Full-scale PsD testing of the SAFECAST three-storey precast concrete buildings

Dionysis BOURNAS
Lecturer, University of Nottingham

Paolo NEGRO and Javier MOLINA
Researcher, ELSA, JRC, European Commission

European Laboratory for Structural Assessment (ELSA)
Institute for the Protection and Security of the Citizen (IPSC)
Joint Research Centre of the European Commission (JRC)
Advantages of Precast Construction

- Speed in construction
- Economy
- Quality of the products (prefabrication is a fully industrialized process)
- Easiness in maintenance, modification, dismantling and recycling
- Natural resources saving and waste reduction
- Noise and pollution reduction

Seismic behaviour of precast structures ???
Northridge Earthquake (1994)
Koçaeli Earthquake (1999)
L’Aquila Earthquake (2009)
Emilia Earthquake (2012)
SAFECAST PROJECT

PERFORMANCE OF INNOVATIVE MECHANICAL CONNECTIONS IN PRECAST BUILDING STRUCTURES UNDER SEISMIC CONDITIONS

CONSORTIUM

**SME Associations:**
- Assobeton (Italy)
- ANDECE (Spain)
- ANPD (Portugal)
- SEVIPS (Greece)
- TPCA (Turkey)

**RTD Providers:**
- POLIMI, Labor srl (Italy)
- NTUA (Greece)
- ITU (Turkey)
- LNEC (Portugal)
- U Ljubljana (Slovenia)
- IPSC/ELSA

► All seismic countries of the Union are represented!
Construction of the MOCKUP

Experimental Programme

Experimental Results

Conclusions
Construction of the MOCKUP

Experimental Programme

Experimental Results

Conclusions
Construction of the MOCKUP
Construction of the MOCKUP
Construction of the MOCKUP
Construction of the MOCKUP
Construction of the MOCKUP
Construction of the MOCKUP
Construction of the MOCKUP
Construction of the MOCKUP
Construction of the MOCKUP
Construction of the MOCKUP

Experimental Programme

Experimental Results

Conclusions
4 Different structural layouts of a 3-storey precast concrete building

The contribution of shear walls in a frame system with hinged beam-column joints

3 Diaphragm systems without topping (No casting on site)

Mechanical Beam-Column connections:
- Hinged joints through dowels → existing practice;
- Emululative joints through new connection devices to provide continuity in the joint
Prototype 1 – Hinged Connections & Structural walls

Interaction between precast and cast in situ elements
Prototype 2 - Hinged connections

*Global behaviour, deformability, …*
Prototype 3 – Hinged + Emulative (top floor) connections

Design methodology (for connections and for the building)
Prototype 4 - Emulative connections

Design methodology (for connections and for the building)
EMULATIVE JOINTS
EMULATIVE JOINTS
EMULATIVE JOINTS
EMULATIVE JOINTS
EMULATIVE JOINTS
Construction of the MOCKUP
Tolmezzo modified accelerogram
Experimental Programme – PsD and Cyclic Tests Performed

<table>
<thead>
<tr>
<th>Model \ Test</th>
<th>PGA of 0.15 g</th>
<th>PGA of 0.30 g</th>
<th>PGA of 0.45 g</th>
<th>Cyclic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prototype 1</td>
<td>X</td>
<td>X</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Prototype 2</td>
<td>X</td>
<td>X</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Prototype 3</td>
<td>--</td>
<td>X</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Prototype 4</td>
<td>--</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

8 tests were performed in total
CONTENTS

Construction of the MOCKUP

Experimental Programme

Experimental Results

Conclusions
Experimental Results – Prototype 1

Displacement PsD response of each floor at PGA of 0.30g

-60
-40
-20
0
20
40
60
Horizontal displacement (mm)
Time (s)

First floor
Second floor
Third floor

Force PsD response of each floor at PGA of 0.30g

-1000
-500
0
500
1000
Restoring force (kN)
Time (s)

First floor
Second floor
Third floor
Experimental Results – Prototype 1

Key Response Parameters

Max. Base Shear
- PGA 0.15: 1457 kN
- PGA 0.30: 2145 kN

Top Displacement
- PGA 0.15: 21.9 mm
- PGA 0.30: 60.3 mm

Max. Interstorey Drift
- PGA 0.15: 0.31 % (3rd floor)
- PGA 0.30: 0.75 % (3rd floor)

“Fundamental” period
- PGA 0.15: 0.30 sec
- PGA 0.30: 0.45 sec
Experimental Results – Prototype 2

Displacement PsD response of each floor at PGA of 0.30g

Force PsD response of each floor at PGA of 0.30g
Experimental Results – Prototype 2

Key Response Parameters

Max. Base Shear: 669 kN, 895 kN
Top Displacement: 117 mm, 208 mm
Max. Interstorey Drift: 1.27% (3rd floor) > 1% (EC8), 2.10% (3rd floor)
“Fundamental” period: 1.08 sec, 1.41 sec
Experimental Results – Prototype 3

Displacement PsD response of each floor at PGA of 0.30g

Force PsD response of each floor at PGA of 0.30g
Experimental Results – Prototype 3

Key Response Parameters

Max. Base Shear: 889 kN
Top Displacement: 199 mm
Max. Interstorey Drift: 2.54 % (2nd floor)
“Fundamental” period: 1.15 sec
Experimental Results – Prototype 4

Displacement PsD response of each floor at PGA of 0.30g

Time (s)
Vertical displacement (mm)
First floor
Second floor
Third floor

Force PsD response of each floor at PGA of 0.30g

Time (s)
Restoring force (kN)
First floor
Second floor
Third floor
Experimental Results – Prototype 4

Key Response Parameters

Max. Base Shear
- PGA 0.30: 1715 kN
- PGA 0.45: 1902 kN

Top Displacement
- PGA 0.30: 132 mm
- PGA 0.45: 206 mm

Max. Interstorey Drift
- PGA 0.30: 1.59 % (2nd floor)
- PGA 0.45: 2.47 % (1st floor)

“Fundamental” period
- PGA 0.30: 0.74 sec
- PGA 0.45: 1.11 sec
Comparison of the 4 Prototypes - PGA 0.30g

Hinged Joints & Walls

Hinged Joints

Hinged & Emulative joints

Emulative joints
Experimental Results – Cyclic Test

Key Response Parameters

- Max. Base Shear: 2229 kN
- Top Displacement: 416 mm
- Max. Interstorey Drift: 6.01% (1st floor)
CONTENTS

Construction of the MOCKUP

Experimental Programme

Experimental Results

Conclusions
Conclusions

- The seismic performance of different structural layouts including existing and also new connections was validated experimentally through large-scale reference testing.

- **Prototype 2**: No damage under 0.30g PGA, but large flexibility and large higher modes effects.

- **Prototype 3**: No damage under 0.30g PGA, but not effective as anticipated to reduce the effect of higher modes and horizontal displacements.

- **Prototype 4**: Good response! Frame behavior. No significant damages were observed under 0.45g PGA. In the final Cyclic Test underwent extensive damages and approached the non-collapse limit state. Damage was concentrated at the base of all ground floor columns which attained a drift ratio of about 6%.
Design Guidelines
for Connections of Precast Structures
under Seismic Actions

Paolo Negro and Giandomenico Toniolo
Editors
2012
Statement of the problem: the Emilia experience

Emilia Earthquakes, May-June 2012
PROJECT SAFECLADDING

Improved Fastening Systems of Cladding Wall Panels of Precast Buildings in Seismic Zones

GA 314122
THANK YOU FOR YOUR ATTENTION !!!