Applying the lesson learnt from precast industrial buildings in Italy to the Balkans

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• Seismic Performance of precast RC buildings in past events

• Vulnerability assessment of precast buildings in Italy and in the Balkans

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Precast industrial buildings

**Precast structures** are typically used for **industrial buildings** in Italy and in Europe (mainly one-story).

**Column structures:**
- socket foundations
- precast columns
- hinged pre-stressed precast beams
- precast RC cladding panels
Past events affecting precast buildings

Several past events severely hit precast industrial buildings in Europe

- 2012 Northern Italy earthquake
- 1998 Adana-Ceyhan (Turkey)
- 1999 Golcuk earthquakes (Turkey)

- The events highlighted the high vulnerability of precast buildings in Europe
- Opportunity to collect data and investigate seismic performance
Case-study: Italy (2012)

M5.9 on 20th May
- 7 fatalities
- 20 injuries
- 5000 displaced

M5.8 on 29th May
- 20 fatalities
- 350 injuries
- 15000 displaced

1 bn EUR Economic damage
5 bn EUR induced economic damage
>50% of precast buildings suffered severe damage

Inadequate capacity
High density and use
Case-study: Italy (2012)

Inadequate capacity

All structures in Emilia designed up to 2003 did not take into account seismic design.

Seismic hazard map up to 2003

High density

The area around the epicentre is a heavily industrialised area, hosting an industrial hub of biomedical companies.

>80% of industrial buildings has a precast RC structure.
How to reduce the risk of precast structures?

**Engineering approach**
- Numerical analysis
- Expert judgement
- Experimental tests

**Vulnerability assessment**
- How will the structure behave when an earthquake occurs?
- What are the main weak points of the structure?
- How can the performance be improved?

**Retrofitting measures**
- Classify the structures according to their features
- Identify the buildings with the largest risk
- Optimize the resources to prioritise the retrofitting actions
Vulnerability assessment of Italian precast buildings

Example for one-storey new buildings

Panels have been the main cause of casualties and damage

Proportion of failure

(Current) not adequate connections

Retrofitted connections

Connections between panels and structures are weak

Panels have been the main cause of casualties and damage.
Large-panel precast buildings in the Balkans

- No Storeys: 6-9
- Resisting System: RC Unconfined Squat Shear Walls
- Precast panels with cast in-situ joints
The seismic performance of Balkan precast buildings can be assessed via numerical methods looking at (a) connection failure and (b) panel damage.
Bespoke form for precast structures

Collection of the data required to predict the vulnerability

Good reliability of the data collected by experienced and trained surveyors

Example of use

One-storey precast building in Italy built in 1998

Specific structural and nonstructural features

- Large span and height
- Friction connections
- Heavy RC panels
Capacity assessment form

Example of use

SEZIONE 2a

Geometry

<table>
<thead>
<tr>
<th>N° Piani totali con interrati</th>
<th>Altezza media di piano [m]</th>
<th>Superficie media di piano [m²]</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>2.7-3.49</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3.5-4.99</td>
<td></td>
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<tr>
<td>3</td>
<td>5.0-6.99</td>
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<tr>
<td>4</td>
<td>7.0-9.99</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>10.0-13.99</td>
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<tr>
<td>6</td>
<td>&gt; 14.0</td>
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</table>

Piani intrecciati

<table>
<thead>
<tr>
<th>N° Piani intrecciati</th>
<th>Altezza massima libera pilastri</th>
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<tbody>
<tr>
<td>A</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>2</td>
</tr>
<tr>
<td>D</td>
<td>3</td>
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</table>

Connessioni

<table>
<thead>
<tr>
<th>Tipologia di connessione</th>
<th>Non identificata</th>
<th>Presunta</th>
<th>Da interviste interviste preparatore</th>
<th>Da interviste esperto</th>
<th>Insezione direttiva</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trave - pilastro/parieti</td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>Appoggio</td>
<td></td>
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</tr>
<tr>
<td>Cerniera (ad es. barre verticali su mensola)</td>
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<tr>
<td>Semi-incastro (ad es. parz. resistenti a flessione)</td>
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<tr>
<td>Incastro (ad es. emulazione a c.a. in opera)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copertura - trave / Copertura - pilastro</td>
<td></td>
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</tr>
</tbody>
</table>

Panelli di tamponatura

<table>
<thead>
<tr>
<th>N° unità</th>
<th>Uso</th>
<th>Use</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>Presenza pilastri reggi-pannello</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Presenza dispositivi di ritenuta</td>
<td></td>
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<tr>
<td>C</td>
<td>Prefabbricati orizzontali appesi esterni al filo pilastri</td>
<td></td>
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<tr>
<td>D</td>
<td>Prefabbricati orizzontali appesi interni al filo pilastri</td>
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<tr>
<td>E</td>
<td>Prefabbricati orizzontali inclinati</td>
<td></td>
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<tr>
<td>F</td>
<td>Prefabbricati verticali con chiave di taglio alla base</td>
<td></td>
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<tr>
<td>G</td>
<td>Prefabbricati verticali senza chiave di taglio alla base</td>
<td></td>
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<tr>
<td>H</td>
<td>Prefabbricati verticali inclinati</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>Prefabbricati inclinati</td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>Prefabbricati verticali appesi esterni al filo pilastri</td>
<td></td>
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<tr>
<td>K</td>
<td>Prefabbricati inclinati</td>
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<tr>
<td>L</td>
<td>Prefabbricati inclinati</td>
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<td>M</td>
<td>Prefabbricati inclinati</td>
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<td>N</td>
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<td>Prefabbricati inclinati</td>
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<td>P</td>
<td>Prefabbricati inclinati</td>
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<td>Q</td>
<td>Prefabbricati inclinati</td>
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<td>R</td>
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<td>Prefabbricati inclinati</td>
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<td>Prefabbricati inclinati</td>
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<td>U</td>
<td>Prefabbricati inclinati</td>
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<td>V</td>
<td>Prefabbricati inclinati</td>
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<td>W</td>
<td>Prefabbricati inclinati</td>
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<tr>
<td>X</td>
<td>Prefabbricati inclinati</td>
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<tr>
<td>Y</td>
<td>Prefabbricati inclinati</td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>Prefabbricati inclinati</td>
<td></td>
</tr>
</tbody>
</table>

Number of impacted people after the earthquake

Low capacity of connections (as highlighted in past events and previous studies)

Retrofit of connections is needed
**Retrofitting measures**

**How to improve the capacity?**

- **Step 1**: Removal of the most significant structural deficiencies
- **Step 2**: Extensive and systematic actions in order to achieve the required performance, integrating into a broader context the actions of the first phase

**Immediate operations for overcoming the emergency in Emilia**

D.L. 6 June 2012 n. 74 converted in Law on 1 August 2012 n. 122

**Uniform approach to risk mitigation**

Two phase process:

- **Step 1**: Removal of the most significant structural deficiencies
- **Step 2**: Extensive and systematic actions in order to achieve the required performance, integrating into a broader context the actions of the first phase

Money - investment

Interruption of use

**“Immediate operations for overcoming the emergency in Emilia”**

D.L. 6 June 2012 n. 74 converted in Law on 1 August 2012 n. 122
Retrofitting measures

A. Inadequate connections

B. Inadequate panels

A. Additional elements

B. Overturning control

Weakness

Retrofitting measure

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Proposed approach for the Balkans - Conclusions

- Study of the capacity and weaknesses in existing buildings
- Engineering study: tests and analysis
- Definition of the classes of buildings with low capacity
- Optimize the resources for risk mitigation
- Training of engineers for collecting data
- Identification of the classes of buildings: assessment form
- Decision about retrofitting actions in buildings at risk: guidelines for practitioners
- Investment plan for retrofitting with prioritization
Thank you for your attention