

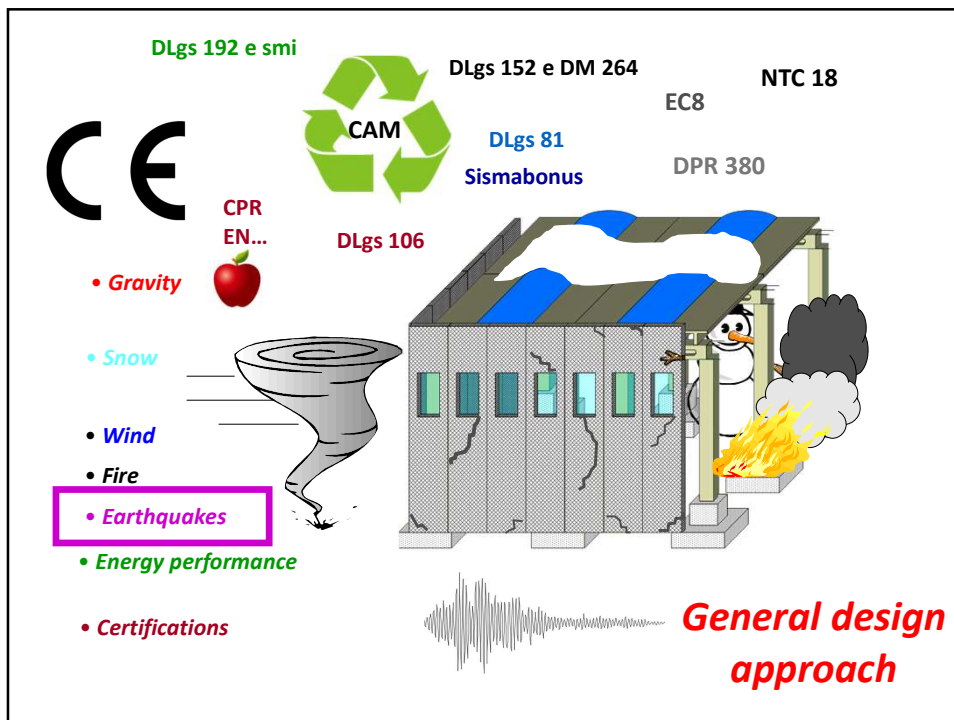


ASSOBETON

Seismic design of precast structures: a quick overview from the Italian manufacturers point of view

Antonella Colombo

4 February 2022



Italian Design codes

National law or Eurocodes?

... As example of countries, where there are no conflicting standards, but the existing national regulations introduce directly design rules which do not fully reflect the entire set of the Eurocodes provisions, one can mention **Italy**,... (The implementation of the Eurocodes in the National Regulatory Framework - JRC technical reports 2019)

- Norme Tecniche per le Costruzioni (DM 17/01/2018)
- Circolare n.7/2019

NTC 2018 - ToC

368 pages

Chapter 1 - Scope

Chapter 2 - Principles and Requirements for the safety, serviceability, ...

Chapter 3 - Actions on structures

Chapter 4 - Design of (concrete, steel, timber, masonry, ...) structures

Chapter 5 - Bridges

Chapter 6 - Geotechnical design

Chapter 7 - Seismic design

Chapter 8 - Existing structures

Chapter 9 - Acceptance criteria for structures

Chapter 10 - Drafting of structural projects and calculation reports

Chapter 11 - Qualification, certification and acceptance of materials and products for structural use

Chapter 12 - Technical references



NTC 2018 - Chapter 1

This document defines the **principles for the design, execution and testing** of constructions, with regard to the performance required in terms of essential requirements of **mechanical resistance and stability**, even in the case of **fire**, and **durability**.

It therefore provides the general **safety criteria**, specifies the **actions** that must be used in the design, defines the **characteristics of materials and products** and, more generally, deals with aspects relating to the **structural safety of the works**.

Regarding the indications for obtaining the prescribed performances, **if not expressly specified in the document**, reference can be made to standards of **proven validity** and other technical documents listed in Chapter 12. In particular indications provided by the **Eurocodes** with the relative National Annexes constitute indications of proven validity and provide the systematic application support of NTC 2018.

Circolare n.7 - ToC

Circolare n.7 aims to provide clarifications, indications and additions, for an easier and more unambiguous application of the NTC.

Same ToC as NTC2018.

337 pages



N. 5

MINISTERO DELLE INFRASTRUTTURE
E DEI TRASPORTI

CIRCOLARE 21 gennaio 2019, n. 7 C.S.I.LL.PP.

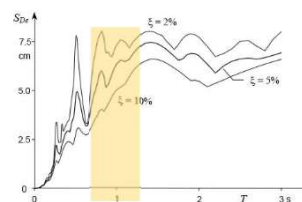
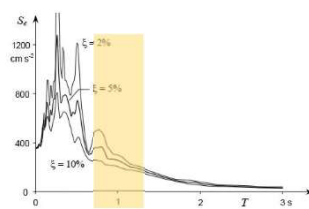
Istruzioni per l'applicazione dell'«Aggiornamento delle «Norme tecniche per le costruzioni»» di cui al decreto ministeriale 17 gennaio 2018.

What we learned from the past

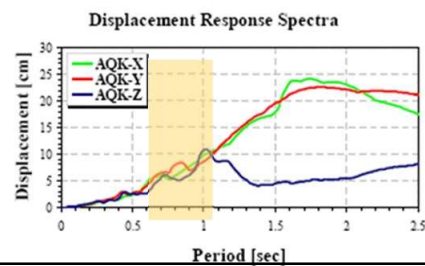
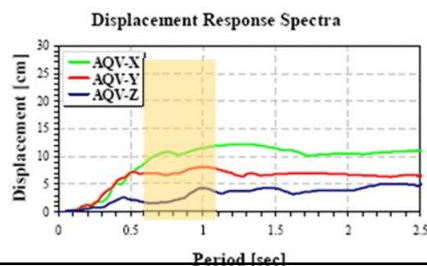
- Tolmezzo earthquake 1976
- L'Aquila earthquake 2009
- Emilia earthquake 2012
- Centro Italia earthquake 2016
- Research project (SAFECAST-SAFECLADDING)

Forces vs deformations

Tolmezzo 1976

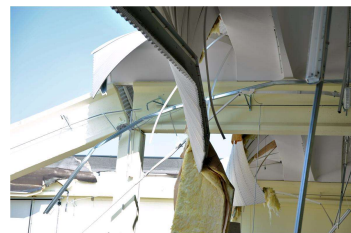


L'Aquila 2009

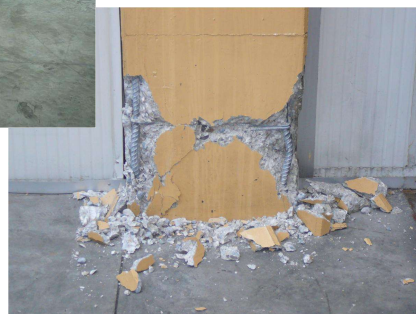


Supports

Emilia 2012

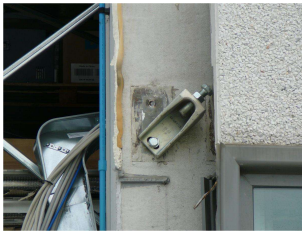


Ductility



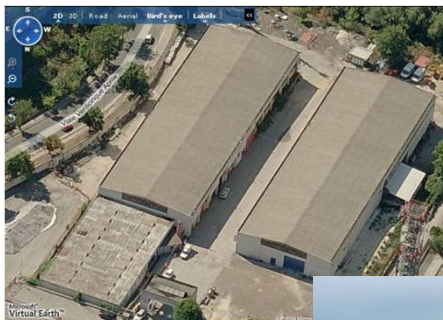
Panels

Emilia 2012



Non-loaded columns

L'Aquila 2009

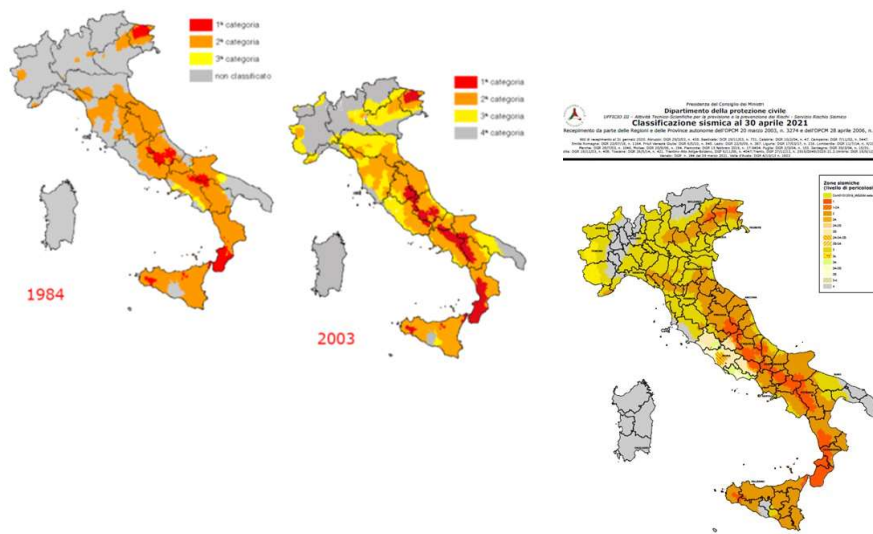


Connections

Centro Italia 2016

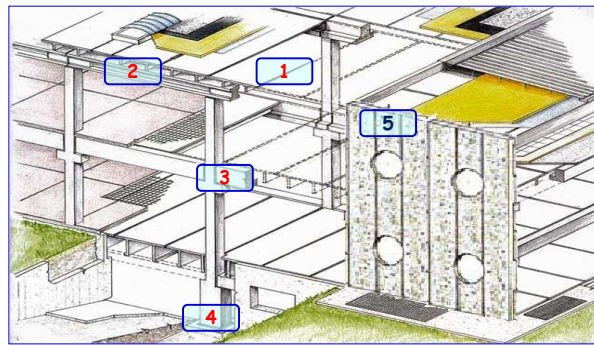


Identification of seismic areas



SAFECAST

Performance of Innovative **Mechanical Connections**
in Precast Building Structures under Seismic Conditions



ISO 20987:2019



JRC SCIENTIFIC AND POLICY REPORTS

Design Guidelines
for Connections of Precast Structures
under Seismic Actions

Paulo Negro and Giandomenico Tomasi
Editors
2012



ISO
ICS 91.01.01; 91.01.02; 91.01.03; 91.01.04

ISO 20987:2019

Simplified design for mechanical connections between precast concrete structural elements in buildings

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FORMAT: PDF + Print

LANGUAGE: English

CHF 178 BUY

ABSTRACT [VIEW](#)

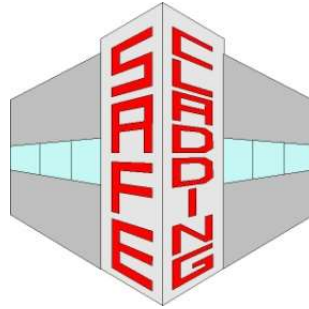
This document relates to connections in precast frame systems, either for single-storey or multi-storey buildings. The connections for all types of joints are considered. Large wall panels and frame-dimensional systems are not considered.

According to the position in the overall construction and of the consequent different structural functions, the seven following types of joints are considered:

- 1) Joints between floor or roof elements (floor-to-floor) that, in the seismic behaviour of the structural system, ensure the diaphragm action of the floor;
- 2) Joints between floor or roof elements and supporting beams (floor-to-beam) that give the peripheral constraints to the floor diaphragm in the seismic behaviour;
- 3) Joints between beams and column/beams to columns that ensure in any direction the required degree of restraint to the frame system;
- 4) Joints between column/segment columns to columns used for multi-storey buildings usually for dual wall-braced systems.

SAFECLADDING

Improved fastening systems of cladding wall panels of precast buildings in seismic zones



ISO 22502:2020



JRC TECHNICAL REPORTS

Design Guidelines for Wall Panel Connections

Antonio Corradi, Piero Luperini, Giulio Ragni, Alessandro Spacone
2020



Design guidelines for precast structures with cladding panels

Antonio Corradi, Piero Luperini, Giulio Ragni, Alessandro Spacone
2020



ISO 22502:2020
ISO 22502:2020

Simplified design of connections of concrete claddings to concrete structures

ABSTRACT

The present document refers to the panel to structure and panel to panel connections used for the cladding systems of reinforced concrete frame structures of single-storey buildings, typically precast. They can be used also for multi-storey buildings with proper modifications.

The fastening devices considered in the present document consist mainly of steel elements or sliding connections. Dissipative devices, with friction or plastic behaviour are also considered. Other types of common supports and bond connections are treated where needed.

The use of any other existing fastening types or the connections with different characteristics than those described in the following clauses is not allowed unless compatible experimental and analytical studies do provide the necessary data and verify the design methodology for that particular type.

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FORMAT

PDF + ZIP

PRICE

EUR 198

LANGUAGE

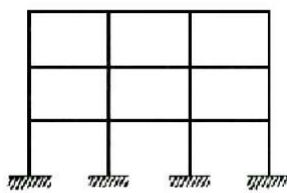
English

NTC 2018 - Chapter 7

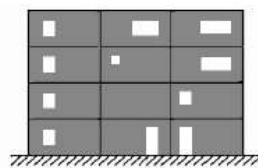
- Structural types
- Behaviour factor
- Structural modelling
- Connections
- Panels

Structural types

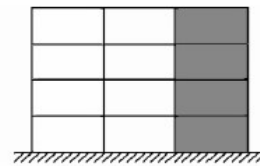
7.4.3.1 For concrete structures



Moment resisting
frame structures



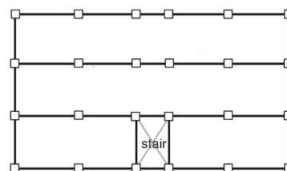
Wall structures



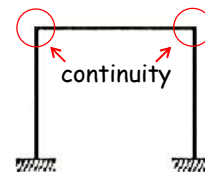
Dual structures



Inverted pendulum



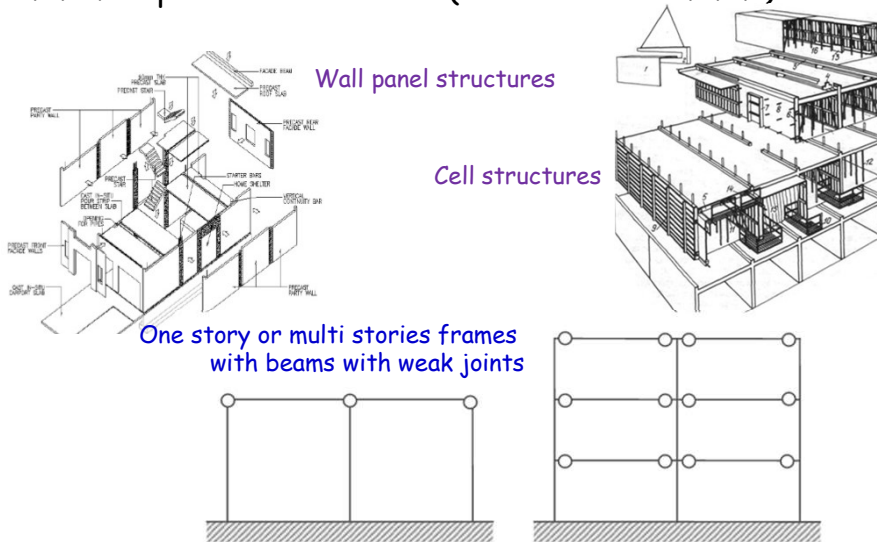
Torsionally flexible system



One storey
inverted pendulum

Structural types...

7.4.5 For precast structures (in addition to 7.4.3.1)

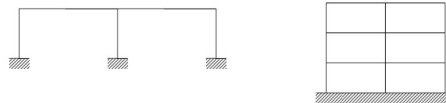


Structural types...

Precast frame structures:

Cast in situ connections (wet):

- Beam-to-column connections:
 1. Rules for concrete structures
- Base of the columns:
 1. Rules for concrete structures
 2. Overdesigned or emulative (mechanical connections)



Mechanical connections (dry):

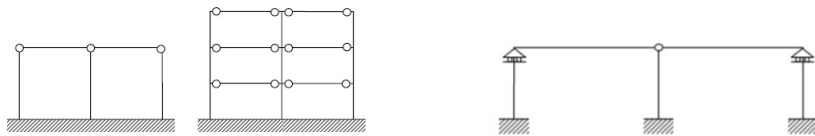
- Beam-to-column connections:
 1. Overdesigned, located away from critical zones, emulative
- Base of the columns:
 1. Rules for concrete structures
 2. Overdesigned or emulative (mechanical connections)

Structural types...

Frames with beams with weak joints

Mechanical connections:

- Beam-to-column connections:
 1. Overdesigned
- Base of the columns:
 1. Rules for concrete structures
 2. Overdesigned or emulative (mechanical connections)

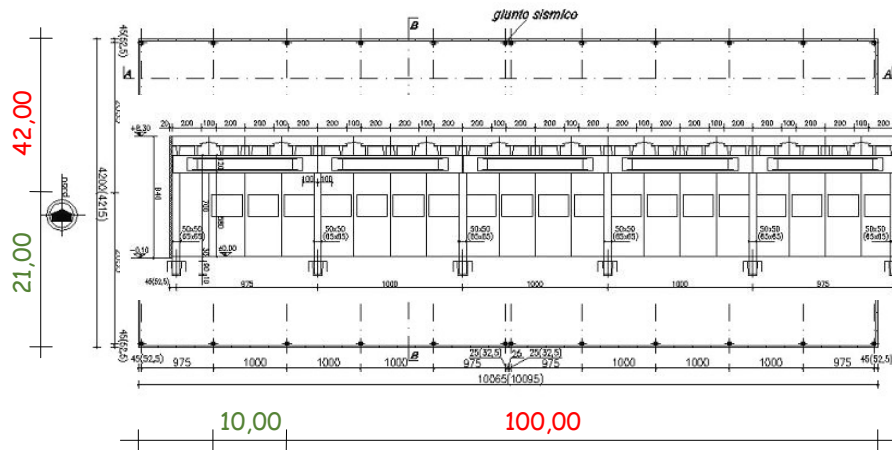


Behaviour factor

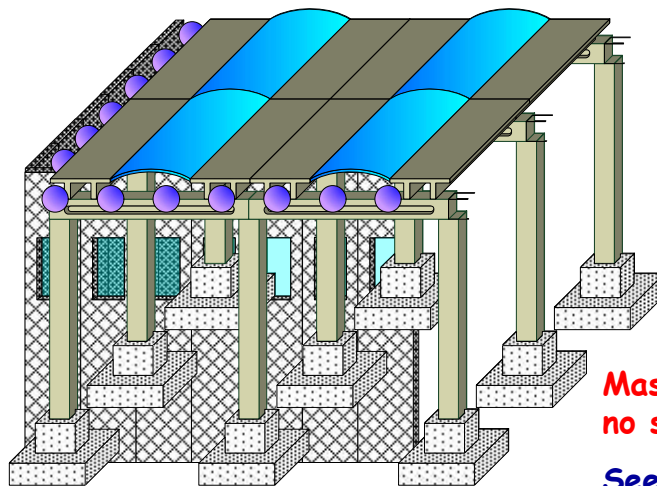
Structural Typology	CD "A"	CD "B"
Concrete structures (§ 7.4.3.2)		
Frame system, coupled wall system, dual system,	4,5 α_u/α_1	3,0 α_u/α_1
Uncoupled wall system	4,0 α_u/α_1	3,0
Torsionally flexible system	3,0	2,0
Inverted pendulum	2,0	1,5
One storey inverted pendulum	3,5	2,5
Precast structures (§ 7.4.5.1)		
Wall panel structures	4,0 α_u/α_1	3,0
Cell structures	3,0	2,0
One story or multi stories frames with beams with weak joints	3,5	2,5

Other numbers are allowed if properly justified.

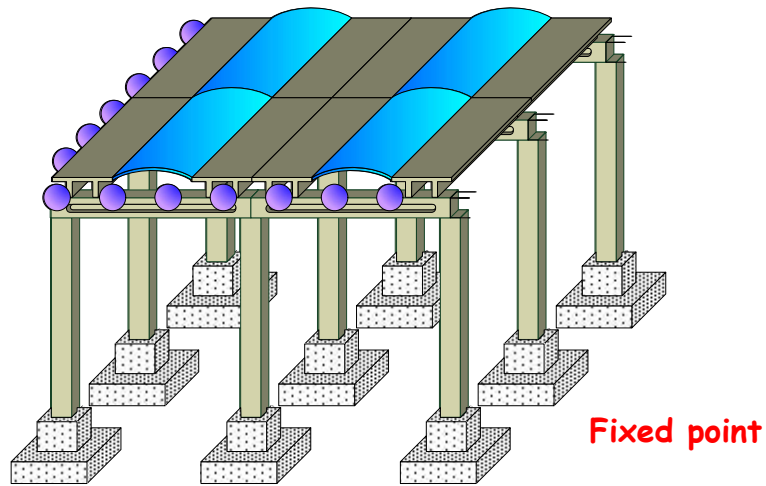
Structural modelling



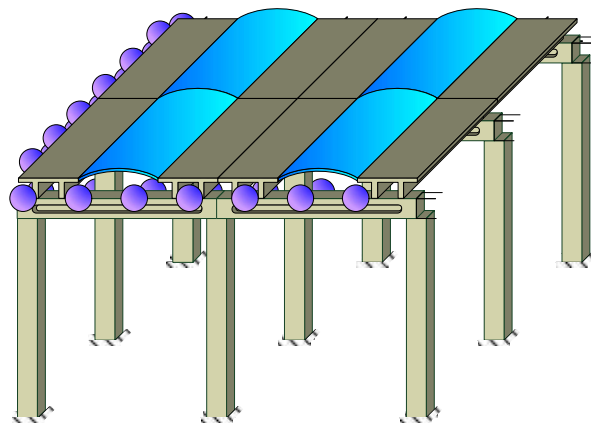
Structural modelling - panels



Structural modelling - foundations



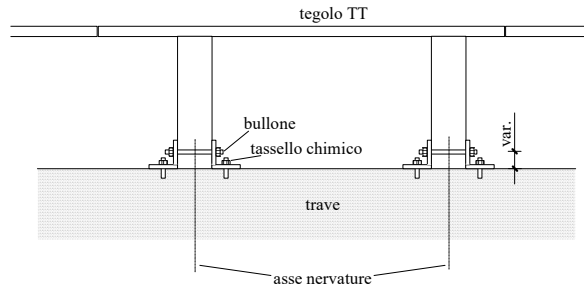
Structural modelling - structural elements



Beam elements (center of gravity)

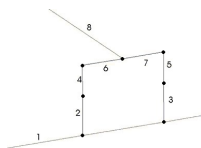
Need of links to connect different beam elements

Structural modelling - Connections

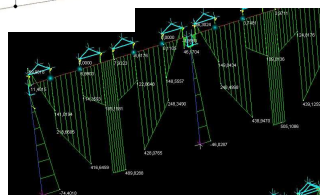


The roof to beam connection affects the deformability of the beam: how to model this effect?

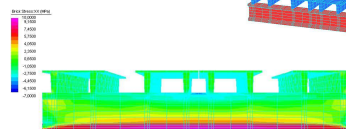
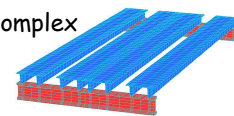
Structural modelling - connections...



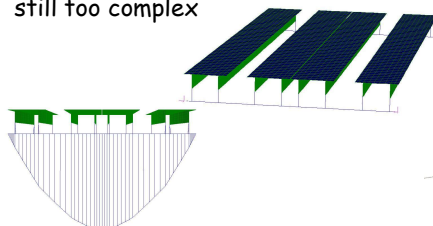
Beam elements + rigid links



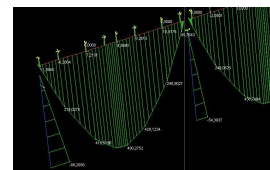
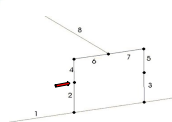
3D elements: too complex



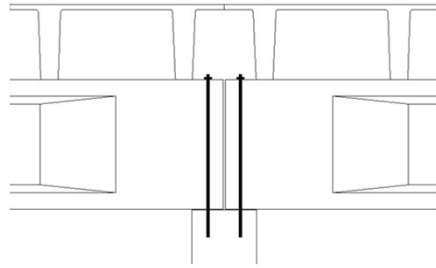
Shell elements + beam elements: still too complex



Max allowed simplification: beam elements + rigid links + deformable link.



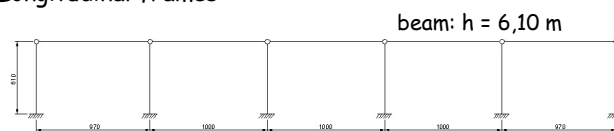
Structural modelling - connections...



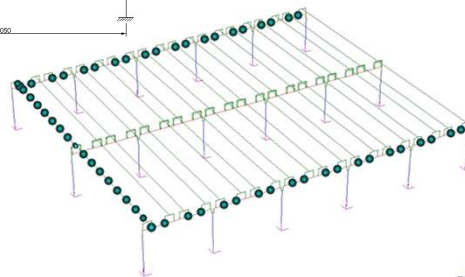
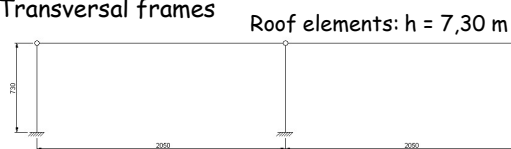
Hinge (only forces) in one direction and **continuity** (also moments) in the orthogonal direction.

Structural modelling - the end

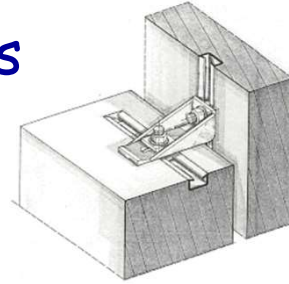
Longitudinal frames



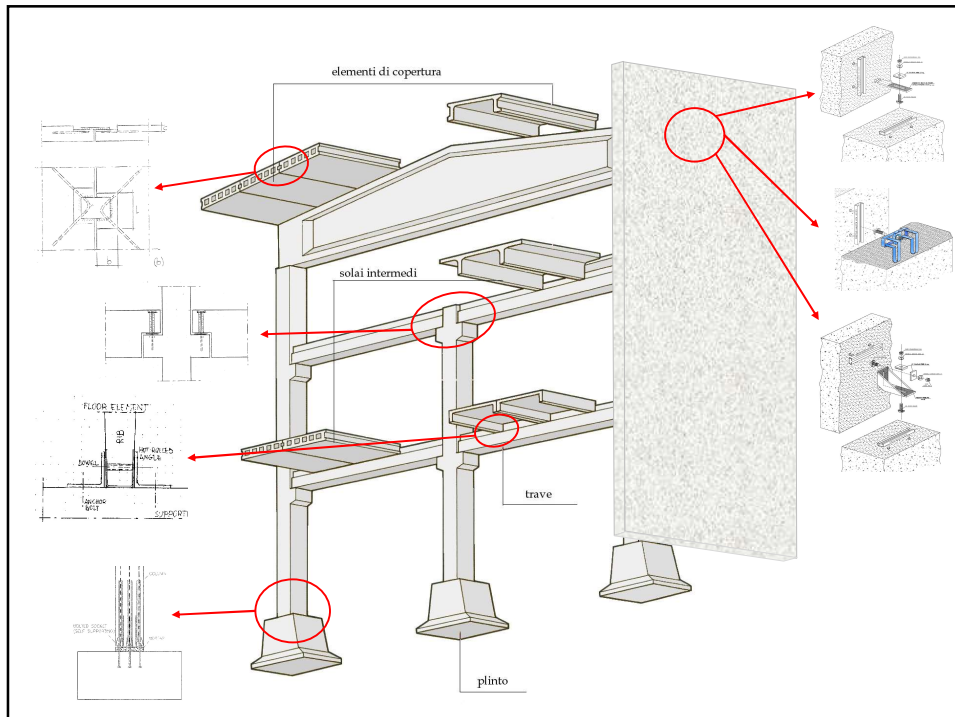
Transversal frames

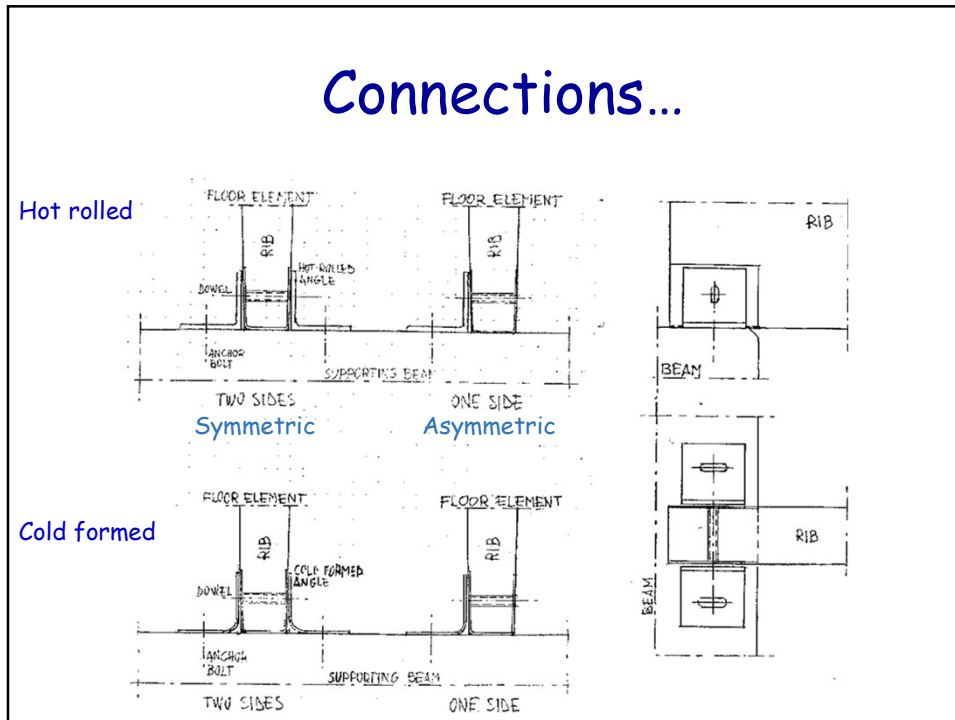
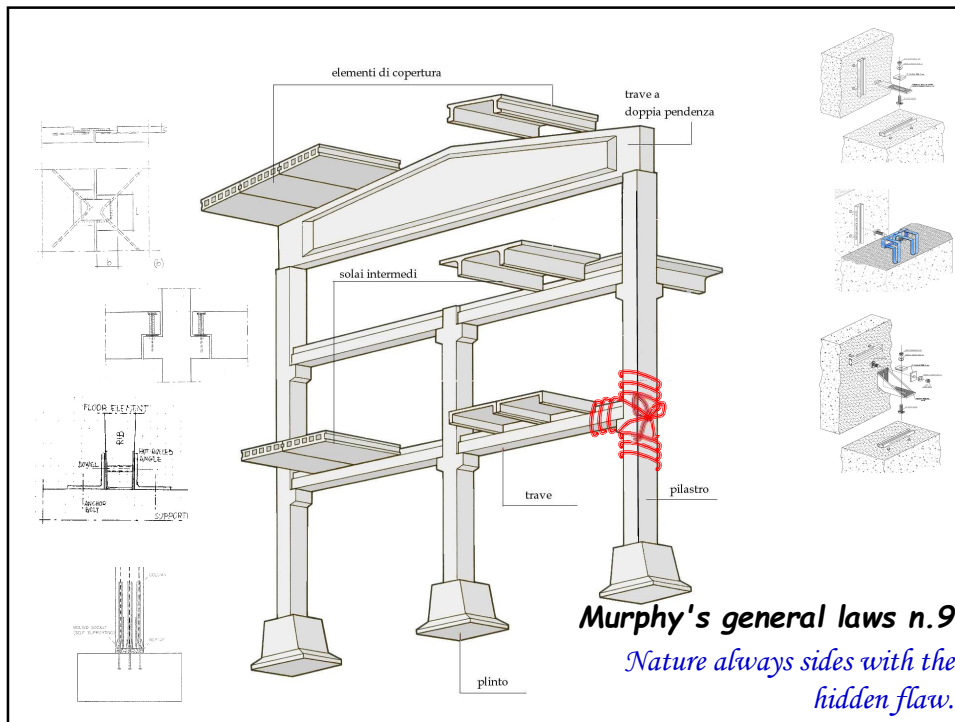


Connections



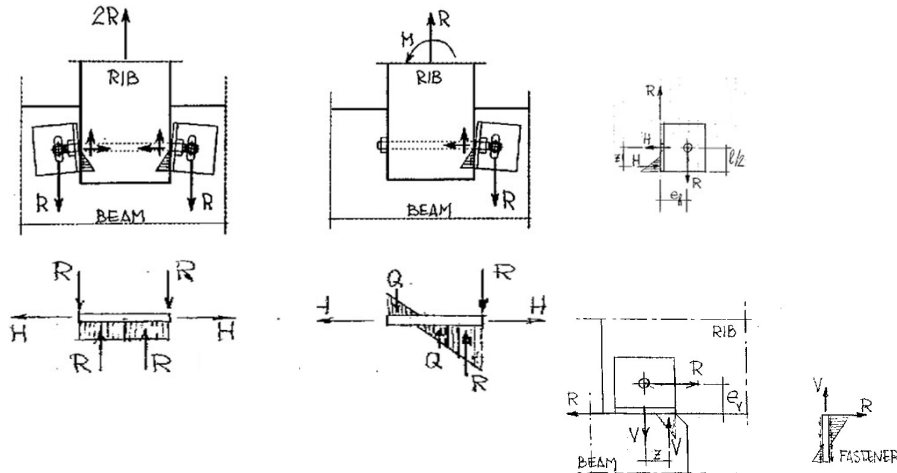
- Connections should be properly designed (forces, moments, deformations)
- Connections should be qualified according to specific indications
 - CE marking (EN, EOTA)
 - National procedures





Connections...

Failure modes...



Technical support

ISO
ICS 91.91.080.91.080.40
ISO 20987:2019
Simplified design for mechanical connections between precast concrete structural elements in buildings

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PRICE CHF 178 BUY

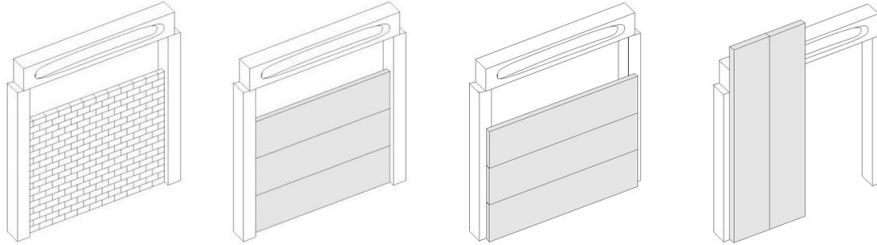
ABSTRACT PREVIEW
This document refers to connections in precast frame systems, either for single-storey or multi-storey buildings. The connections for all concrete elements are considered. Light wall panels and their dimensional callouts are not considered.
According to the position in the overall construction and of the consequent different structural functions, the seven following orders of joints are considered:
(1) joints between floor or roof elements (floor-to-beam) that, in the seismic behaviour of the structural system, concern the diaphragm action of the floor;
(2) joints between floor or roof elements and supporting beams (beam-to-beam) that give the peripheral consistency to the floor diaphragm in the seismic behaviour;
(3) joints between beams and columns (beam-to-column) that ensure in any direction the required degree of restraint to the frame system;
(4) joints between columns (column-to-column) used for multi-storey buildings usually for dual wall braced systems.

ISO
ICS 91.91.080.91.080.40
ISO 22502:2020
Simplified design of connections of concrete claddings to concrete structures

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ABSTRACT PREVIEW
The present document refers to the panel-to-structure and panel-to-panel connections used for the cladding systems of reinforced concrete frame structures of single-storey buildings, typically precast. They can be used also for multi-storey buildings with proper modifications.
The fastening devices considered in the present document consist mainly of steel elements or sliding connections. Dissipative devices with friction or plastic behaviour are also considered. Other types of common supports and bond connections are treated (where needed).
The use of any other existing fastening type or the connections with different characteristics than those described in the following clauses is not allowed unless comprehensive experimental and analytical studies do provide the necessary data and verify the design methodology for the particular type.

Walls or panels



Different materials:

- Blocks
- Panels
- «Light»
- ...

Different position:

- Inserted between columns
- Attached

Different orientation:

- Horizontal
- Vertical

Different behaviour:

- Not interactive
- Just mass
- Mass plus stiffness

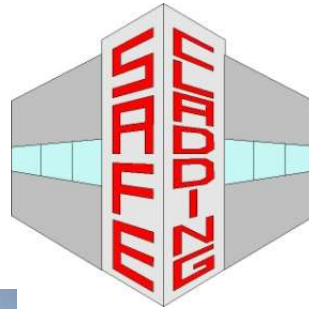
It is possible to reduce interaction?



Are they always integrated?



Improved fastening systems of cladding wall panels of precast buildings in seismic zones

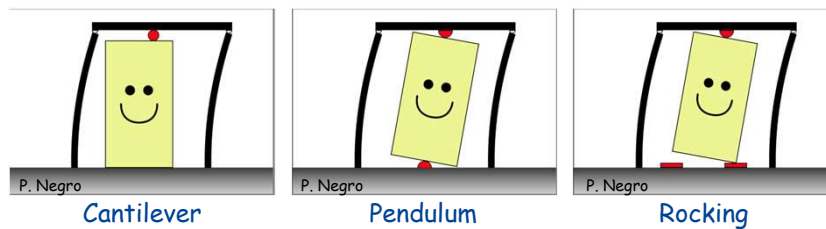


Typology 1

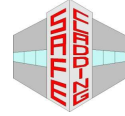


- **ISOSTATIC SYSTEM**: No interaction between earthquake resistance structure and panels
- **New connections** able to allow relative movements between panels and structure
- **Old design approach** for the structure
- **Pay attention to details**

NOT INTERACTIVE

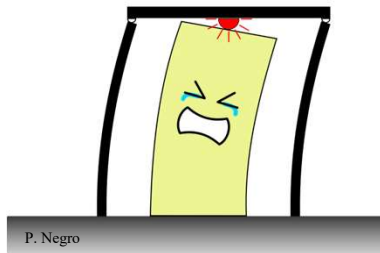


Typology 2



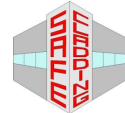
- **INTEGRATED SYSTEM**: Panels **strongly connects** to the structure
- **New connections** able to transmit high forces
- **New design approach** for the whole structure and for panels

INTERACTING

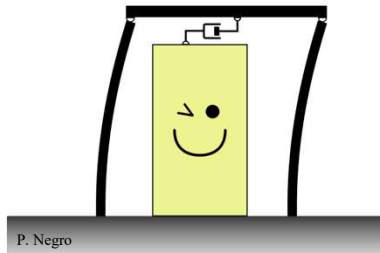


P. Negro

Typology 3

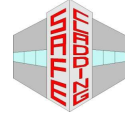


- **DISSIPATIVE SYSTEM**: Panels connected by means **dissipative connections**; combined earthquake resistance system
- **New connections** able to dissipate energy
- **New design approach** for the whole system

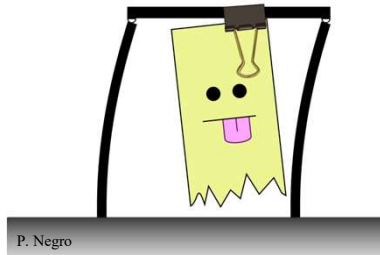


P. Negro

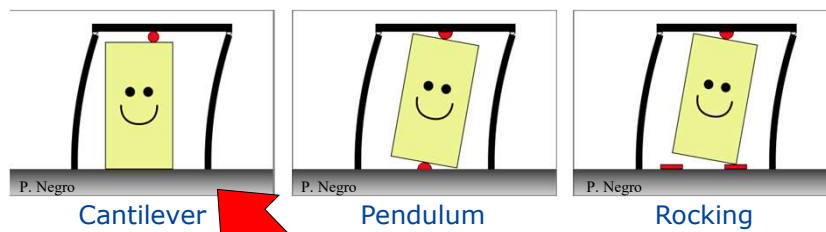
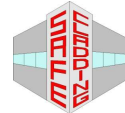
Typology 4



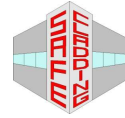
- **BACKUP SYSTEM:** for **existing structures**. Additional connections that avoid the collapse of the panel
- **New connections**



Isostatic systems

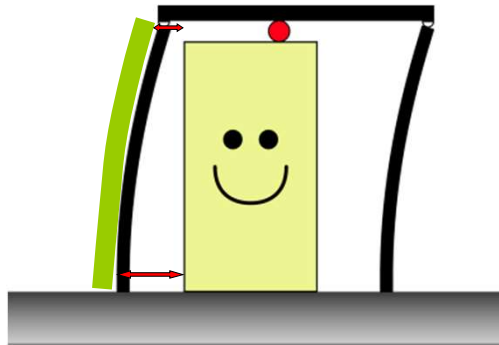


Common problems

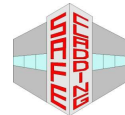


Corner interaction (both horizontal and vertical panels)

- The directions of the earthquakes usually do not coincide with main directions of the structures
- The behaviour of the structure in the two directions is not independent
- The structure is a 3D entity

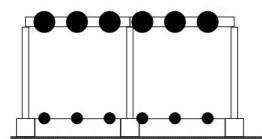
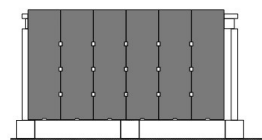
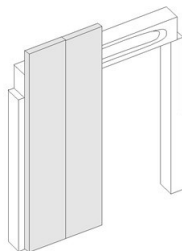


Common problems ...

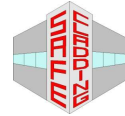


• Vertical panels:

- Only the upper X% of the panel mass contributes to the seismic behaviour of the structure and is applied to beams
- Also the roof elements mass is applied to beams
- No additional masses are applied to columns
- In the transversal direction the panel mass is applied to roof elements

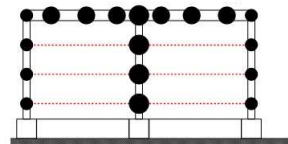
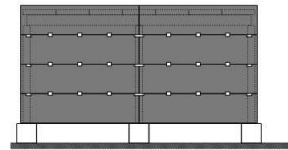
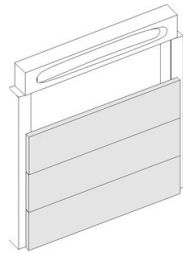


Common problems ...



• Horizontal panels (main direction):

- The panel mass is applied to columns
- The central columns are charged by a double mass (panels in each side)
- The roof mass is applied to beams



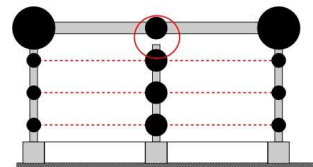
Common problems ...



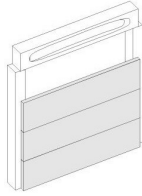
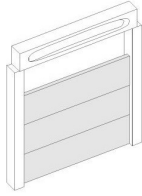
• Horizontal panels (transversal direction):

- The panel mass is applied to columns
- Pay attention to non-loaded columns
- Non-loaded columns are connected to the structures through panels
- The mass acting on non-loaded columns is different from that of other columns (non vertical load from roof)
- The dynamic behaviour of non-loaded columns is different from the rest of the structure
- Problems with the connections of the upper panels

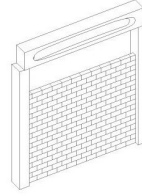
$$T = 2\pi\sqrt{\frac{m}{k}}$$



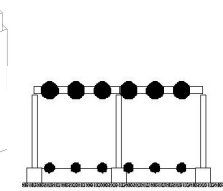
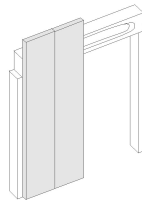
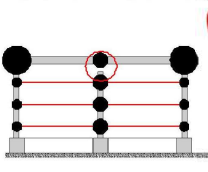
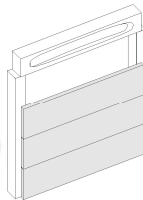
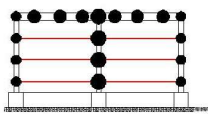
Common problems ...



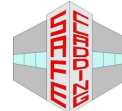
Integrated or not?



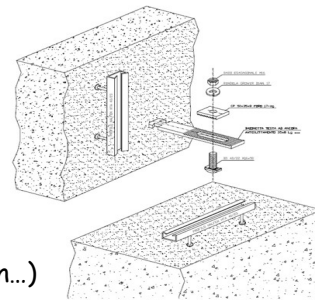
Only mass or
mass&stiffness?



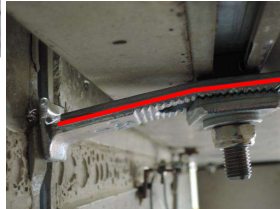
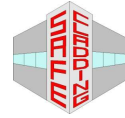
Sliding connections



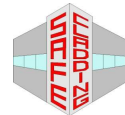
- Do they slide in reality?
- If not, why?
- Tolerances, dust, waste, ...
- Low friction coating does not work
- Unexpected friction
- What about 3D effects?
(tests are usually performed in one direction...)
- Connection \neq whole structure



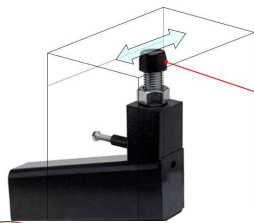
Sliding connections...



Sliding connections...



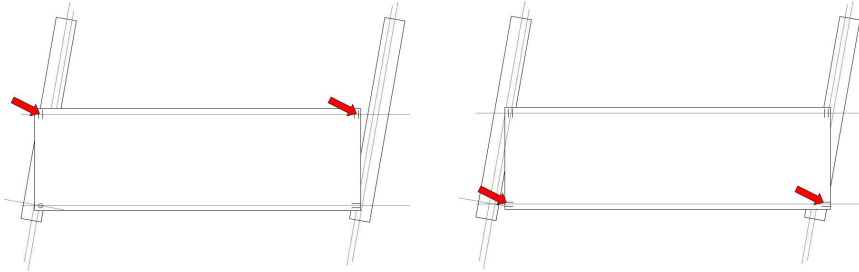
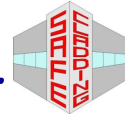
- Supporting system for panels



teflon

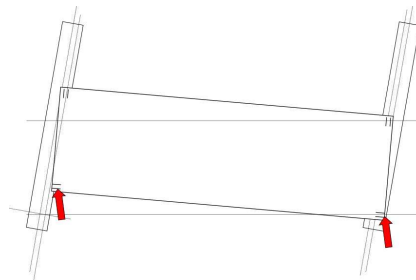


Geometry of the system...

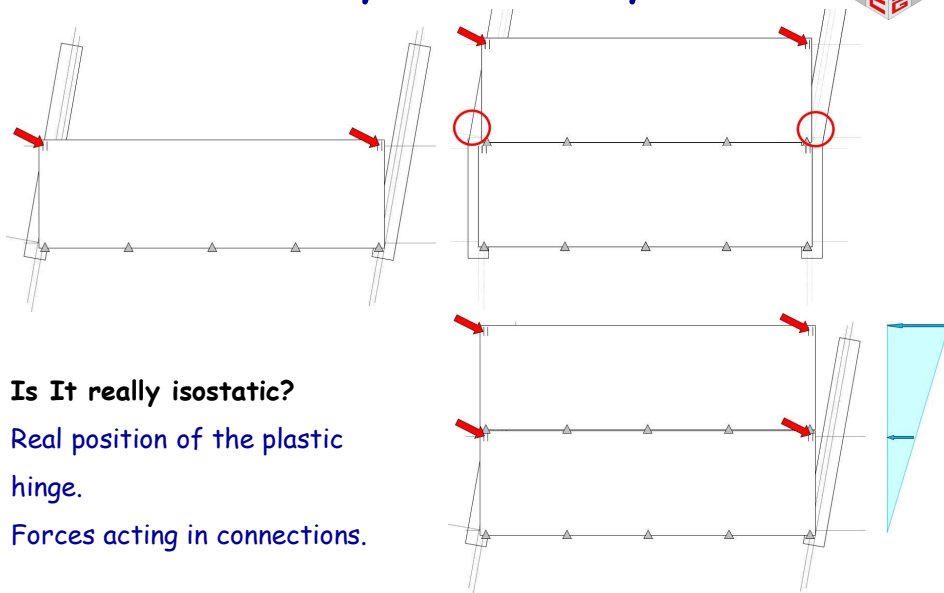


Behaviour of the base panel:

Potential problems with connections in the upper or lower part of the panel



Geometry of the system...

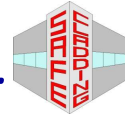


Is It really isostatic?

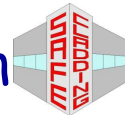
Real position of the plastic hinge.

Forces acting in connections.

Geometry of the system...

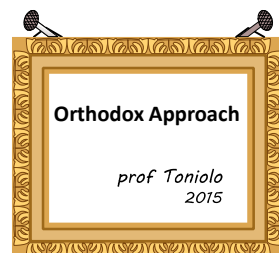


Scheme of the connection

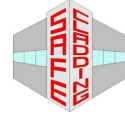


Horizontal panels:

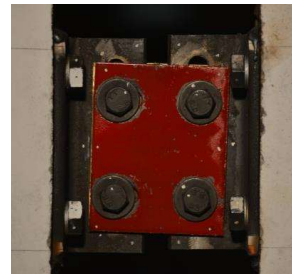
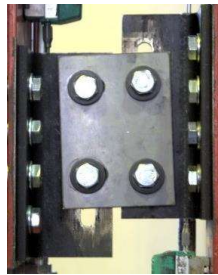
- How are they connected to the structure?
- Is this the best scheme?
- Is it possible to use an orthodox approach?
- But... what is an orthodox approach (*cit. prof. Toniolo*)?
In other words, what is the best way to hang a painting?



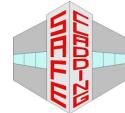
Dissipative systems



- Dissipative systems are subjected to CE marking according to EN 15129 "Anti-seismic devices"
- Dissipative systems must be rigidly connected to the structure: gaps, relative movements and so on modify the global behaviour of the system and have to be included in the certification of the system
- Tollerances in execution do not help ...



Welding



- Quality of welding is essential
- Welding must be done by certified operator



Do not forget sustainability

Design for disassembly



Separate collection
for recycling



End... tomorrow?

Design

- Revision of Eurocodes (Italian mirror group EC8, WG5 - Concrete)
- Revision of NTC



Certification

- EADs for connections in precast structures





ASSOBETON

Thank you!!!

