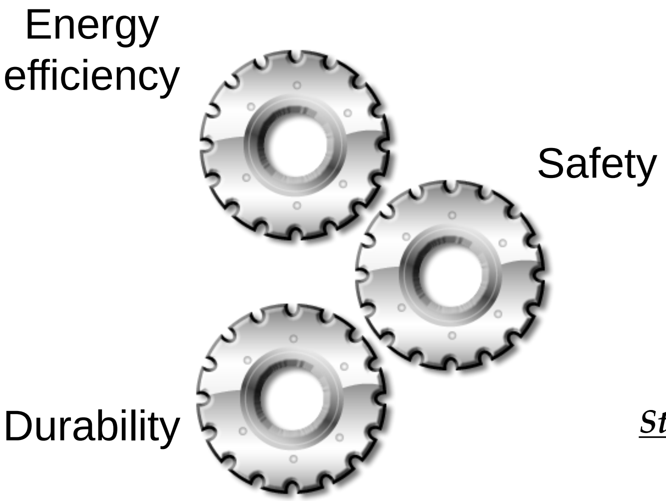
Reduction of seismic risk and sustainability

t=t_0

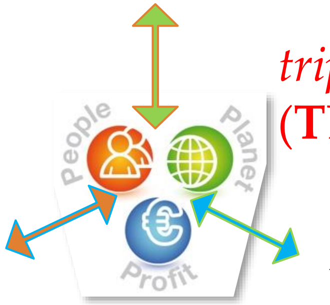
Entire life cicle → Potential critical events

t=t_{end}

Therefore, Sustainability (economic, environmental, quality of life) should be pursued by aiming at requirements of energy efficiency, safety, durability based on the activities and functions that people play in the relevant buildings



Human health and Safety
Life cycle management
Environmental issues
Emissions reduction



triple-bottom-line
(TBL)

Structural Robustness
Social progress
Risk Management
Innovations

Maintainance
Durability
Resources efficiency
Protection of products
Flexibility

Effectiveness of local strengthening interventions

EFFECTIVNESS OF LOCAL STRENGTHENING

'FRP RETROFITTED' structure: 0.30 g input

'AS BUILT': TEST 0.20g

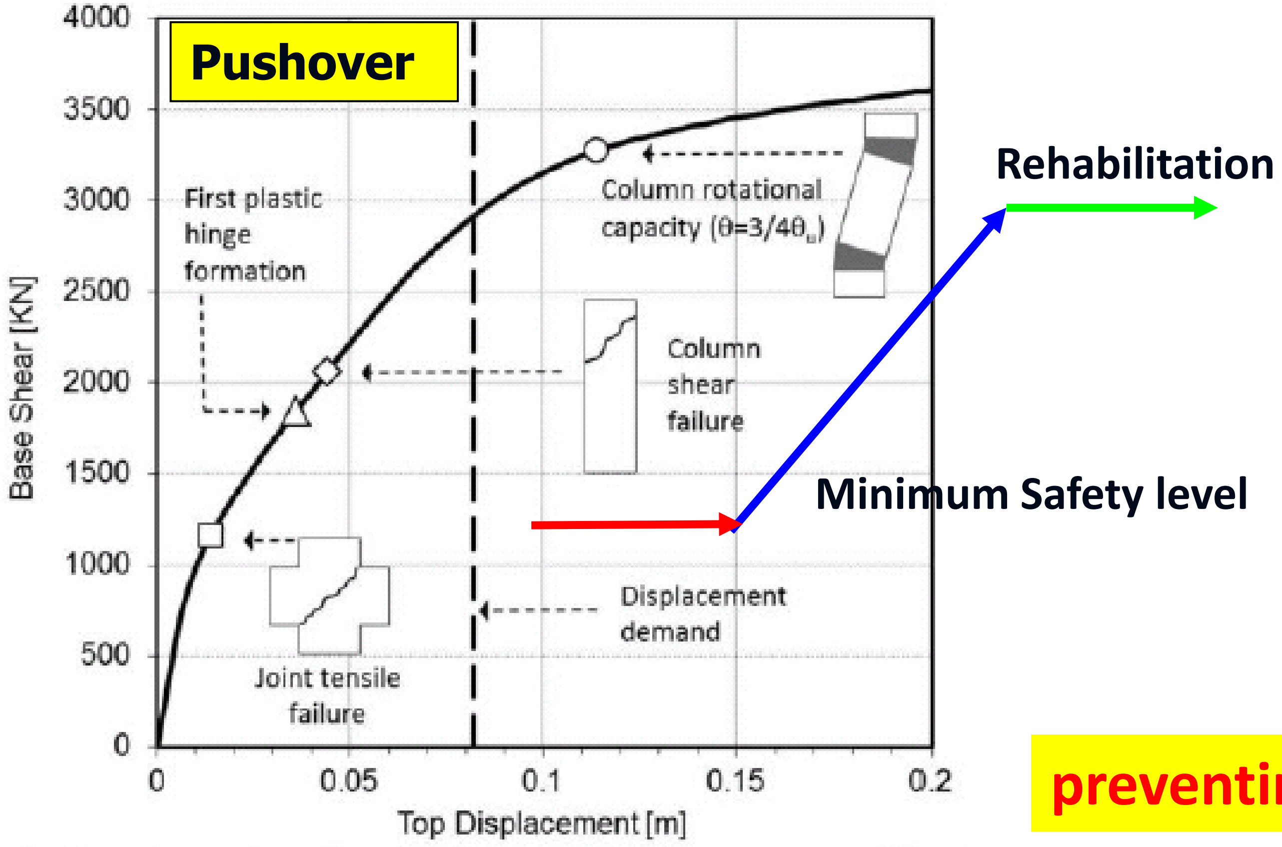
FRP RETROFITTED: TEST 0.30g

TEST	Adsorbed Energy [KJ]	Base Shear [KN]	Max top displ. [m]
'as-built' 0.20g	**65.00**	**276**	**0.1031**
FRP retrofit 0.20g	68.66	287	0.1125
FRP retrofit 0.30g	**104.38**	**281**	**0.1266**

- **FRP intervention does not change the structural mass (seismic demand unchanged)**
- **Global ductility increase (123%) without changing the strength hierarchy**
- **Seismic actions increased of 50% without structural damages**

EFFECTIVNESS OF LOCAL STRENGTHENING

SAFETY INDEX INCREASE PROVIDED BY LOCAL STRENGTHENING SOLUTIONS



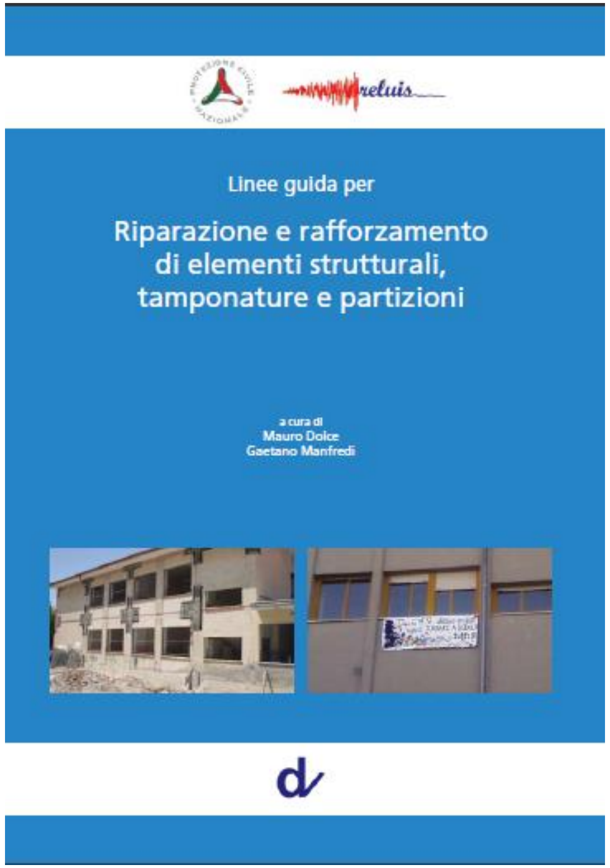
preventing brittle failure mechanisms

Frascadore R., Di Ludovico M., Prota A., Verderame G.M., Manfredi G., Dolce M., Cosenza E. (2015) Local Strengthening of Reinforced Concrete Structures as a Strategy for Seismic Risk Mitigation at Regional Scale. *Earthquake Spectra*, vol. 31(2)

CODE AND TECHNICAL GUIDELINES

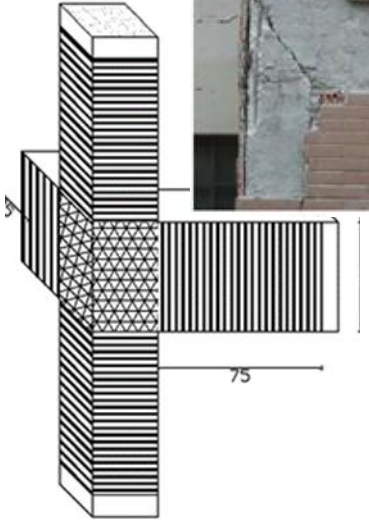
❖ Exterior joint FRP strengthening

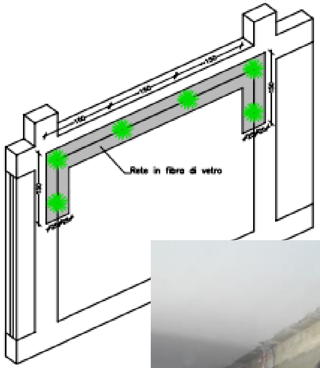
L'Aquila Earthquake

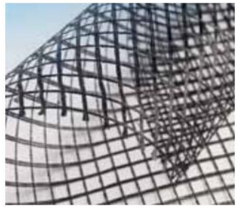


GUIDELINES AND CALCULATION EXAMPLES

REPAIR AND STRENGTHENING OF STRUCTURAL ELEMENTS, INFILLS, AND PARTITIONS







- ✓ Laboratory tests
- ✓ Exp. Validation
- ✓ Theor. prediction equations

Freely downloadble on website: *www.reluis.it*

CODE AND TECHNICAL GUIDELINES

2004 - CNR-DT 200/2004 – Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Existing Structures

CNR – Advisory Committee on Technical Recommendations for Construction

NATIONAL RESEARCH COUNCIL

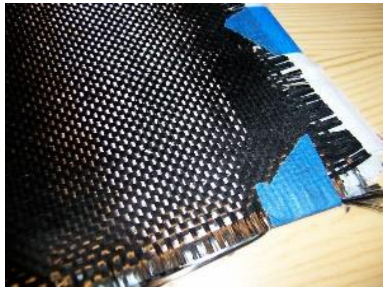
ADVISORY COMMITTEE
ON TECHNICAL RECOMMENDATIONS FOR CONSTRUCTION

and…revised version

2013 - CNR-DT 200 R1/2013

Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Existing Structures

Materials, RC and PC structures, masonry structures



https://www.cnr.it/en/node/2636

CNR-DT 200 R1/2013

ROMA – CNR October 10th 2013 – release of May 15th 2014

2018 - CNR-DT 215/2018 - Guide for the Design Execution and Control of FRCM Systems for Strengthening Existing Structures

CNR – Advisory Committee on Technical Recommendations for Construction

NATIONAL RESEARCH COUNCIL

ADVISORY COMMITTEE
ON TECHNICAL RECOMMENDATIONS FOR CONSTRUCTION

Guide for the Design and Construction of Externally Bonded Fibre Reinforced Inorganic Matrix Systems for Strengthening Existing Structures

https://www.cnr.it/en/node/12827

CNR-DT 215/2018

ROME – CNR 06.02.2019; version of June 30, 2020

FRCM….Fibre-Reinforced Cementitious Matrix…..

Masonry buildings

CODE AND TECHNICAL GUIDELINES

2008 – Italian building code (NTC)

revised in 2018

Supplemento ordinario alla "Gazzetta Ufficiale" n. 42 del 20 febbraio 2018 - Serie generale

Spediz. abb. post. - art. 1, comma 1
Legge 27-02-2004, n. 46 - Filiale di Roma

GAZZETTA UFFICIALE
DELLA REPUBBLICA ITALIANA

PARTE PRIMA Roma - Martedì, 20 febbraio 2018 SI PUBBLICA TUTTI I GIORNI NON FESTIVI

DIREZIONE E REDAZIONE PRESSO IL MINISTERO DELLA GIUSTIZIA - UFFICIO PUBBLICAZIONE LEGGI E DECRETI - VIA ARENULA, 70 - 00186 ROMA
AMMINISTRAZIONE PRESSO L'ISTITUTO POLIGRAFICO E ZECCA DELLO STATO - VIA SALARIA, 691 - 00138 ROMA - CENTRALINO 06-85081 - LIBRERIA DELLO STATO
PIAZZA G. VERDI, 1 - 00198 ROMA

N. 8

MINISTERO DELLE INFRASTRUTTURE
E DEI TRASPORTI

DECRETO 17 gennaio 2018.

Aggiornamento delle «Norme tecniche per le costruzioni».

Local strengthening is defined

8.4.1. RIPARAZIONE O INTERVENTO LOCALE

Gli interventi di questo tipo riguarderanno singole parti e/o elementi della struttura. Essi non debbono cambiare significativamente il comportamento globale della costruzione e sono volti a conseguire una o più delle seguenti finalità:

- ripristinare, rispetto alla configurazione precedente al danno, le caratteristiche iniziali di elementi o parti danneggiate;
- migliorare le caratteristiche di resistenza e/o di duttilità di elementi o parti, anche non danneggiati;
- impedire meccanismi di collasso locale;
- modificare un elemento o una porzione limitata della struttura.

Il progetto e la valutazione della sicurezza potranno essere riferiti alle sole parti e/o elementi interessati, documentando le carenze strutturali riscontrate e dimostrando che, rispetto alla configurazione precedente al danno, al degrado o alla variante, non vengano prodotte sostanziali modifiche al comportamento delle altre parti e della struttura nel suo insieme e che gli interventi non comportino una riduzione dei livelli di sicurezza preesistenti.

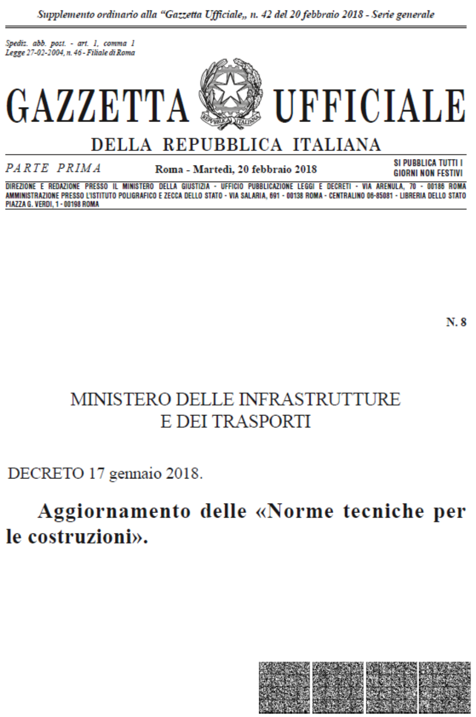
CODE AND TECHNICAL GUIDELINES

2008 – **Italian building code (NTC)**

revised in 2018

2019 – **fib bulletin 90 –** **Externally applied reinforcement for concrete structures**

Local strengthening is defined



Supplemento ordinario alla "Gazzetta Ufficiale,, n. 42 del 20 febbraio 2018 - Serie generale

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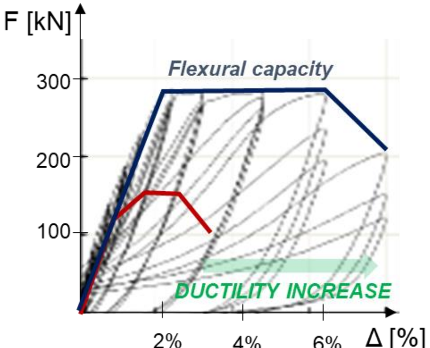
retrofitting through FRP jacketing is considered a ***local intervention*** *in seismic rehabilitation of RC structures (local interventions are those that increase the deformation capacity of deficient components – by suppressing shear failures – without affecting the overall structural stiffness which controls the seismic demand).*

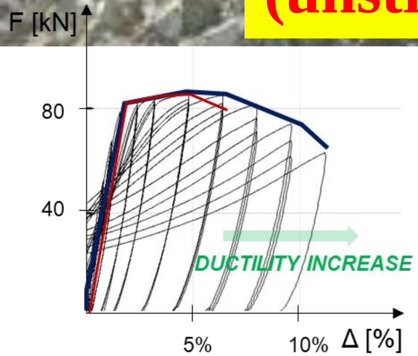
Local strengthening is defined

https://www.fib-international.org/news/378-fib-bulletin-90.html

EFFECTIVNESS OF LOCAL STRENGTHENING

Earthquake evidence have confirmed how FRP can to avoid collapse (and save lives)





EFFECTIVNESS OF LOCAL STRENGTHENING

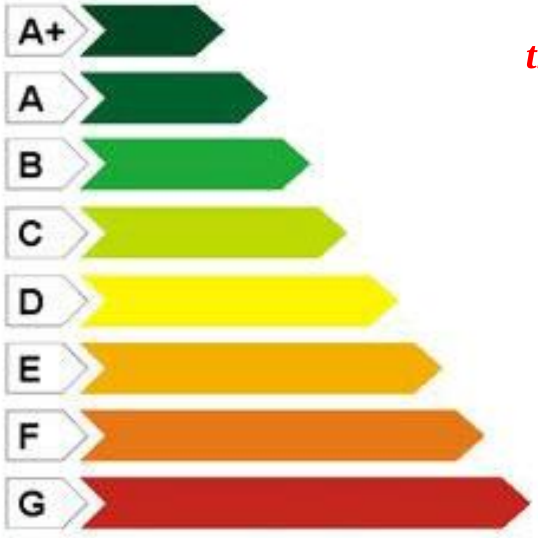
But this is not enough!

We need to have an extensive intervention at **national scale**

CODE AND TECHNICAL GUIDELINES

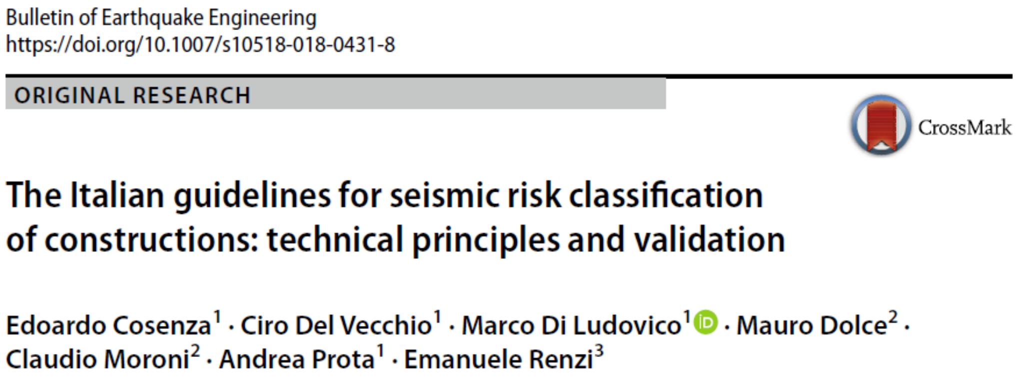
➢ Italian guidelines for seismic risk classification of constructions

Approved by: High Council of Public Works
20th February 2017,
Ministry Decree n.58 28/02/2017



Enhance the seismic risk class

- Seismic classes from **A+ to G**
- It defines the technical principles for exploiting **tax deductions (70%-85%)** in case of seismic strengthening interventions on existing buildings (*Sismabonus*). *Currently (from 2020) tax deduction up to 110%*


Bulletin of Earthquake Engineering
https://doi.org/10.1007/s10518-018-0431-8

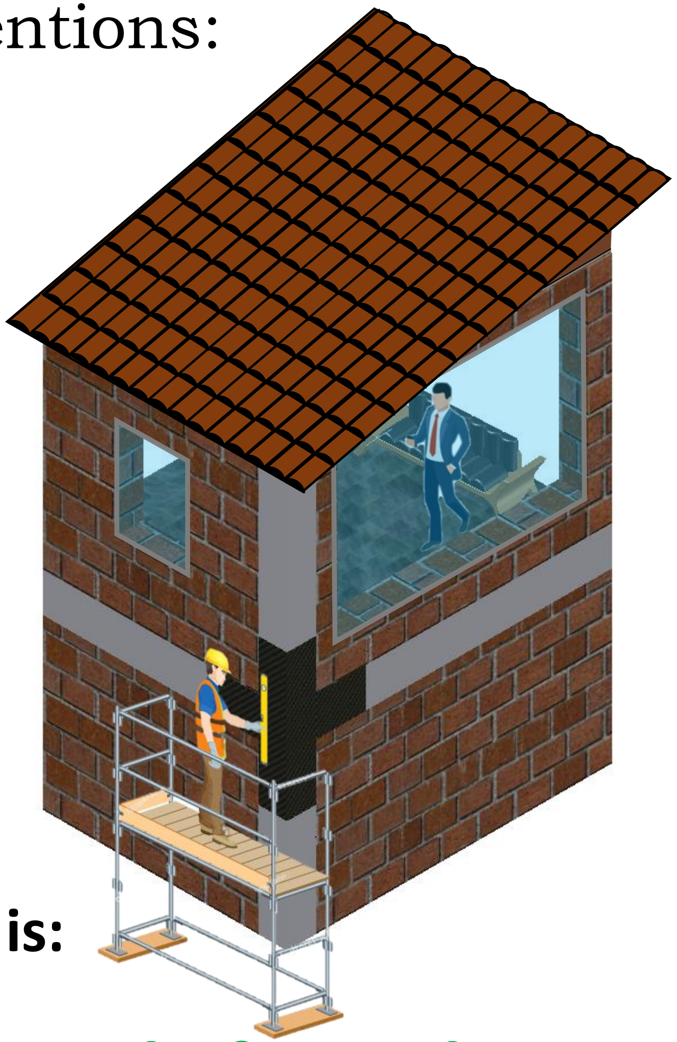
ORIGINAL RESEARCH

CrossMark

The Italian guidelines for seismic risk classification of constructions: technical principles and validation

Edoardo Cosenza[1] · Ciro Del Vecchio[1] · Marco Di Ludovico[1] · Mauro Dolce[2] · Claudio Moroni[2] · Andrea Prota[1] · Emanuele Renzi[3]

Need for low impact strengthening interventions:



New challenge:

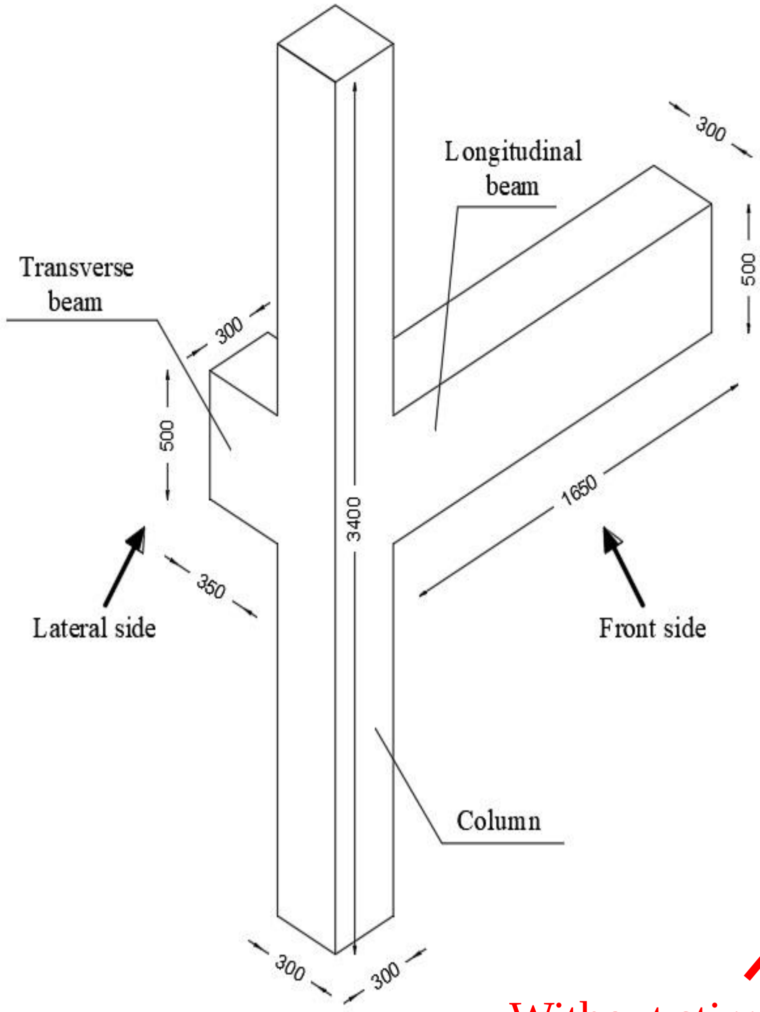
Avoid demolition of small portion of the infills

The challenge is:

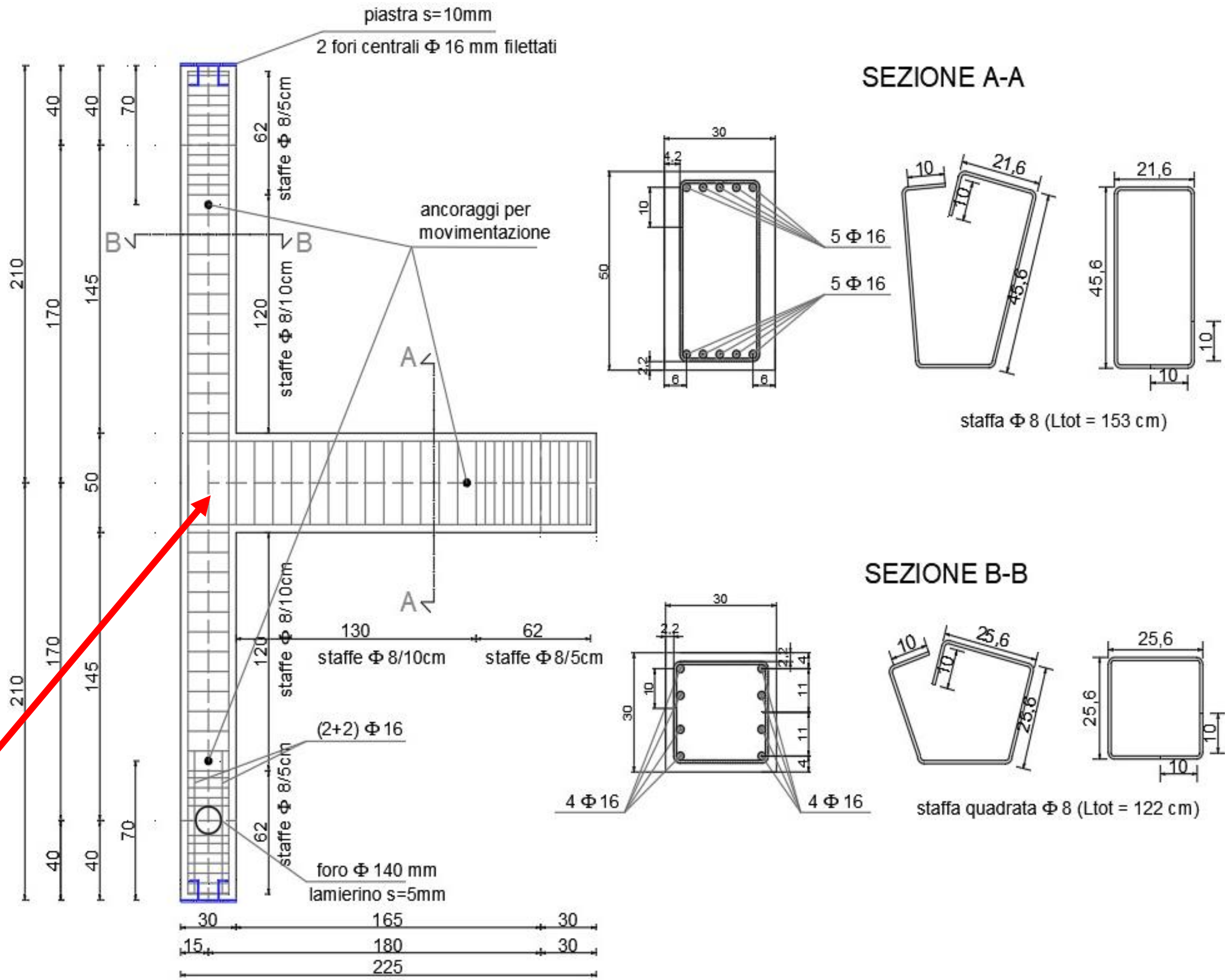
Application only from the exterior of the building

EXPERIMENTAL PROGRAM

EXPERIMENTAL PROGRAM

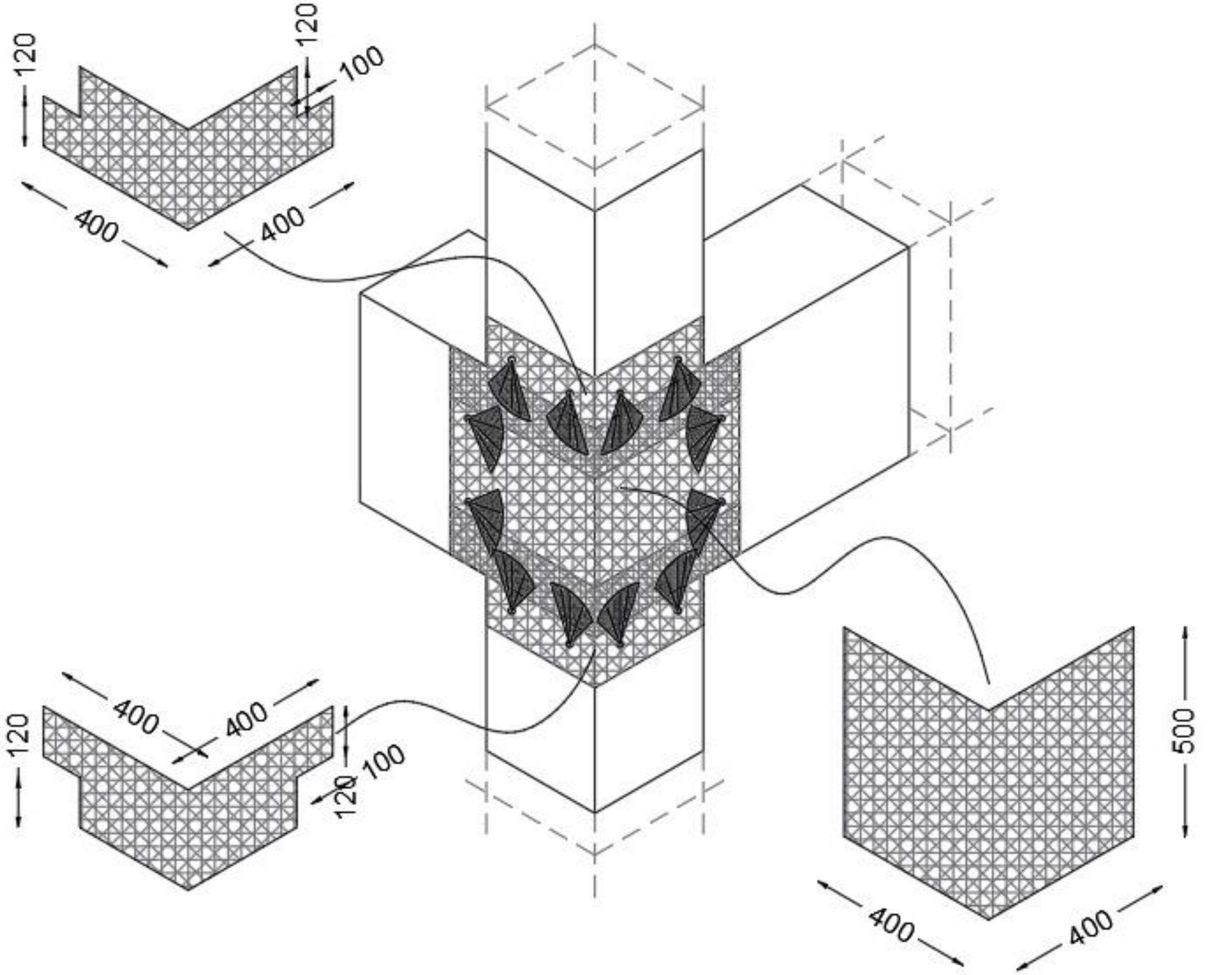


Without stirrups in the joint panel

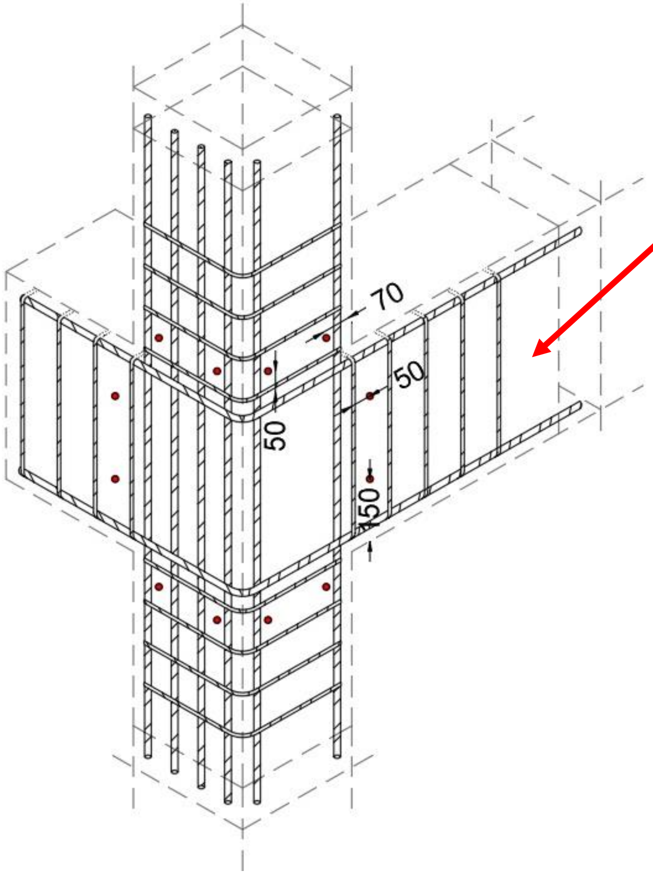


STRENGTHENING LAYOUTS

T_1L - 12A

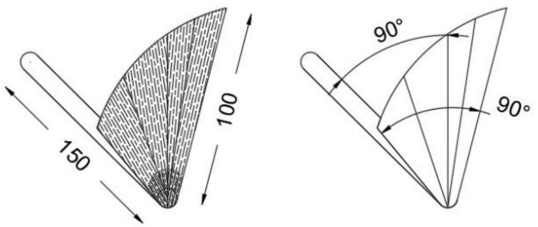


1 layer quadriaxial
CFRP 380g/m^2



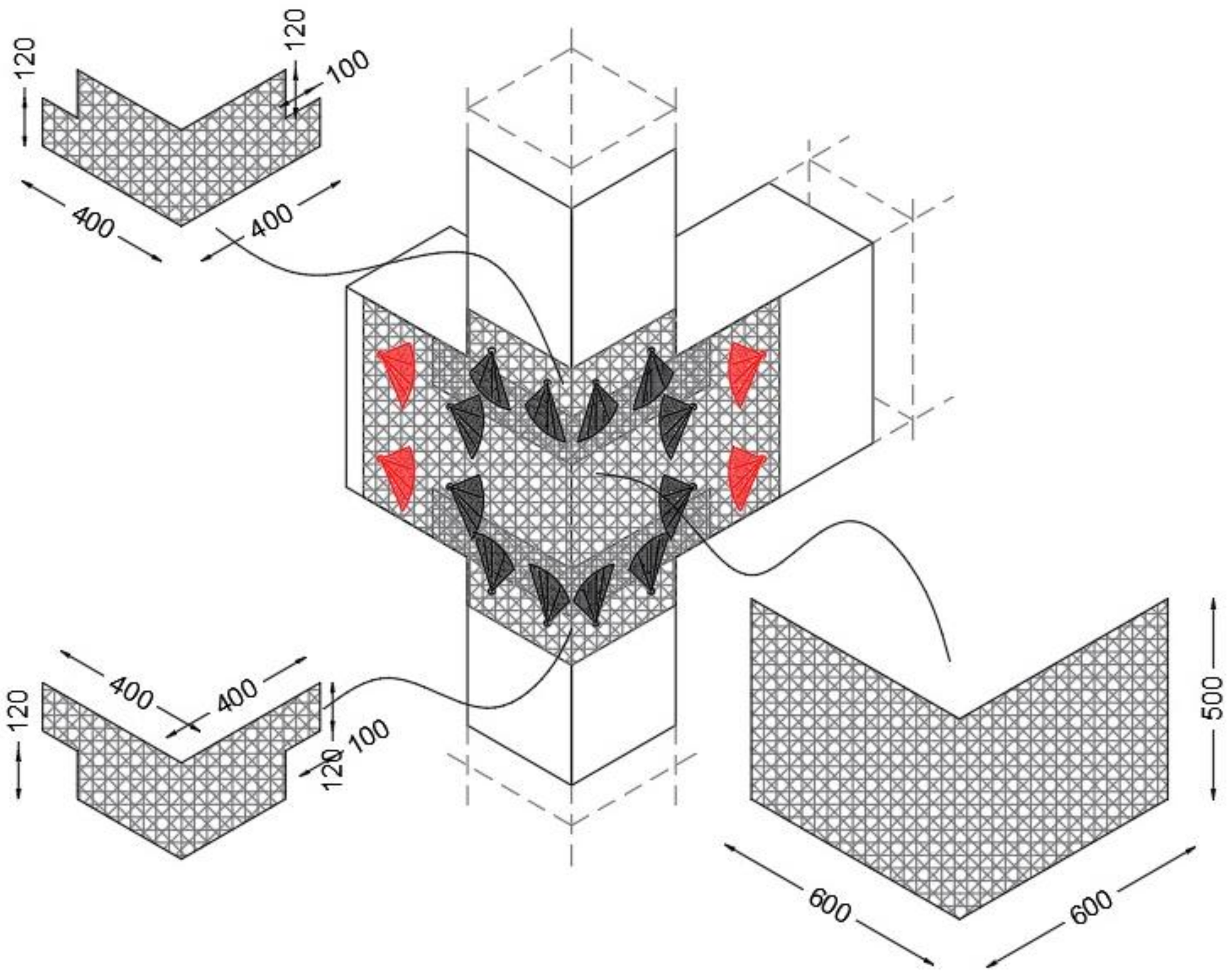
CFRP spikes (anchors)

12 spikes ϕ 10 mm

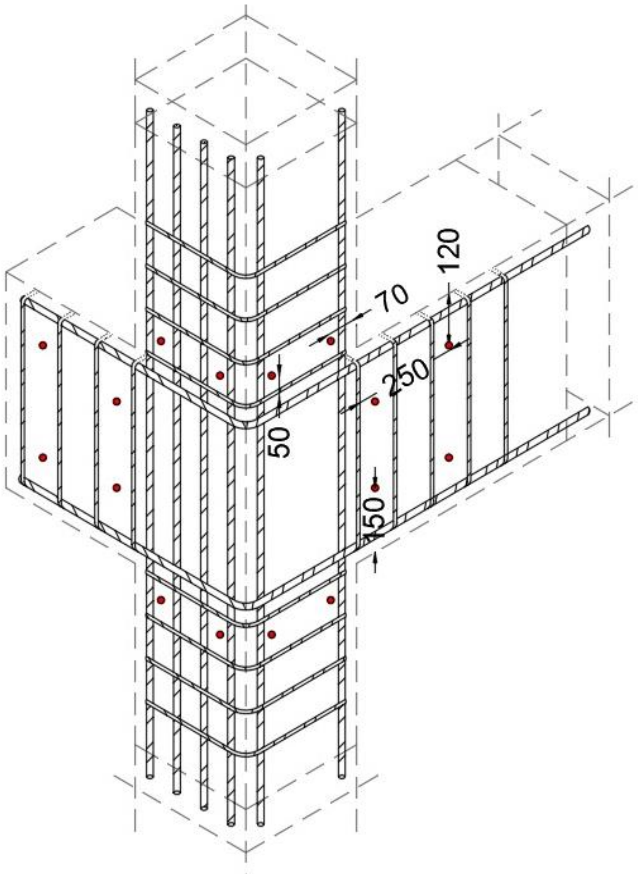


STRENGTHENING LAYOUTS

T_1L - 16A

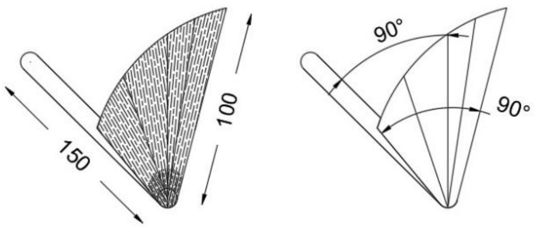


1 layer quadriaxial CFRP 380g/m^2



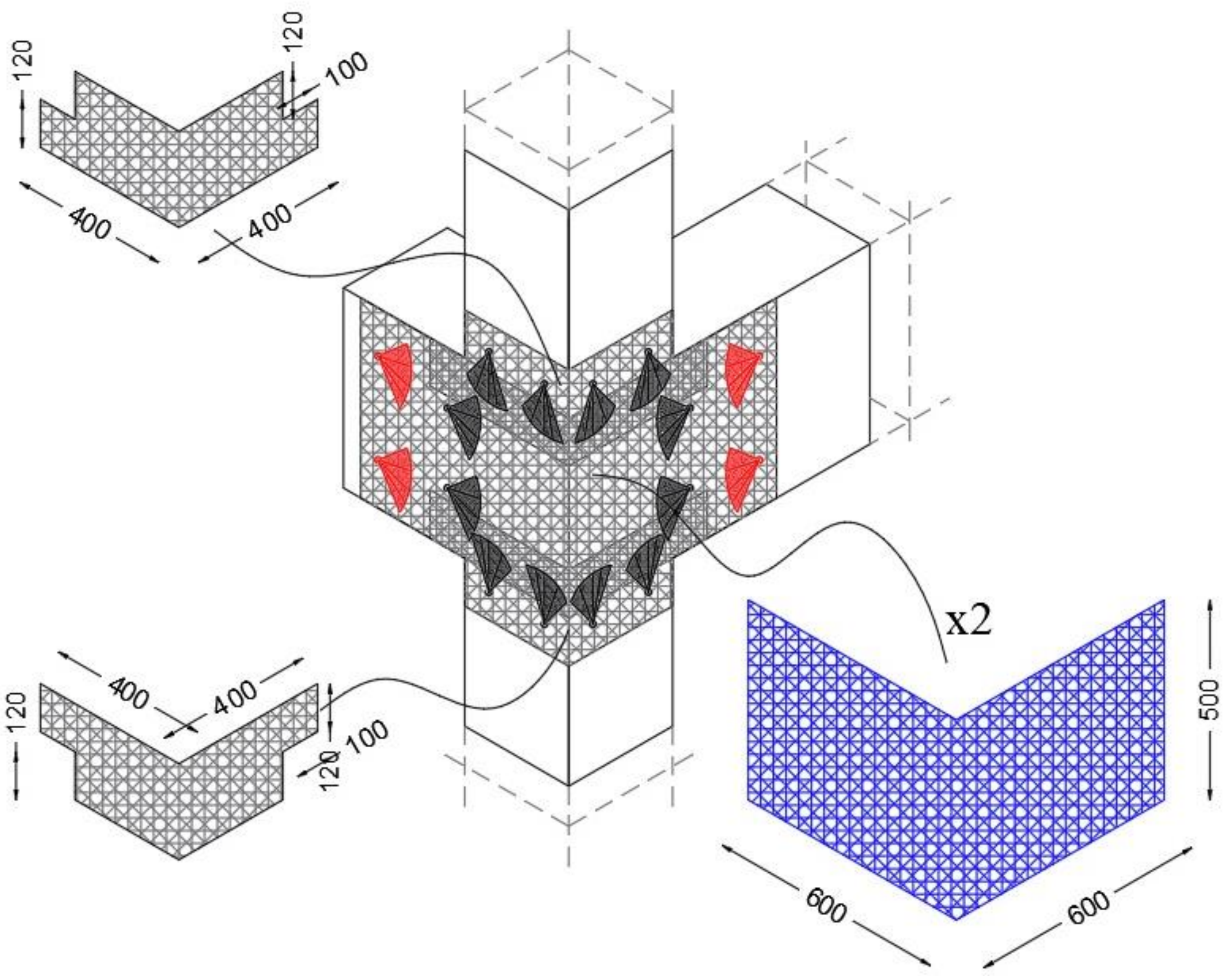
CFRP spikes (anchors)

16 spikes ϕ 10 mm

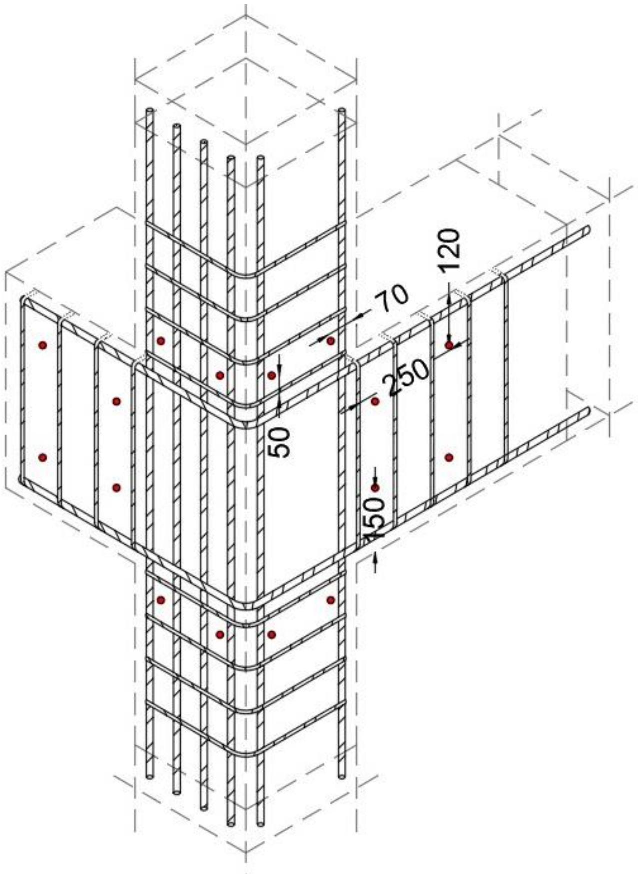


STRENGTHENING LAYOUTS

T_2L - 16A



2 layers quadriaxial
CFRP 380g/m^2



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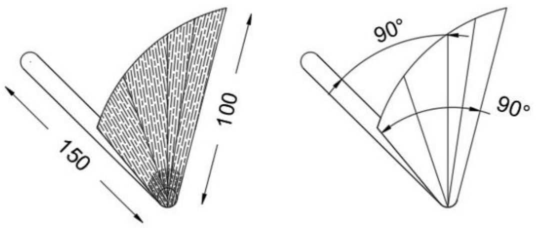
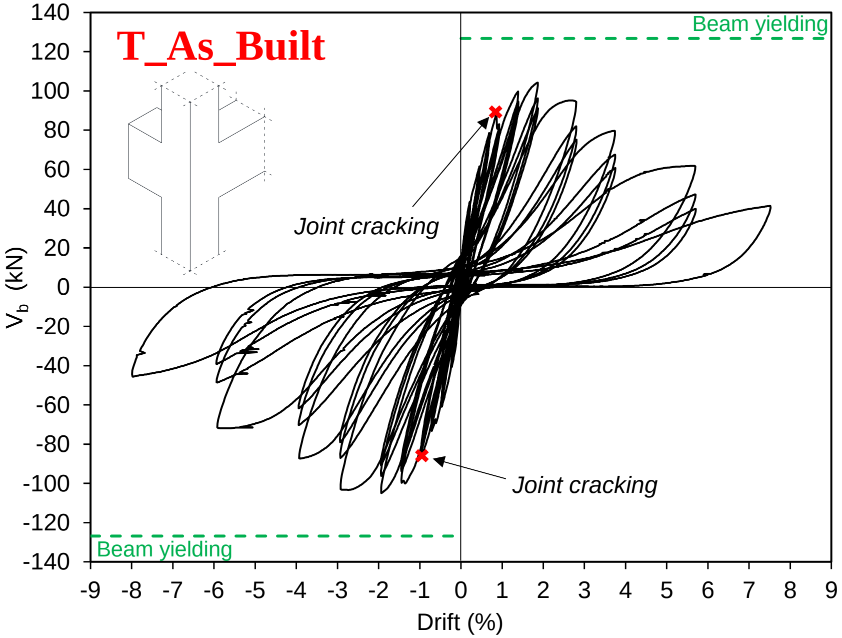
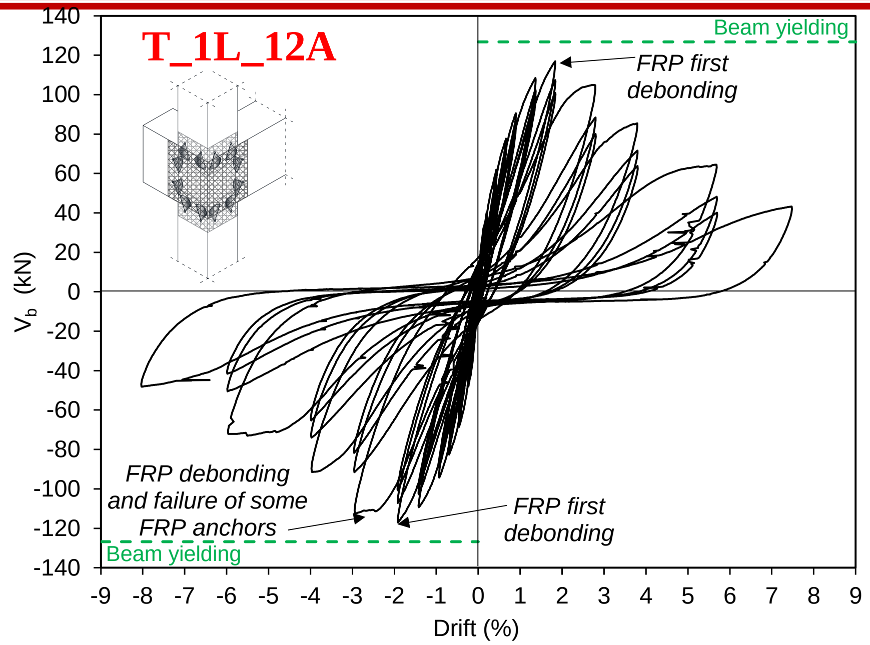
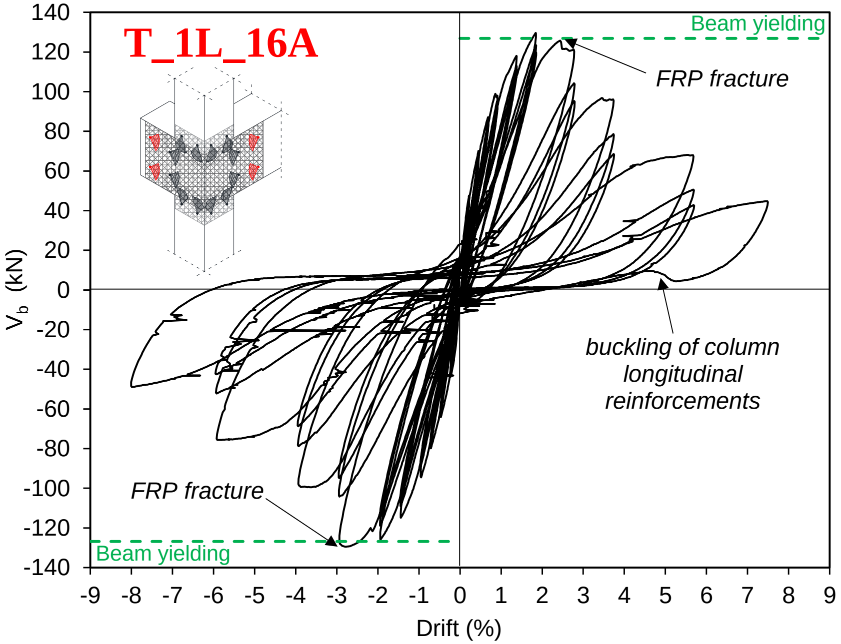
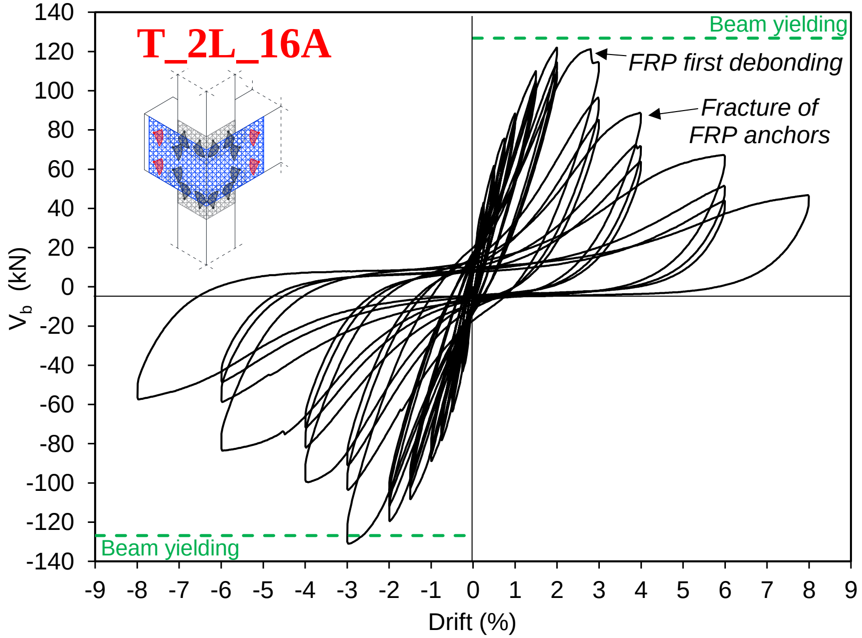


TEST RESULTS



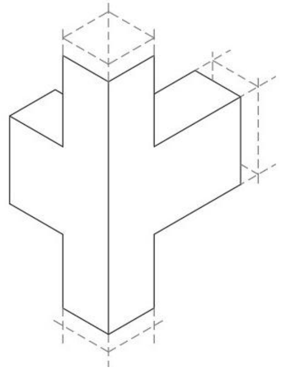


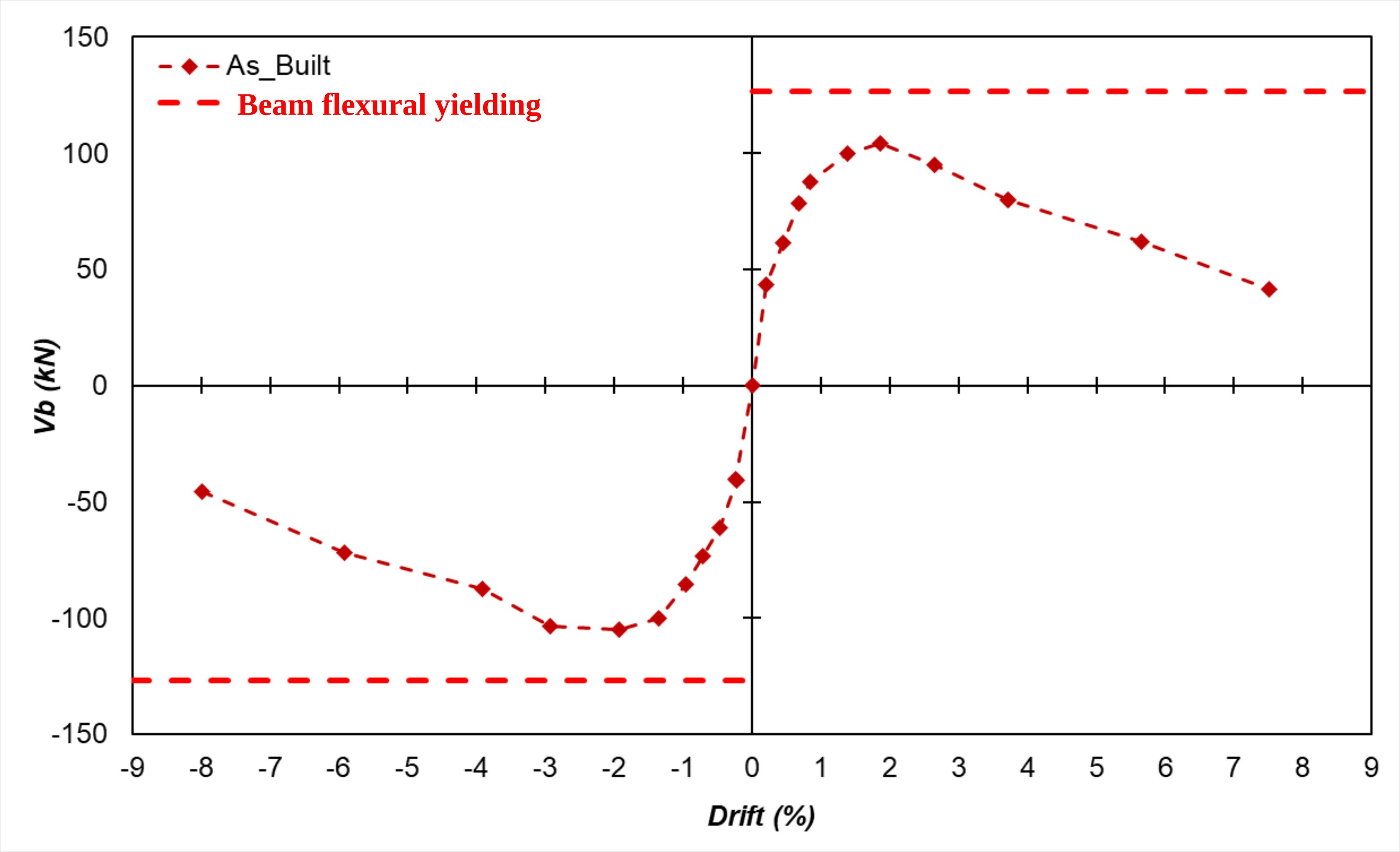




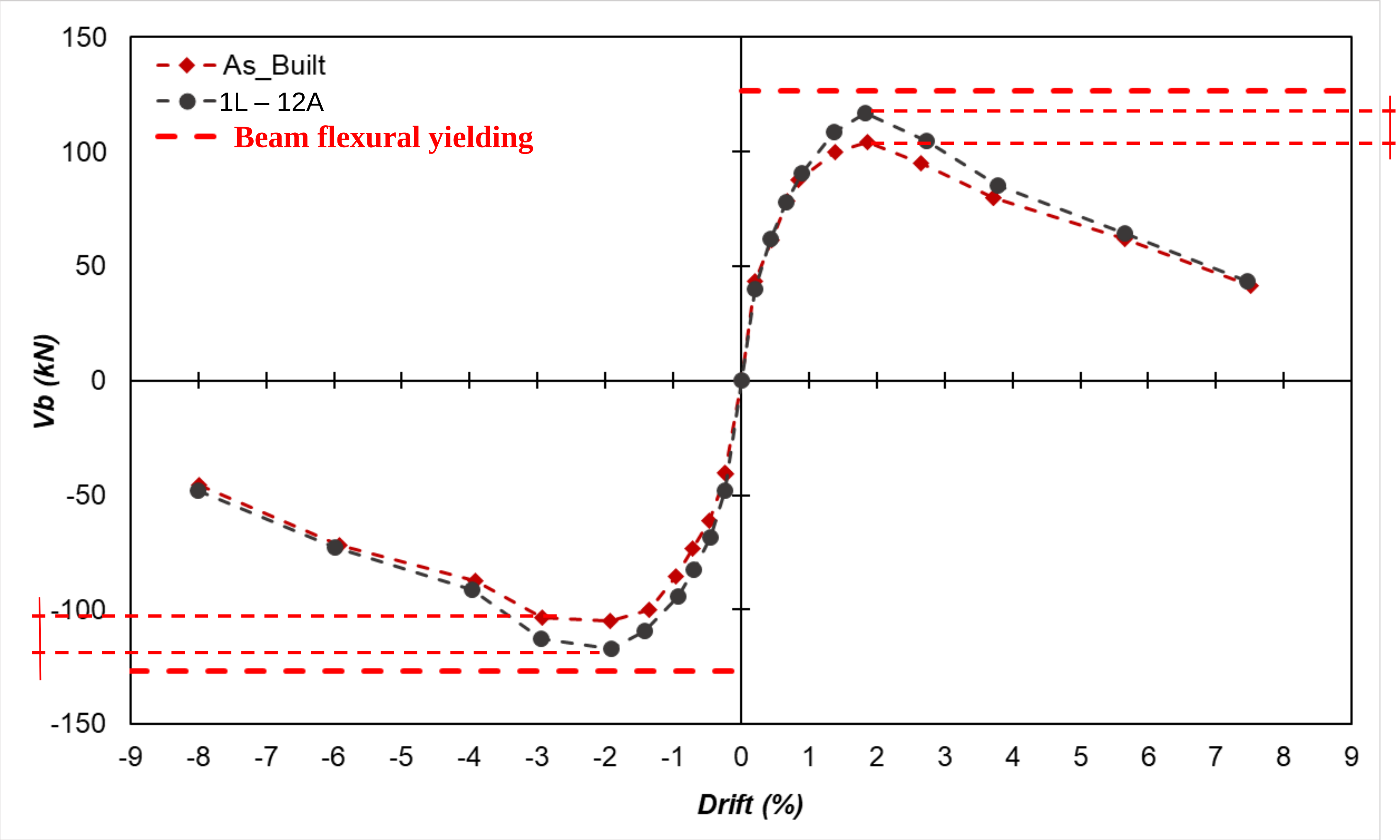
TEST RESULTS

T_As_Built





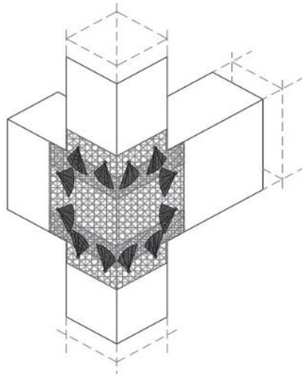
TEST RESULTS



$\Delta_{T\_1L - 12A}^{+} = 12\%$

$\Delta_{T\_1L - 12A}^{-} = 12\%$

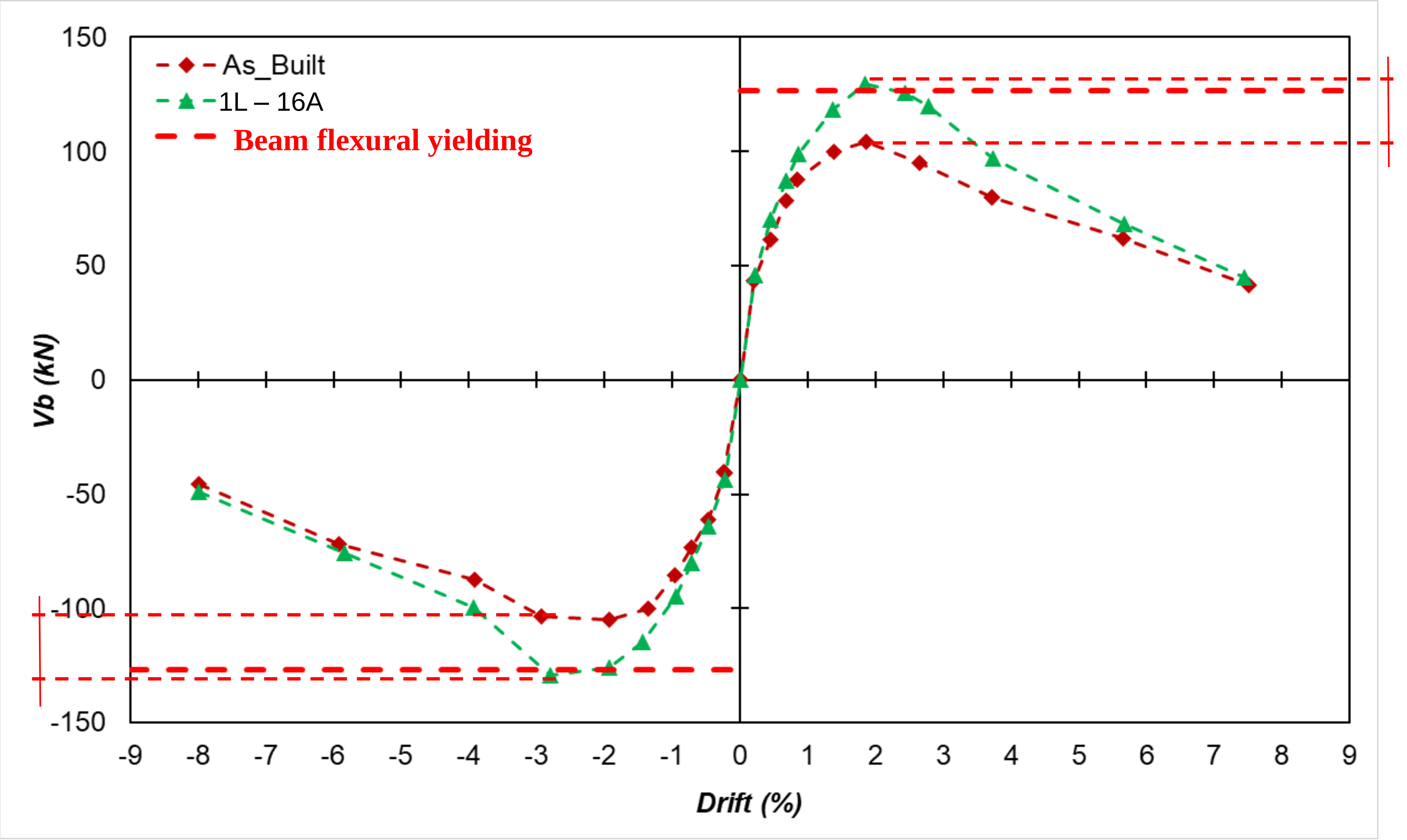
T_1L – 12A



1 Layer CFRP

12 anchors

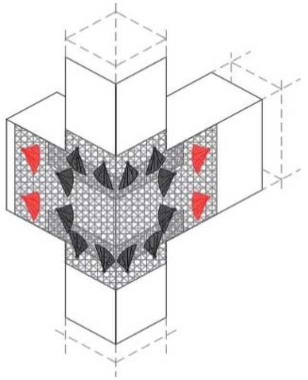
TEST RESULTS



$\Delta_{T\_1L-16A}^{+} = 24\%$

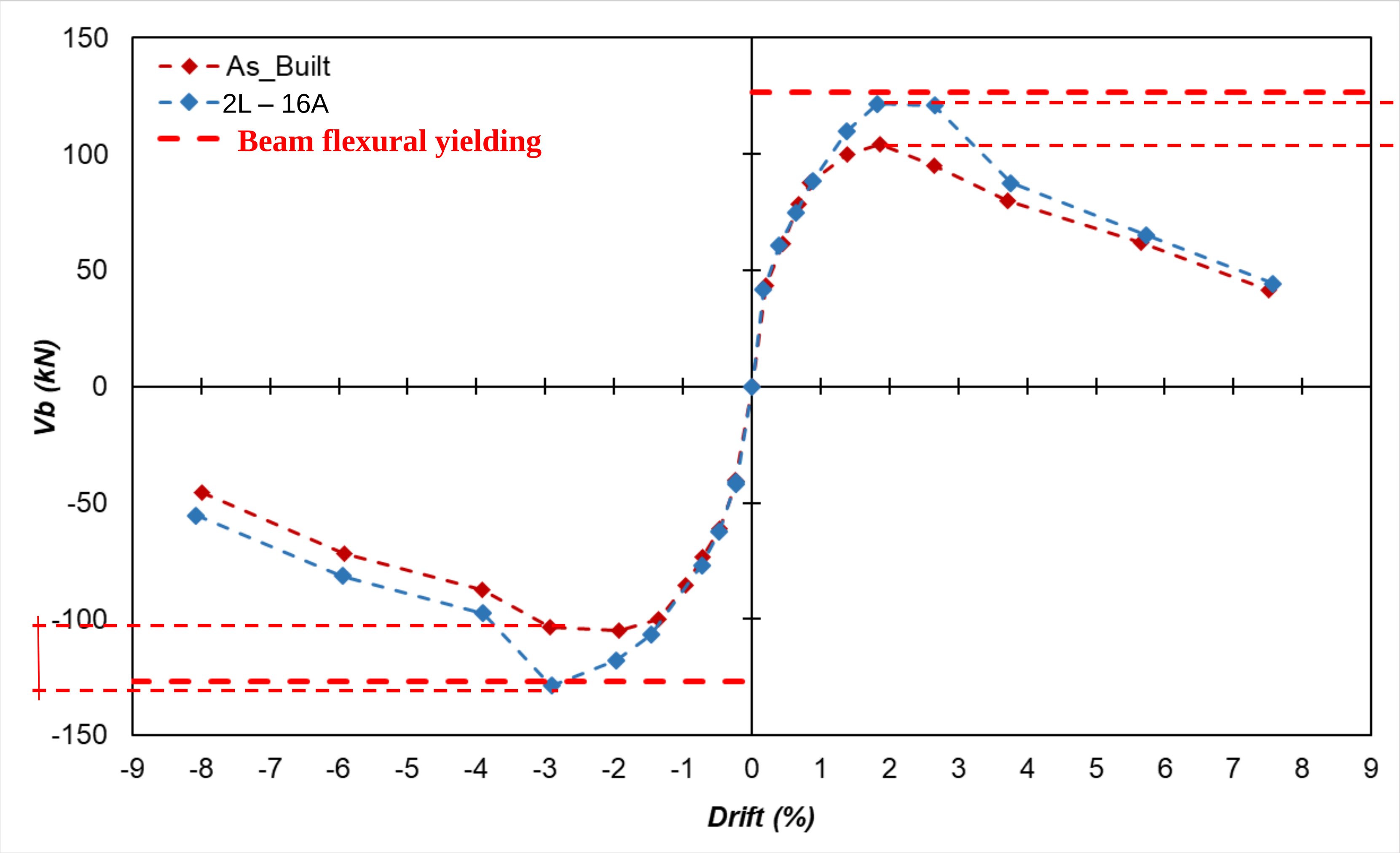
$\Delta_{T\_1L-16A}^{-} = 23\%$

T_1L – 16A



1 Layer CFRP
16 anchors

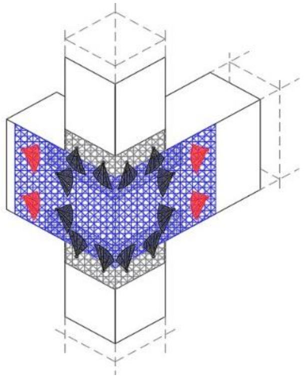
TEST RESULTS



$\Delta_{T\_2L\ -\ 16A}^{+} = 17\%$

$\Delta_{T2L\ -\ 16A}^{-} = 23\%$

T_2L – 16A



2 Layers CFRP
16 anchors

NEW CHALLENGES AND RECENT DEVELOPMENTS

New challenges and recent developments:

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

reluis

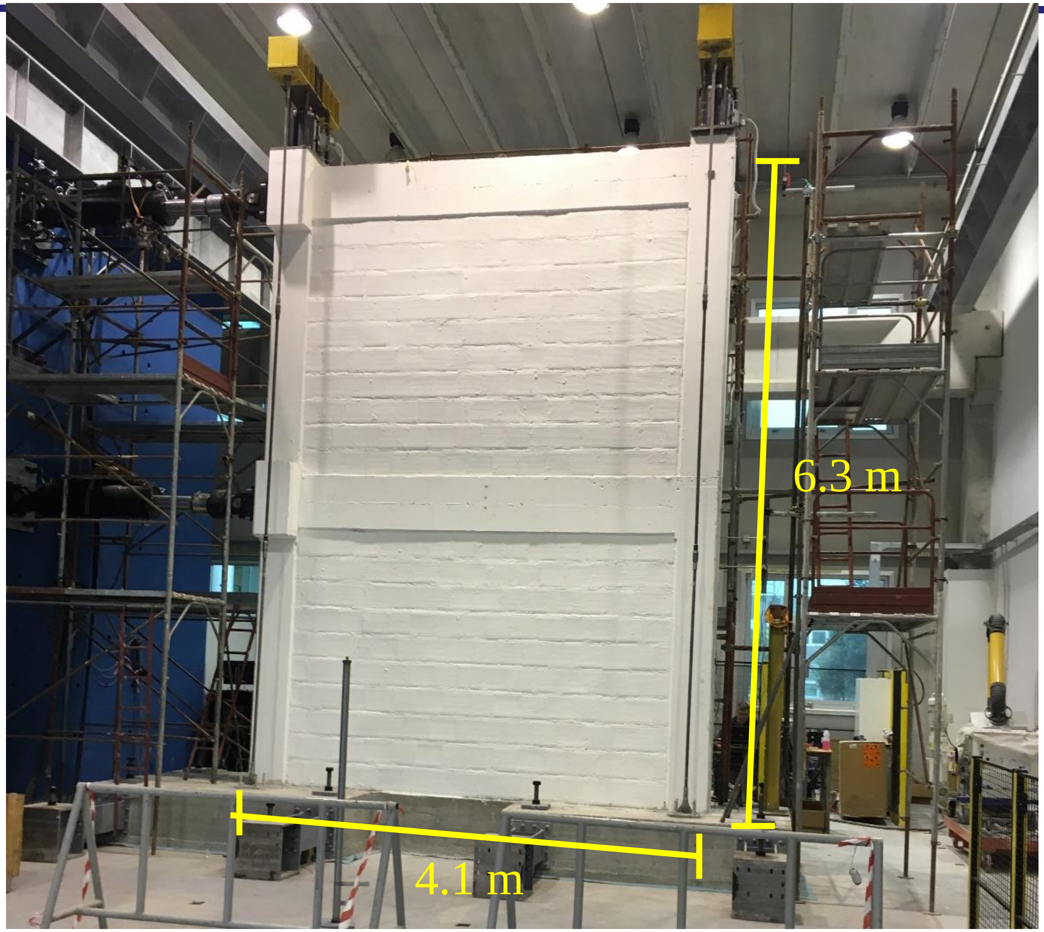
the Italian Department of Civil Protection within the framework of the
PE 2019–2021 joint program DPC-ReLUIS

WP5: “**Fast and Integrated Retrofit Interventions**” supported the research activities to develop a proper methodology for the integrated (E+S) retrofitting of existing buildings by using fast and innovative solutions

NEW CHALLENGES AND RECENT DEVELOPMENTS

Top column shear failure due to infill-to-structure interaction

NEW CHALLENGES AND RECENT DEVELOPMENTS



Full-scale

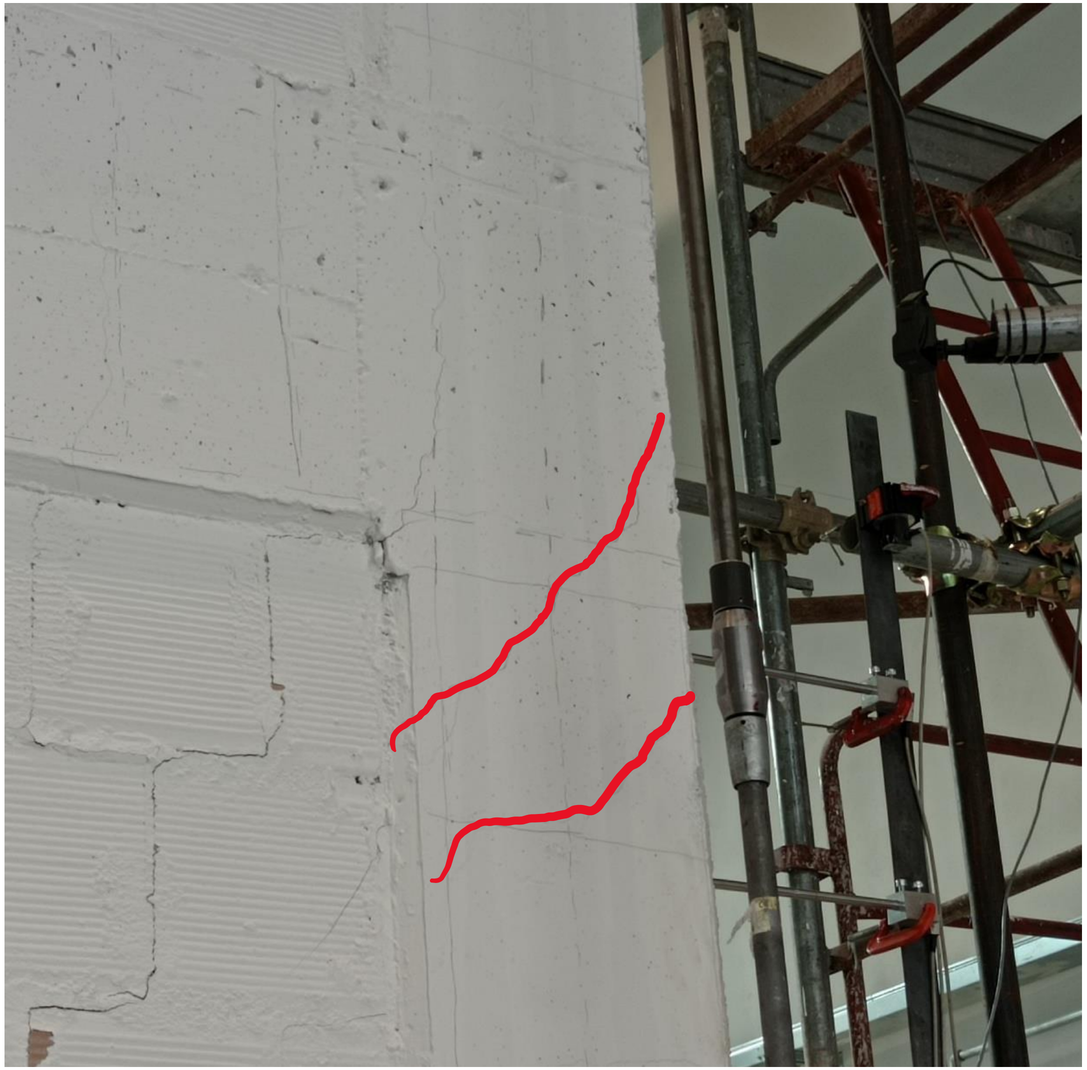
The most damaged frame was reproduced in
a laboratory environment

NEW CHALLENGES AND RECENT DEVELOPMENTS

Experimental test

Actual damage detected on the building

NEW CHALLENGES AND RECENT DEVELOPMENTS



Experimental test

Actual damage detected on the building

NEW CHALLENGES AND RECENT DEVELOPMENTS

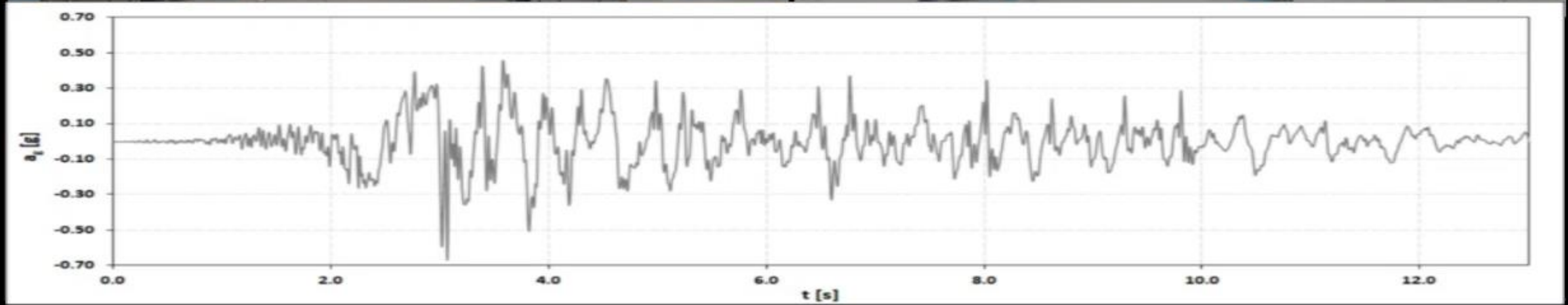
FRCM to enhance the infill to structure connection

FRP shear strengthening of the joint panel and column end

Out-of-plane strengthening of the infills

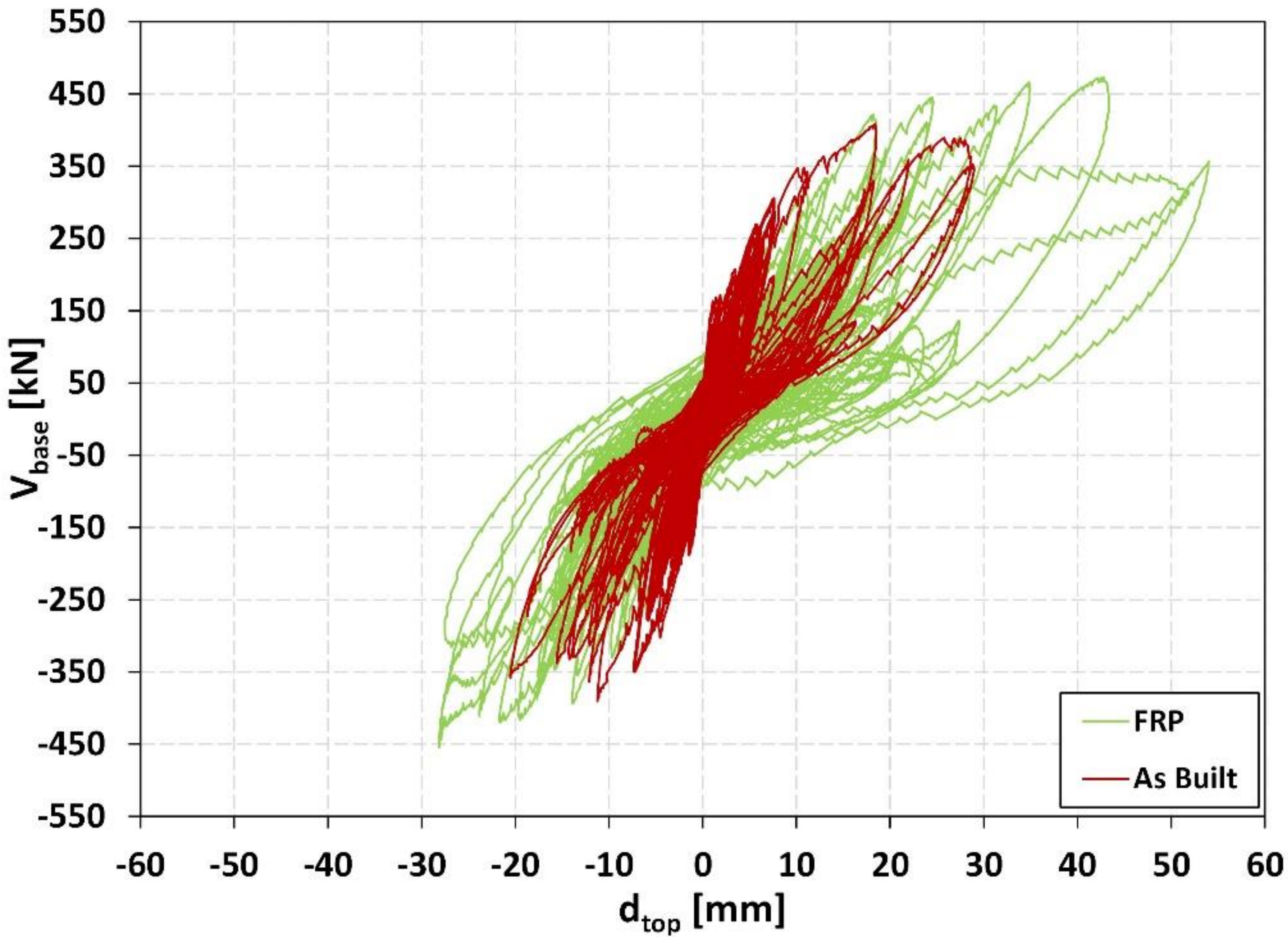
As-built

FRP strengthened



150%_AQG
L'Aquila 2009

NEW CHALLENGES AND RECENT DEVELOPMENTS

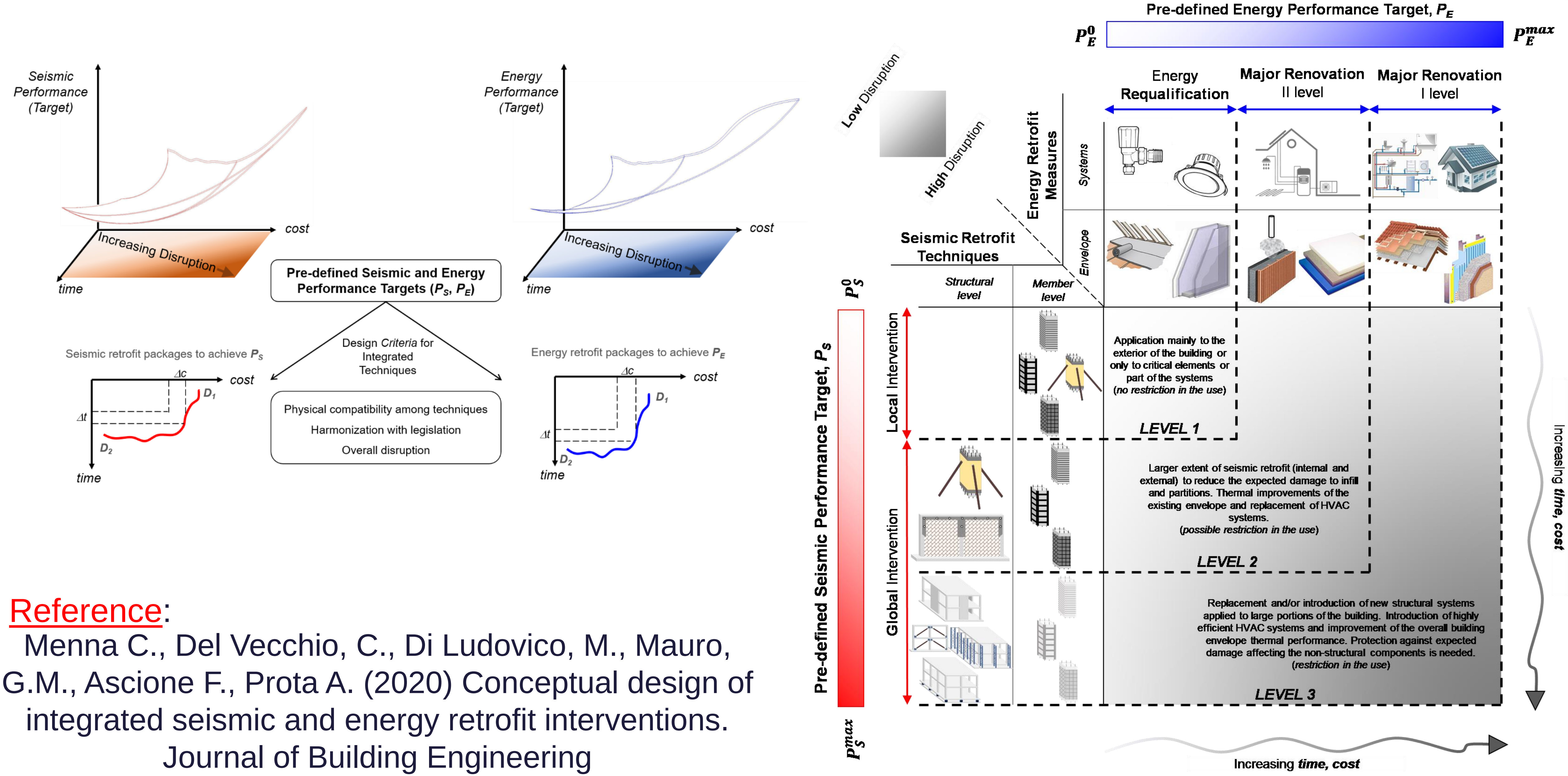


The FRP+FRCM strengtheing system allowed to:

- Reduce the observed damage at fixed PGA
- Increase the strength and deformation capacity
- Increase of the energy dissipation

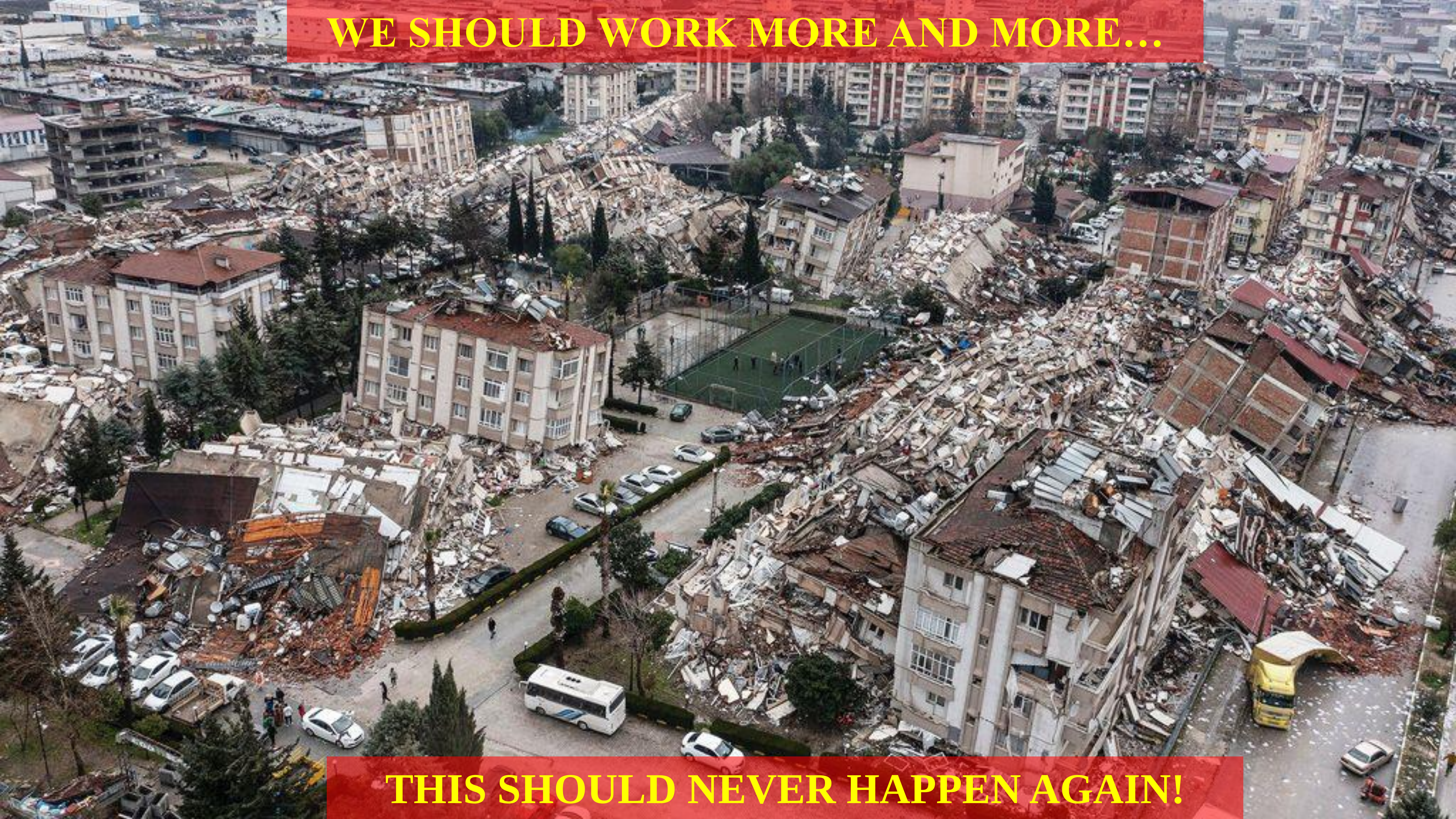
Del Vecchio C., Di Ludovico M., Balsamo A., Dolce M., Manfredi G., Prota A. Low impact interventions based on composite materials for a diffused reduction of seismic vulnerability of existing reinforced concrete buildings. Structural vol. 235 (2021)

NEW CHALLENGES AND RECENT DEVELOPMENTS



Reference:

Menna C., Del Vecchio, C., Di Ludovico, M., Mauro, G.M., Ascione F., Prota A. (2020) Conceptual design of integrated seismic and energy retrofit interventions. Journal of Building Engineering


WE SHOULD WORK MORE AND MORE…
THIS SHOULD NEVER HAPPEN AGAIN!

Thank you

Andrea Prota

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