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Ispra  
5-7 October 2009

International Workshop on Seismic performance of precast structures

## Technical Session 2: National Perspectives Portugal



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## Summary:

- The Portuguese Precast Industry
- Previous Research on Seismic Performance of Precast Structures in Portugal
- Portuguese Precast Industry Expectations



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## THE PORTUGUESE PRECAST INDUSTRY

- Activity
- Market
- Common typologies
- Common products



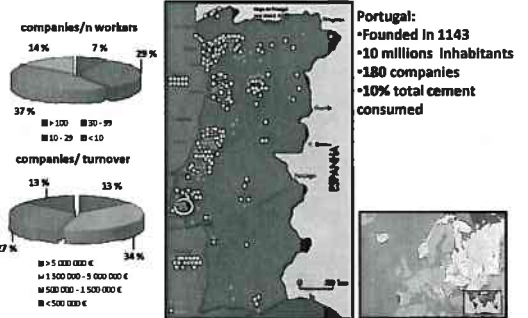
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## The Portuguese Precast Industry Activity

ANIPB → National Association of Precast Concrete Industry



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## The Portuguese Precast Industry Precast Concrete Market

		Values	Trends
Turnover	2008 vs. 2007 [%]	50	↓
	2009 vs. 2007 [%]	10	↔
Order book filling	Mid 2008 [months]	10	-
	End 2008 [months]	10	-
	Mid 2009 [months]	15	↑
Profitability (EBITDA)	Mid 2008 [%]	15	-
	End 2008 [%]	15	-
	Mid 2009 [%]	15	↔

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## The Portuguese Precast Industry



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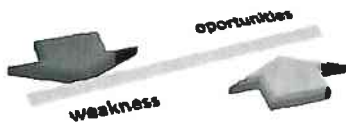


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### The Portuguese Precast Industry



- o excessive offer
- o strong "competition" among producers
- o low skilled labour and production technology
- o selection based on price and not on quality
- o lack of legislation and supervision
- o public investment
- o clean energies
- o association of companies (takeovers and merges)
- o replacement of materials (precast concrete elements vs other materials)

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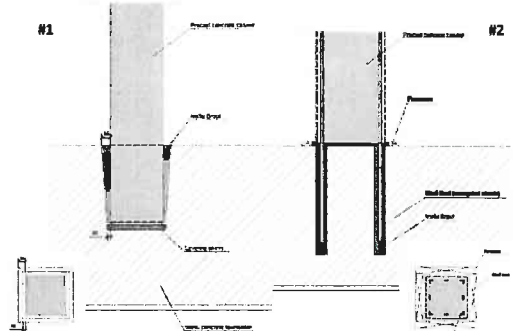
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### The Portuguese Precast Industry

#### Common connections used in Portugal

##### Column - Foundation



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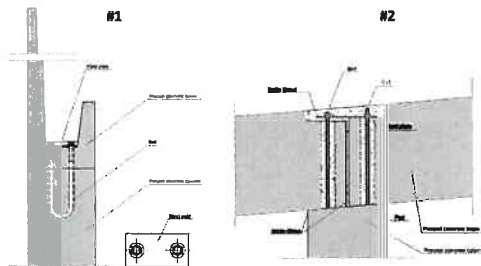
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### The Portuguese Precast Industry

#### Common connections used in Portugal

##### Beam - Column



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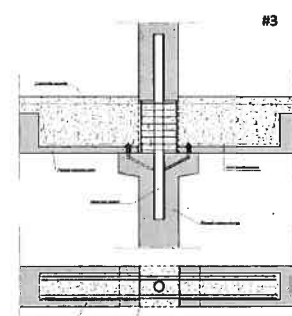
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#### Common connections used in Portugal

##### Beam - Column



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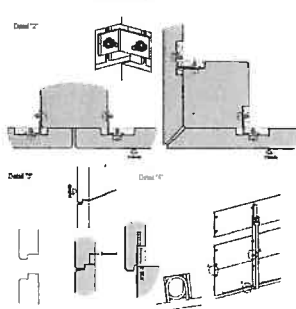
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### The Portuguese Precast Industry

#### Common connections used in Portugal

##### Cladding - Structure



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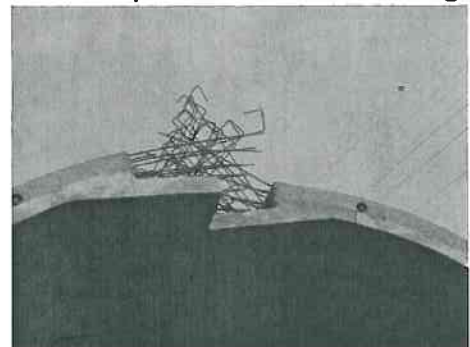
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### The Portuguese Precast Industry

#### Common products used in Portugal



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## The Portuguese Precast Industry Common products used in Portugal



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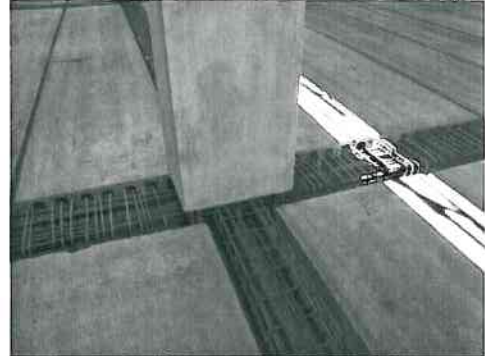


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## PREVIOUS RESEARCH ON SEISMIC PERFORMANCE OF PRECAST STRUCTURES IN PORTUGAL

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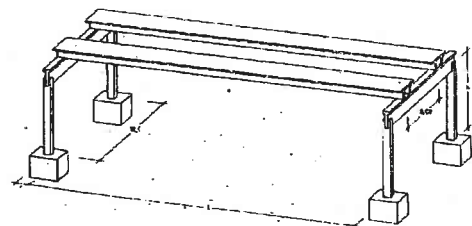
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### Previous research on Seismic performance of precast structures in Portugal

Appleton, J. (1981) – "Solidarização de estruturas pré-fabricadas de grande vão", Thesis submitted for obtaining the scientific title of "Especialista LNEC" (in Portuguese)

- Behaviour of long span precast concrete structures under horizontal actions
- A parametric linear analysis taking into account the seismic loading for seismic coefficient evaluation and to define equivalent static forces to those involved in a dynamic analysis.
- A secondary study on connections with emphasis on structural bracing solutions, in particular their relative efficiency and economic costs vs. benefits for long span structures.

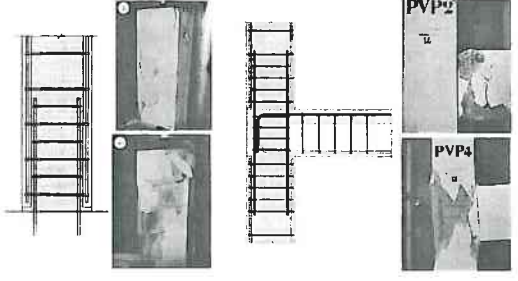


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### Previous research on Seismic performance of precast structures in Portugal

Pompeu dos Santos, S. G. (1983) - "Comportamento de Ligações de Estruturas Prefabricadas de Betão", Thesis submitted for obtaining the scientific title of "Especialista LNEC" (in Portuguese)

- Cyclic tests on column-to-column, column-to-strong-element, beam-to-column and beam-to-strong-element connections.

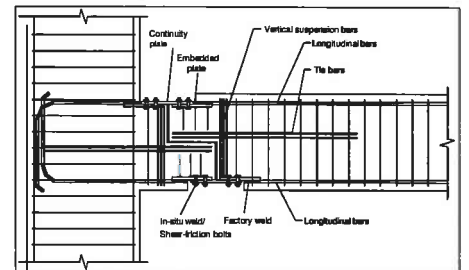


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### Previous research on Seismic performance of precast structures in Portugal

Proença, J.; Romba, J.; Viegas, J.; Vieira, A. (2003) - "Experimental Development Stages of an Innovative Earthquake-resistant Precast Frame System", fib 2003 Symposium "Concrete structures in seismic regions"; Athens, Greece, 2003.

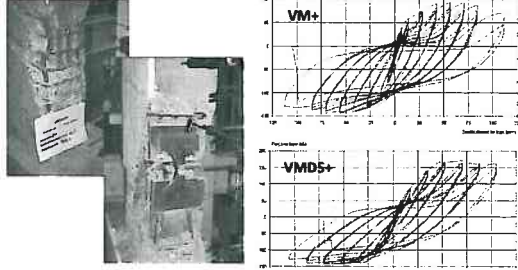
- The tested connections have different characteristics in terms of the design approach/location, detailing (bolted/welded) and longitudinal reinforcement percentage
- Cyclic tests on 4+10 specimens and non-linear numerical models



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### Previous research on Seismic performance of precast structures in Portugal

Proença et al. (2002)



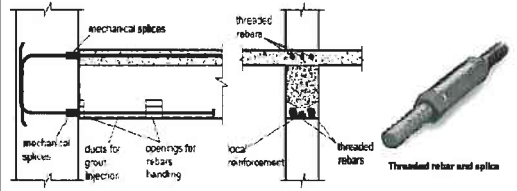
- Main conclusions:**
- This connection system can be effectively used for jointed and equivalent monolithic connection types.
  - The performance of the system is similar to the equivalent monolithic solution

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### Previous research on Seismic performance of precast structures in Portugal

Lúcio, V.; Reis, P. (2002) - "Beam-column connection for precast concrete structures in seismic regions", BIBM 17th International Congress of the precast concrete industry, Istanbul.

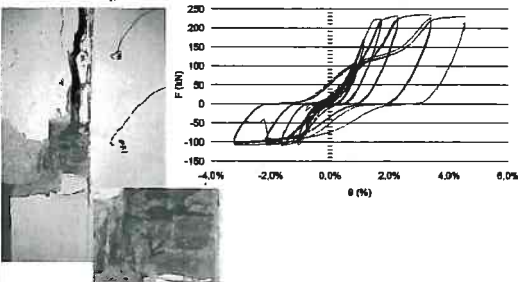
- Cyclic tests on dissipative beam-column connections
- Continuity of the longitudinal reinf. established through mechanical splices
- Vertical joints sealed with a cement mortar



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### Previous research on Seismic performance of precast structures in Portugal

Lúcio, V.; Reis, P. (2002) - "Beam-column connection for precast concrete structures in seismic regions", BIBM 17th International Congress of the precast concrete industry, Istanbul.



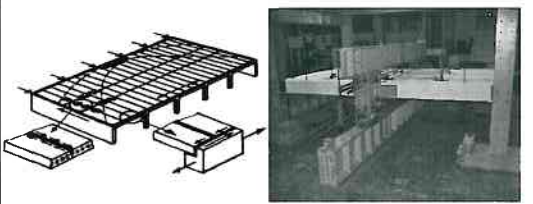
- Main conclusions:**
- Displacement ductility:  $\mu_d = 3$   $\mu_d = (q+1)^2 / 4$  [Tassios 1988]  $\rightarrow q = 2.5$

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### Previous research on Seismic performance of precast structures in Portugal

Faria, D.; Proença, J.; Zubia, J. (2003) - "Seismic Behaviour of Hollow-core Slabs. Experimental assessment stages" - fib 2003 Symposium "Concrete structures in seismic regions"; Athens, Greece, 2003

- Cyclic tests on hollow-core slabs under in-plane loading - Diaphragm effect



- Main conclusions:**
- The maximum shear stress between slabs was around 0.4-0.5 MPa
  - Even without casting the compression layer, the panels revealed high strength and stiffness, although with some stiffness degradation between cycles.

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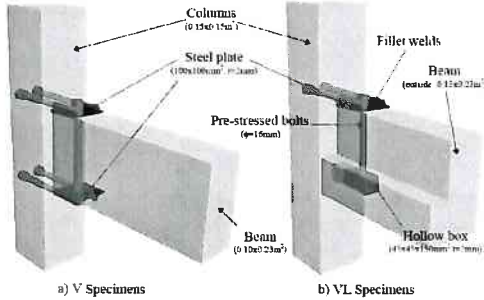
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### Previous research on Seismic performance of precast structures in Portugal

Mendes, L.; Coelho, E.; Costa, A.C. (2006) – "PRECAST-Seismic Tests of a RC Precast Building System", 1<sup>st</sup> ECEES, Geneva, Switzerland.



a) V Specimens      b) VL Specimens

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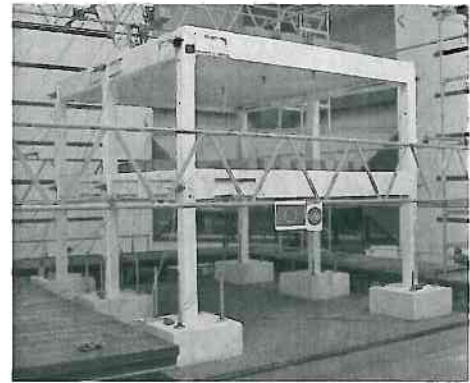


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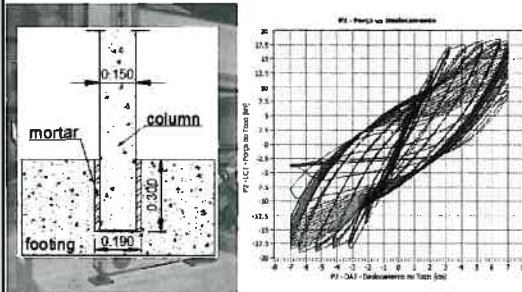
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Mendes, L.; Coelho, E.; Costa, A.C. (2007) – "PRECAST - Ensaios cíclicos a nós de um sistema de betão armado", 7<sup>th</sup> Cong. de Sismologia e Eng. Sísmica, Porto.



Quasi-static cyclic tests on the column-footing connections

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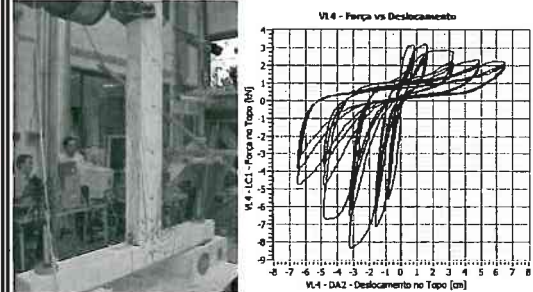
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Quasi-static cyclic tests on the beam-column connections

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### Previous research on Seismic performance of precast structures in Portugal

Reguengo, R.; Lúcio, V.; Chastre, C. (2008) – "Precast column-foundation connection with protruding reinforcement from the column", 2<sup>nd</sup> Cong. Nacional da Prefabricação em Betão, LNEC, Lisboa (in Portuguese)

- Monotonic and cyclic tests on connections made from column protruding rebars that are inserted in holes left or drilled in the foundation.
- Several solutions for establishing the connection were studied:
  - smooth or prestressing sleeves embedded in the foundation concrete
  - rebars sealed with grout or embedded directly on the foundation concrete



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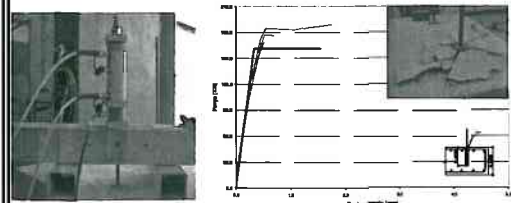
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#### Main conclusions:

- The best response in terms of resistance was achieved when using prestressing sleeves embedded in concrete or holes drilled in the concrete. In both cases the bars were sealed with grout.
- The use of smooth sleeves is not recommended because they presented a very low resistance.
- The most ductile solution is that where the connection is designed for a load higher than the rebar resistance since, in that case, the behaviour is controlled by the steel ductility.

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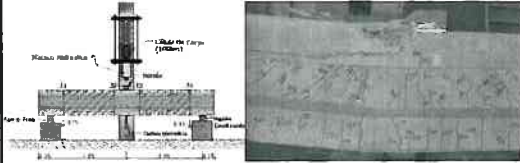
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### Previous research on Seismic performance of precast structures in Portugal

Câmara, J.; Cavaco, E.; Pacheco, I. (2008) - "Behavior of precast concrete continuity joints", Encontro Nacional de Engenharia Estrutural, Guimarães.

- Experimental study on cast-in-situ continuity joints in linear elements under high hogging/sagging moments and shears forces areas (e.g. near the supports)
- Models with vertical joints or with 45° in both directions and application of several types of glues



#### Main Conclusions:

- The cast in situ joints did not reduce the load capacity of the beams, however, there was a reduction on the concrete tensile strength on the interface and, for cases without web reinforcement, a loss of ductility.
- The glue applications on the interfaces did not improve significantly the response.
- The joints between a precast unit and cast in situ elements, with reinforcement continuity, can be designed even in zones with high strengths without any disadvantage in terms of global behavior.

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## PLANNED ACTIVITY FOR THE SAFECAST PROJECT

Portuguese Group



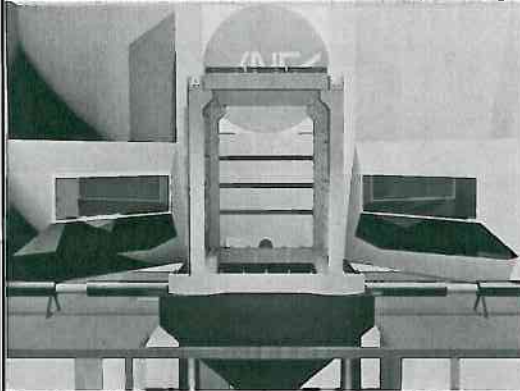
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### Planned activity for the SAFECAST project

o Cladding Panels-to-Structure Connections (Dynamic)



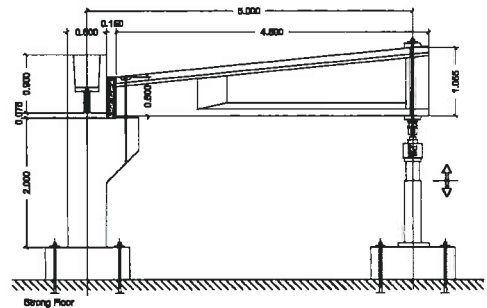
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### Planned activity for the SAFECAST project

o Beam-Column Connection – Cyclic (quasi-static)



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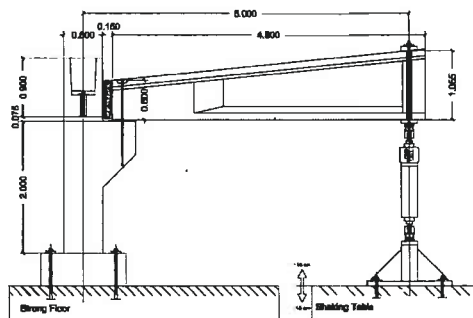
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### Planned activity for the SAFECAST project

o Beam-Column Connection – Cyclic/Seismic (Dynamic)



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## PORTUGUESE PRECAST INDUSTRY FUTURE EXPECTATIONS



## The Portuguese Precast Industry

### Future expectations from SAFECAST project

- o Seismic behaviour of precast concrete structural connections
- o Improve the used connections
- o Improve the precast concrete industry image among the stakeholders
- o Common rules
  - use when designing and constructing
  - supervision
- o Similar treatment between precast structures and others types of structures – e.g. EC 8

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- Prof. Vítor Lúcio (FCT-UNL)

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**Thank you**