SEISMIC ISSUES IN PRECAST BUILDING CONSTRUCTION

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NEED OF PRECAST CONSTRUCTION

- Conventional construction systems are time consuming
  → **Due to rapid urbanization and population growth, it is difficult to satisfy housing demand with traditional construction systems.**
- Forms used in a precast plant may be reused hundreds to thousands of times before they have to be replaced, which allow cost of formwork per unit to be lower than that for site-cast production.
- High strength, Quality, and Durability.
- Design flexibility and Aesthetic versatility.
- Wide range of colours, textures and shapes.

ISSUES IN PRECAST CONSTRUCTION

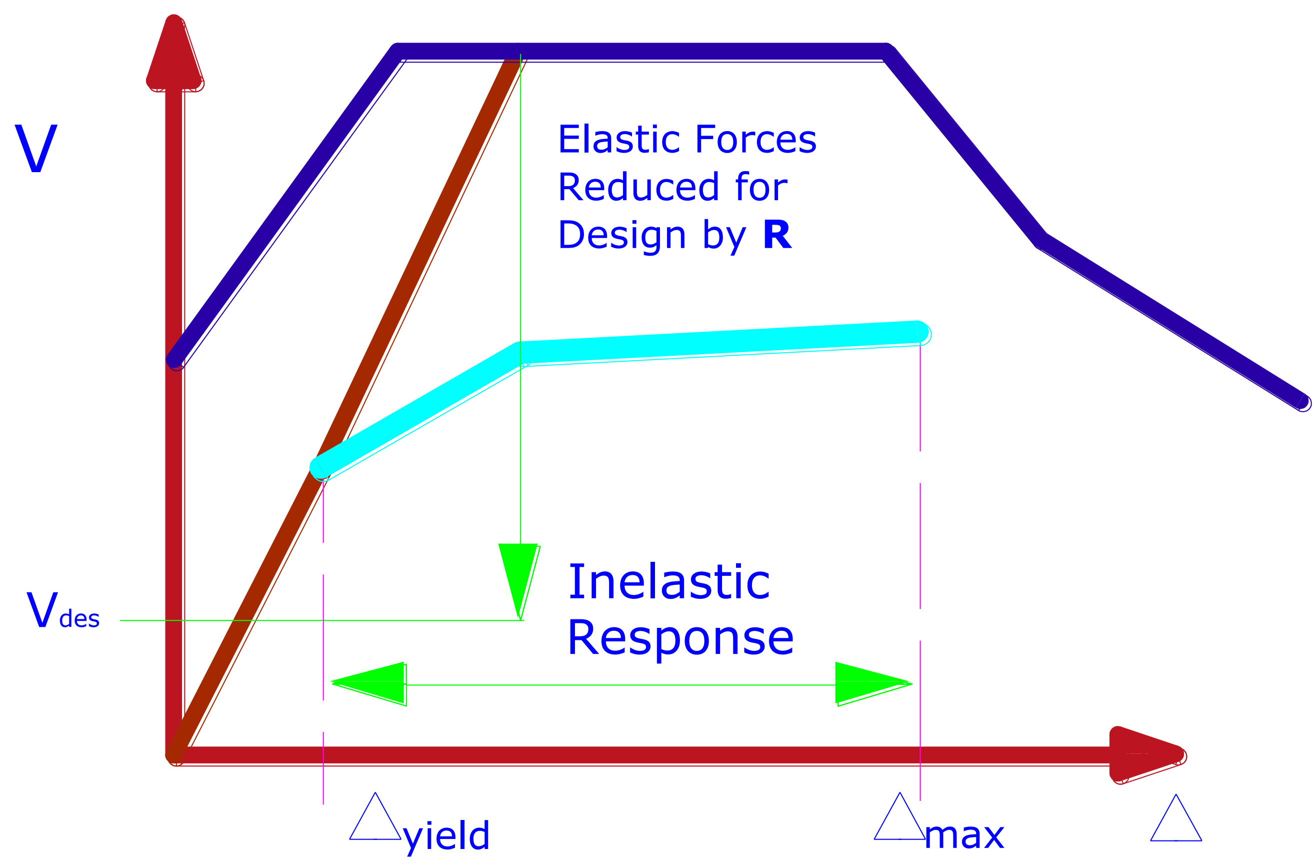
- Lifting and handling machines are required.
- High accuracy in construction, less margin for error.
- **Connections between members are difficult and complicated.**
- Monotonous type of design due to repetition of formwork.
- Skilled labor is required.
- Mostly one-way structural system due to limitation of panel size → **Rigid diaphragm action is not available.**
- **Seismic Performance during past earthquakes has been questionable.**

PHILOSOPHY OF EARTHQUAKE RESISTANT DESIGN

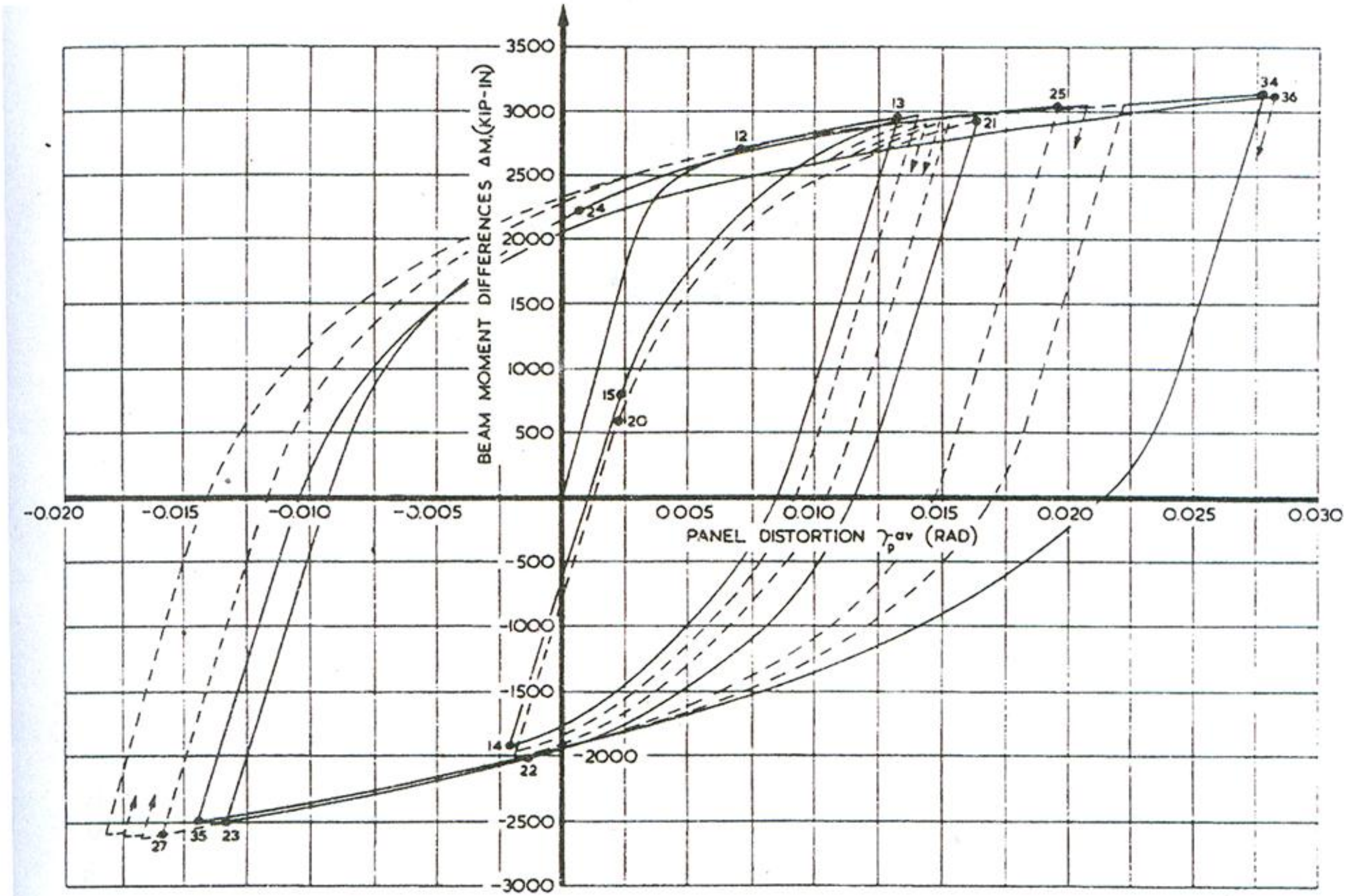
IS:1893-2002; Page 2 (Foreword):

"It is not intended in this standard to lay down regulation so that no structure shall suffer any damage during earthquake of all magnitudes. It has been endeavored to ensure that, as far as possible, structures are able to respond, without structural damage to shocks of moderate intensities and without total collapse to shocks of heavy intensities."

PHILOSOPHY OF EARTHQUAKE RESISTANT DESIGN

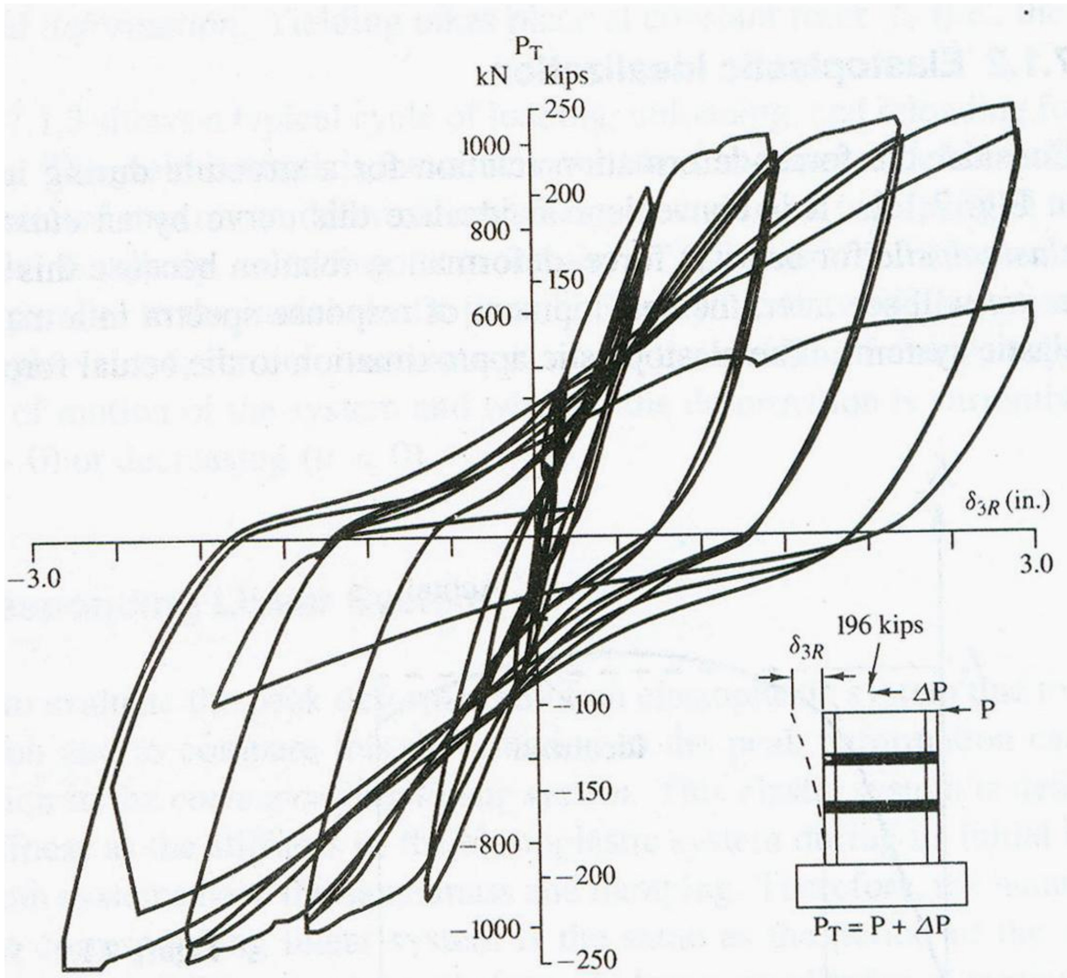


INELASTIC ENERGY DISSIPATION



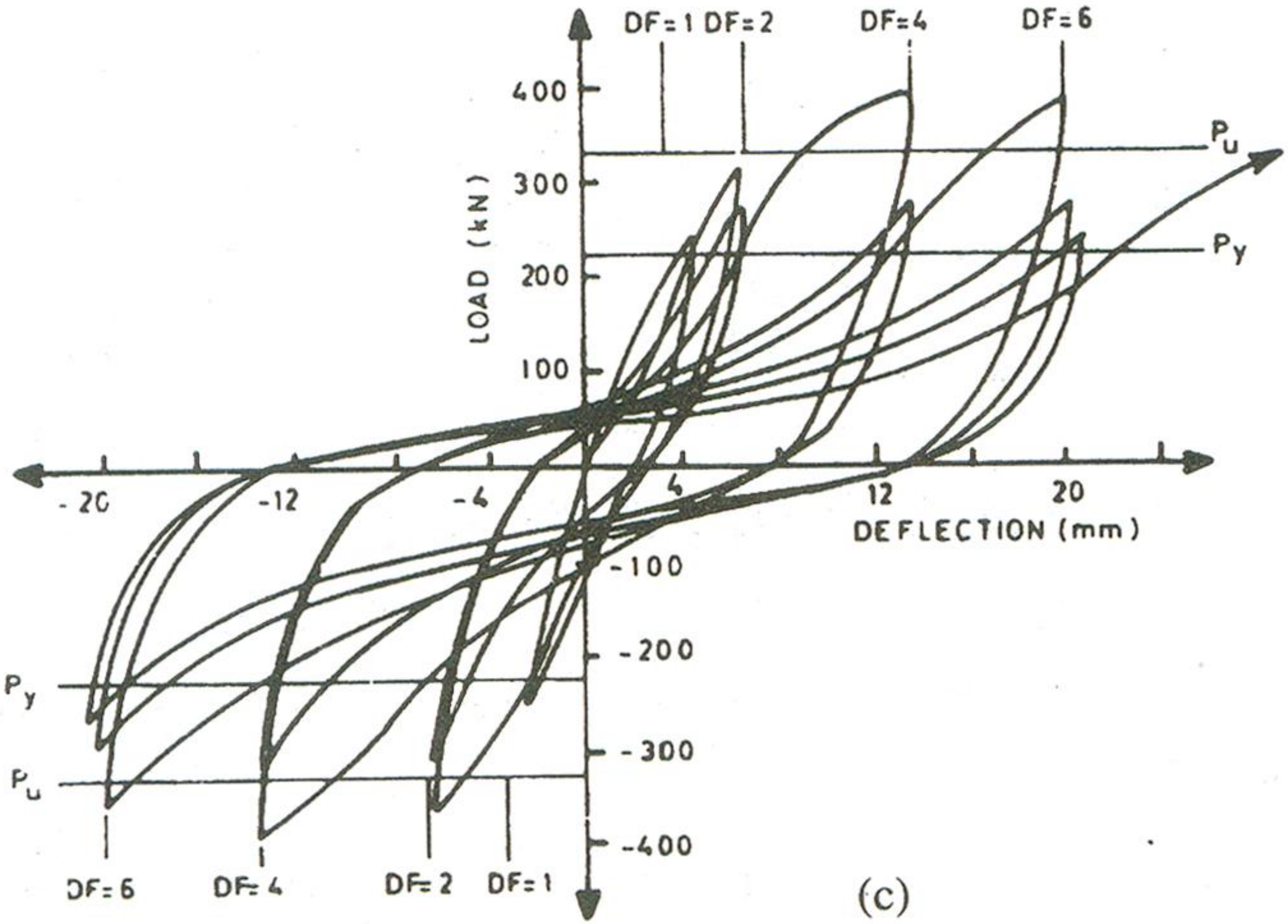
STRUCTURAL STEEL

INELASTIC ENERGY DISSIPATION



REINFORCED CONCRETE

INELASTIC ENERGY DISSIPATION



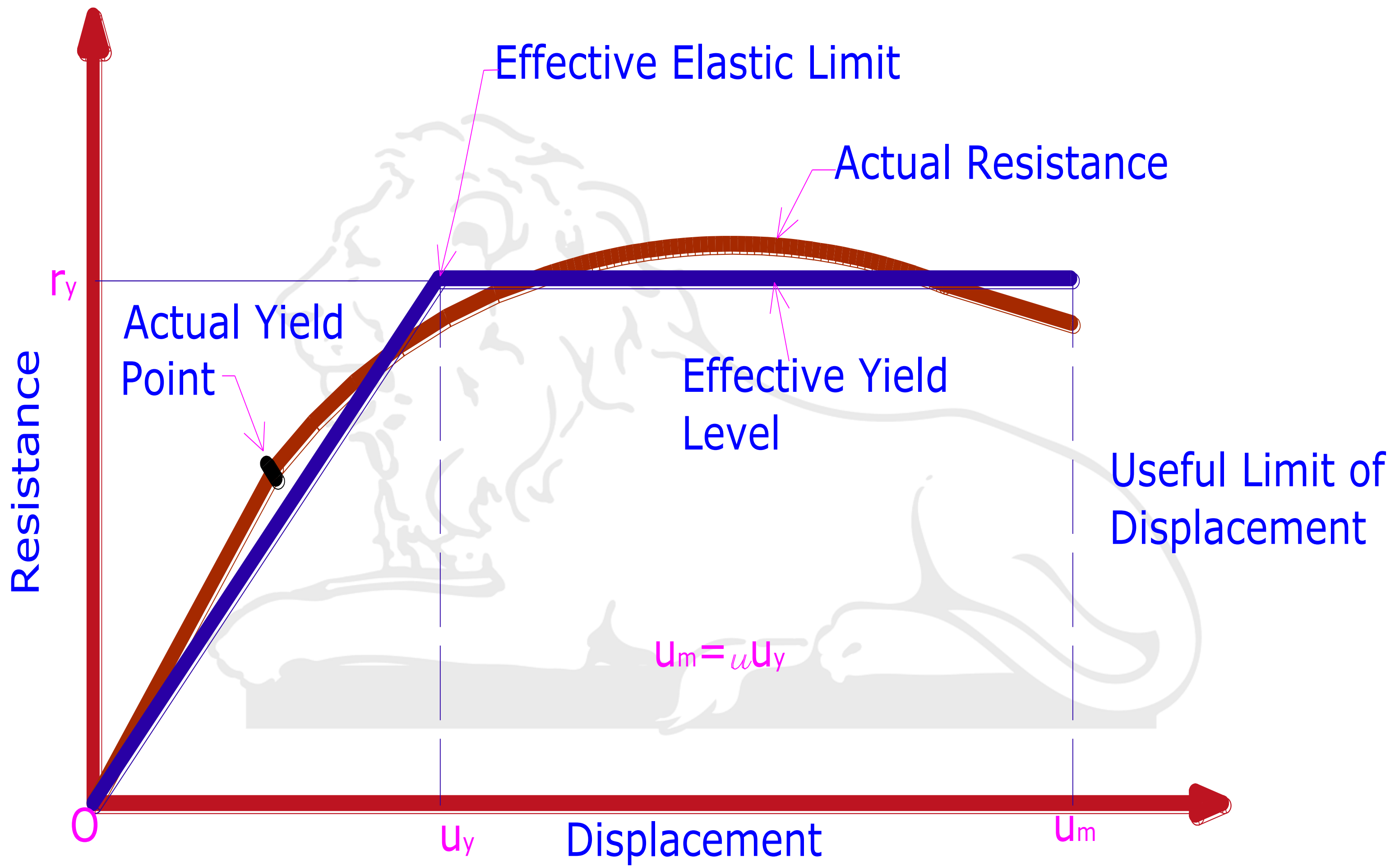
MASONRY

INELASTIC ENERGY DISSIPATION

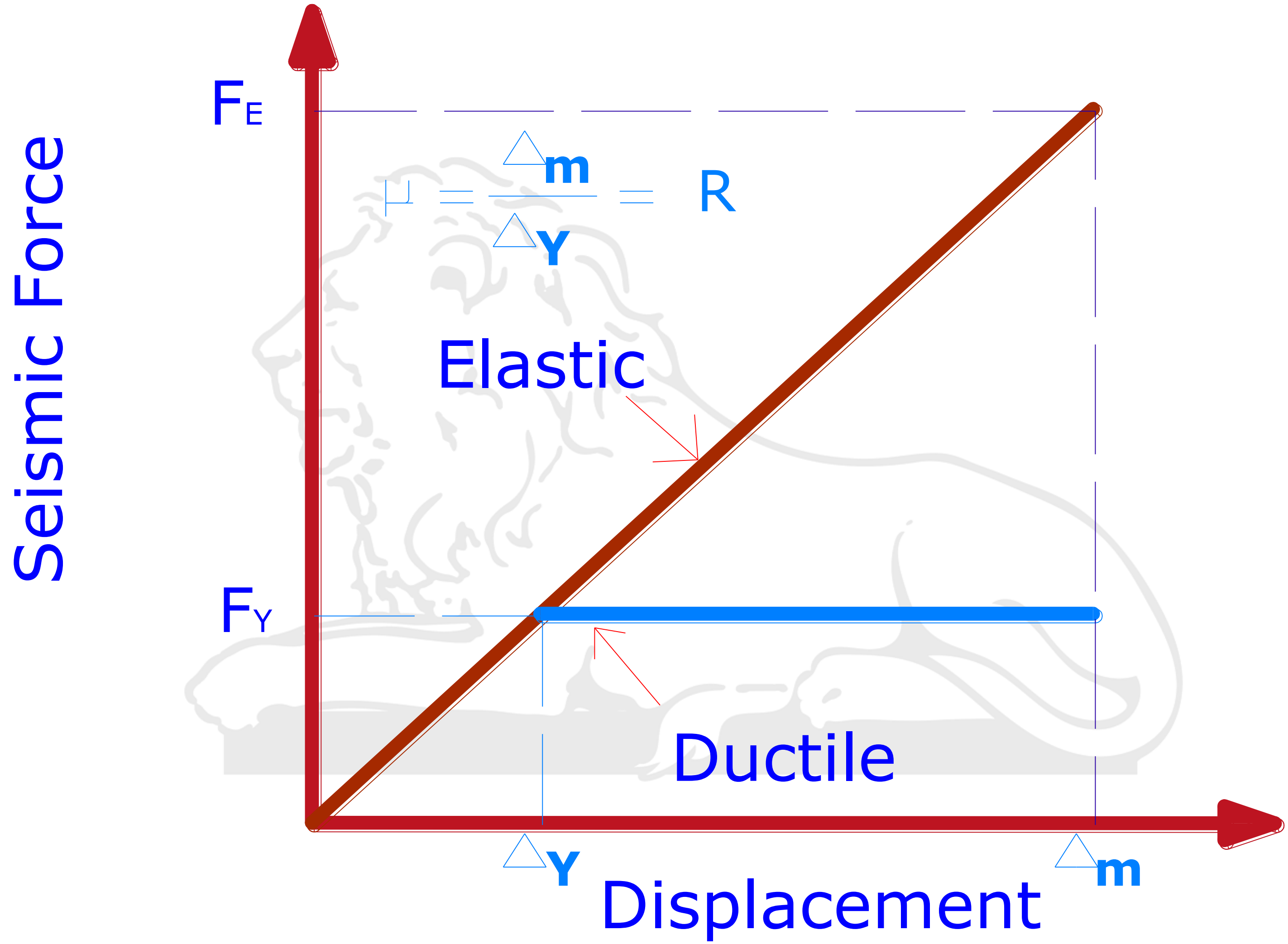
WHAT ABOUT PRECAST CONCRETE CONSTRUCTION

?

ROLE OF DUCTILITY



ROLE OF DUCTILITY



ROLE OF DUCTILITY

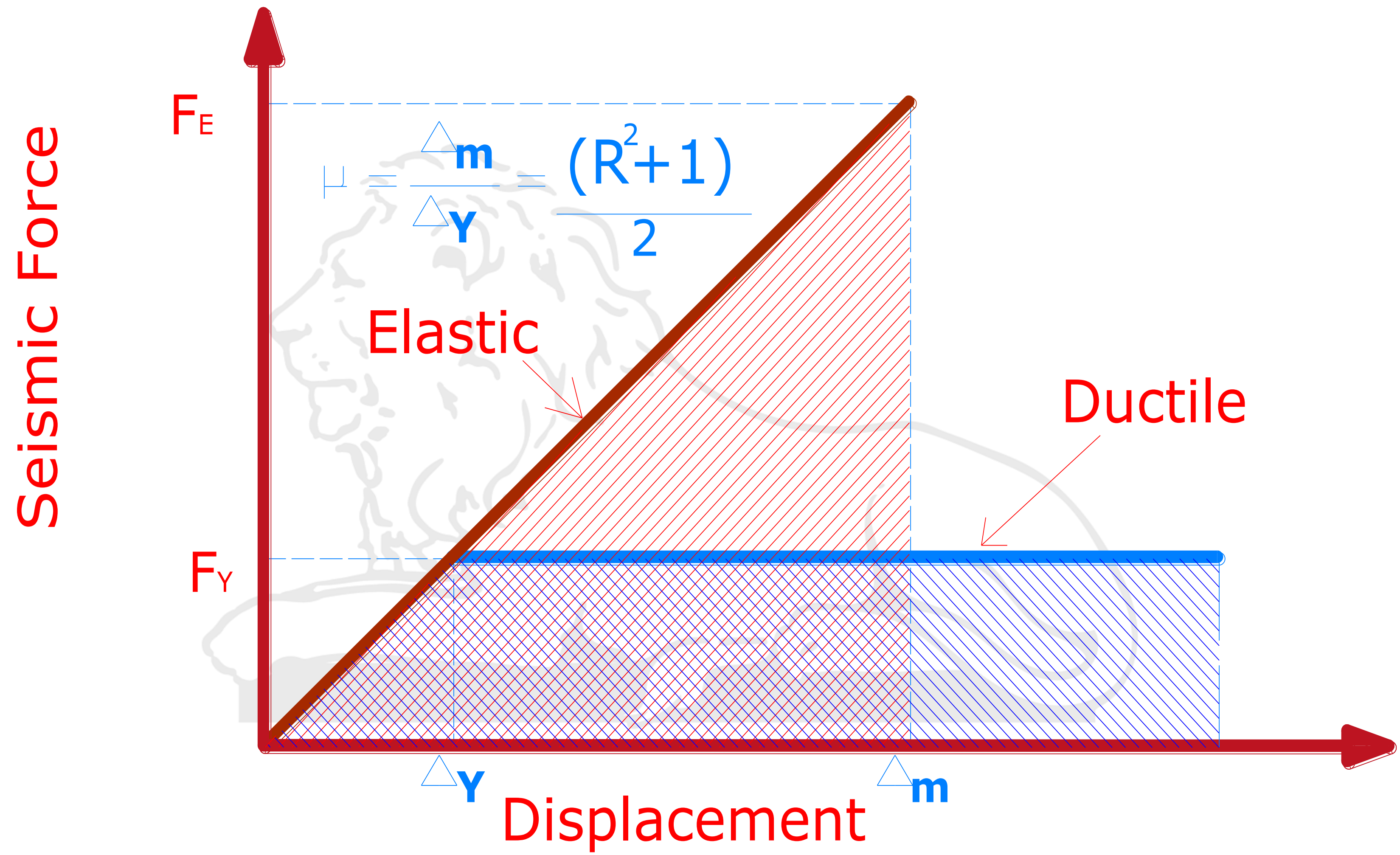
Ductility results in the reduction of effective earthquake forces on the structure.

For long period systems : Equal displacement principle:

Reduction factor = ductility ratio

$$R = \mu$$

ROLE OF DUCTILITY



ROLE OF DUCTILITY

For short period systems : Equal energy principle

Reduction factor is less than the ductility ratio

$$R = \sqrt{2\mu - 1}$$

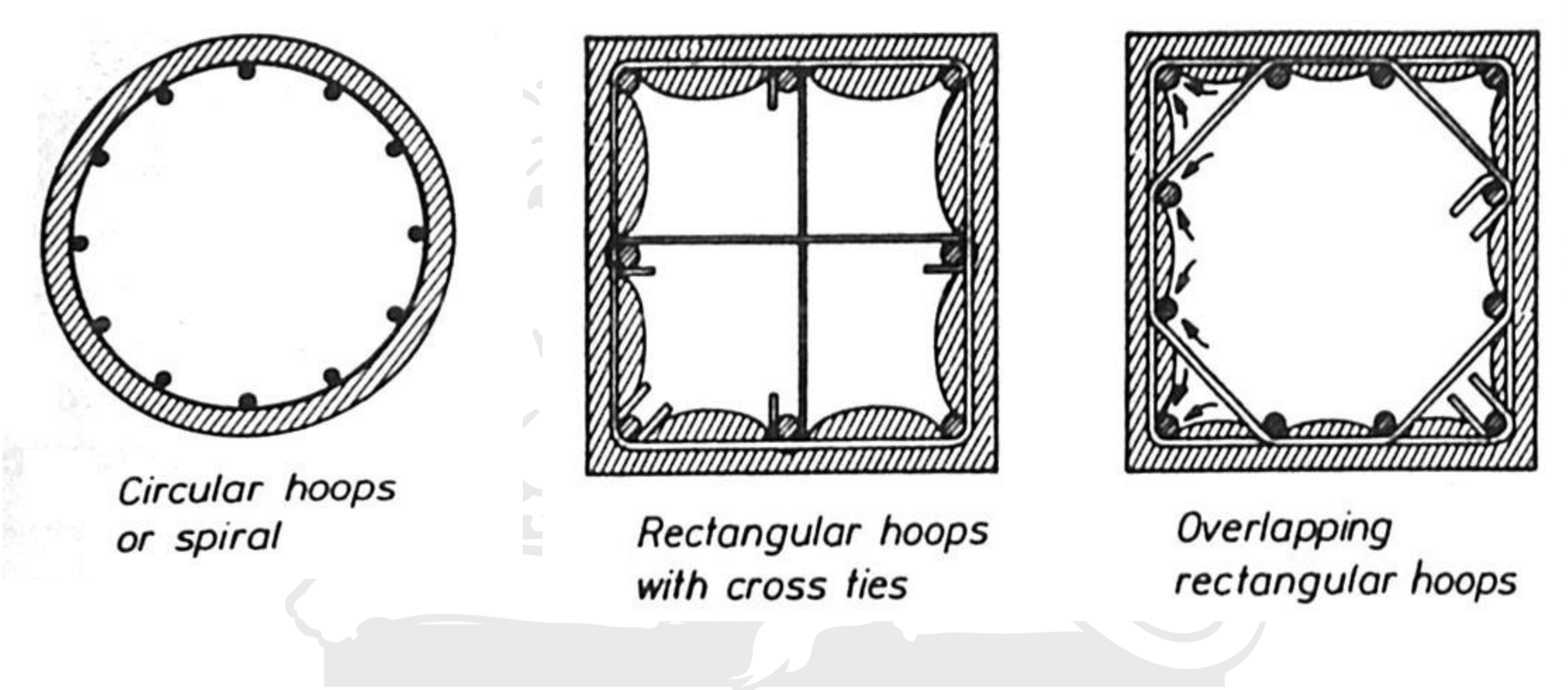
RESPONSE REDUCTION FACTORS

1. Ordinary RC Moment resisting frames : 3.0
2. Special RC moment resistant frames : 5.0
3. Steel frames with concentric braces : 4.0
4. Steel frames with eccentric braces : 5.0
5. Un-reinforced masonry buildings : 1.5
6. Masonry buildings with horizontal RC Bands : 2.5
7. Masonry buildings with horizontal RC Bands and vertical reinforcement : 3.0

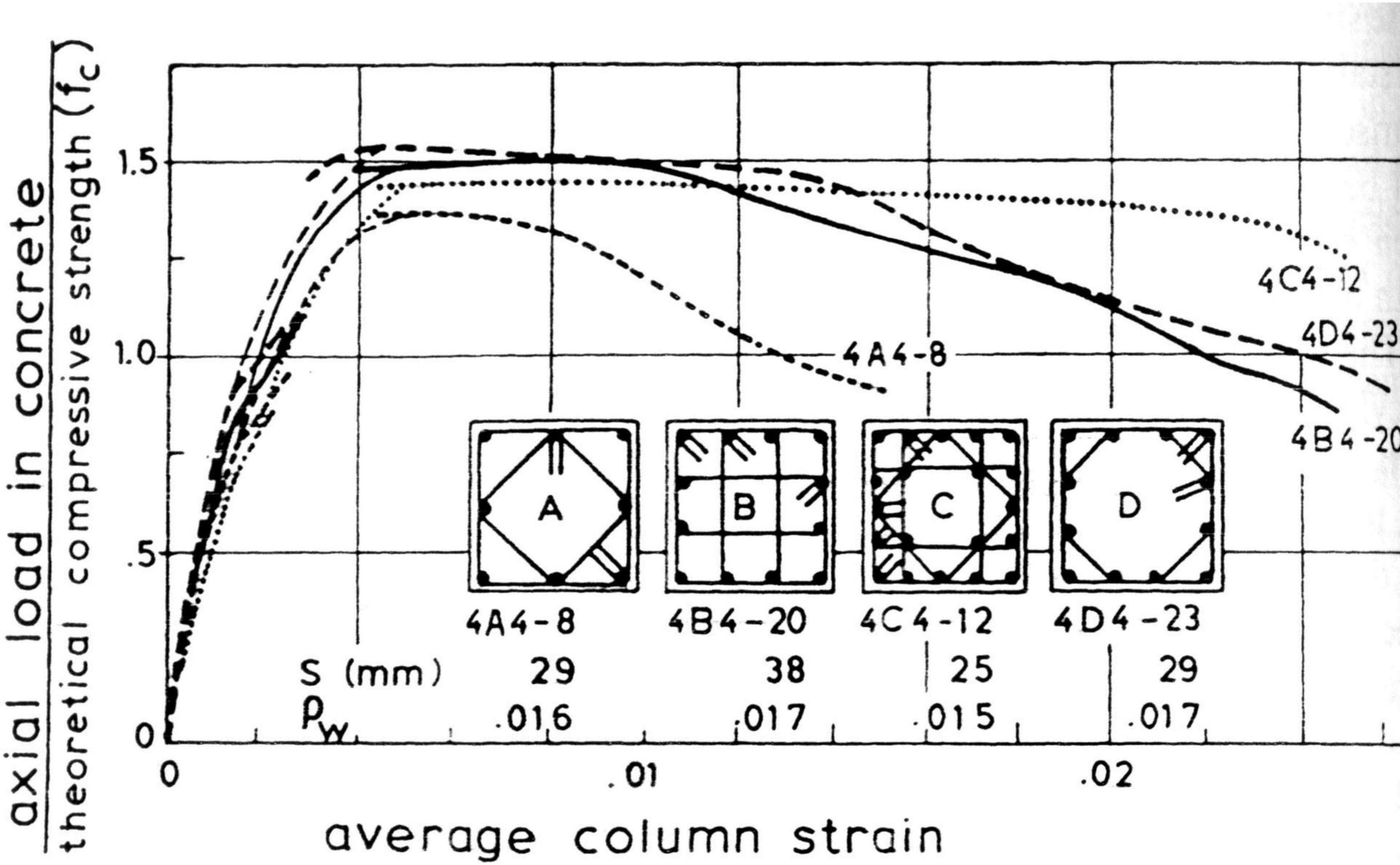
RESPONSE REDUCTION FACTORS

8. Ordinary RC shear walls : 3.0
9. Ductile shear walls : 4.0
10. Ordinary shear walls with OMRF : 3.0
11. Ordinary shear walls with SMRF : 4.0
12. Ductile shear walls with OMRF : 4.5
13. Ductile shear walls with SMRF : 5.0

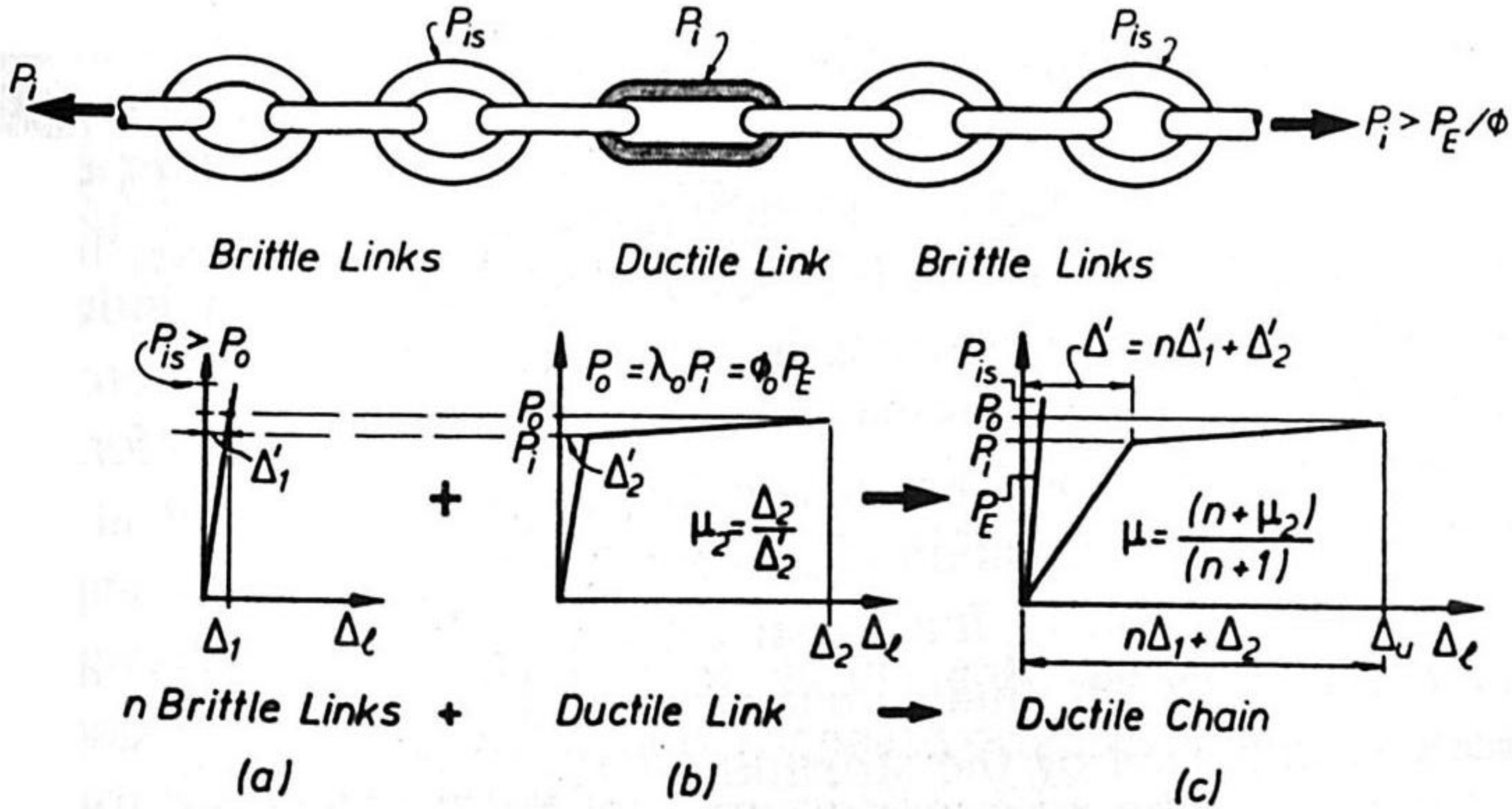
DUCTILITY IN CONCRETE (!?)



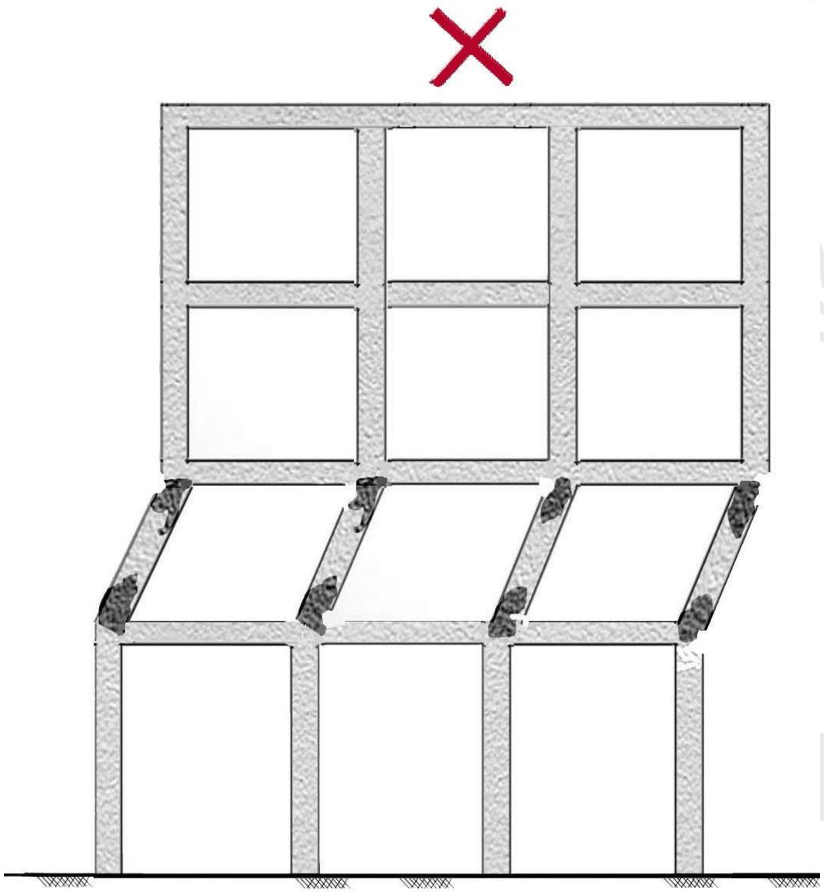
DUCTILITY IN CONCRETE (!?)



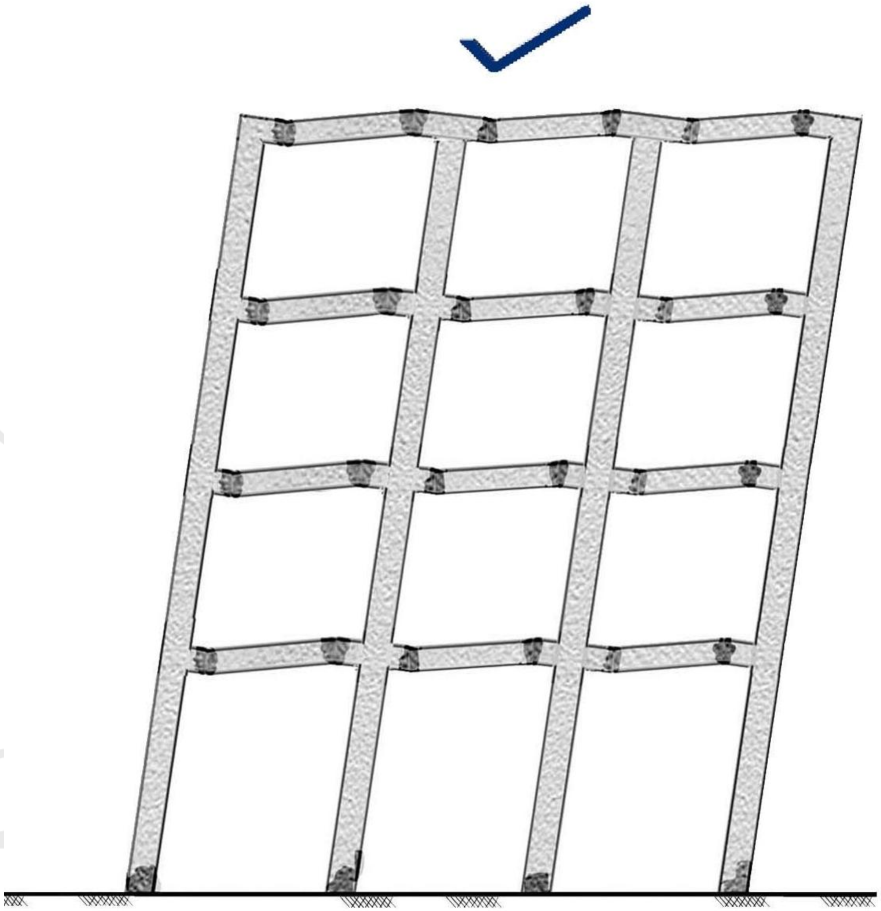
CAPACITY DESIGN PHILOSOPHY



CAPACITY DESIGN PHILOSOPHY



Local failure mode is undesirable



Weak beam and strong column design is desirable

PRECAST CONCRETE CONSTRUCTION

- Prefabricated elements (pre-stressed or conventionally reinforced) are used for framing structures
- Elements are assembled by equivalent monolithic and hinged joints or other types of welded and bolted connections.
- **Absence of continuity and redundancy** in these precast structures, has caused concern about the stability and ability to resist high lateral loads induced by strong earthquakes.
- Challenge → **Reliable and economic method to join prefabricated members**

Equivalent monolithic system:

Emulation of monolithic reinforced concrete connections; resulting structural systems have strength and stiffness characteristics equivalent to those for monolithic reinforced concrete construction. In-situ (wet) connections are used to join the elements.

Jointed system:

In this system precast elements are interconnected predominately by dry joints.

WET VS. DRY CONNECTION

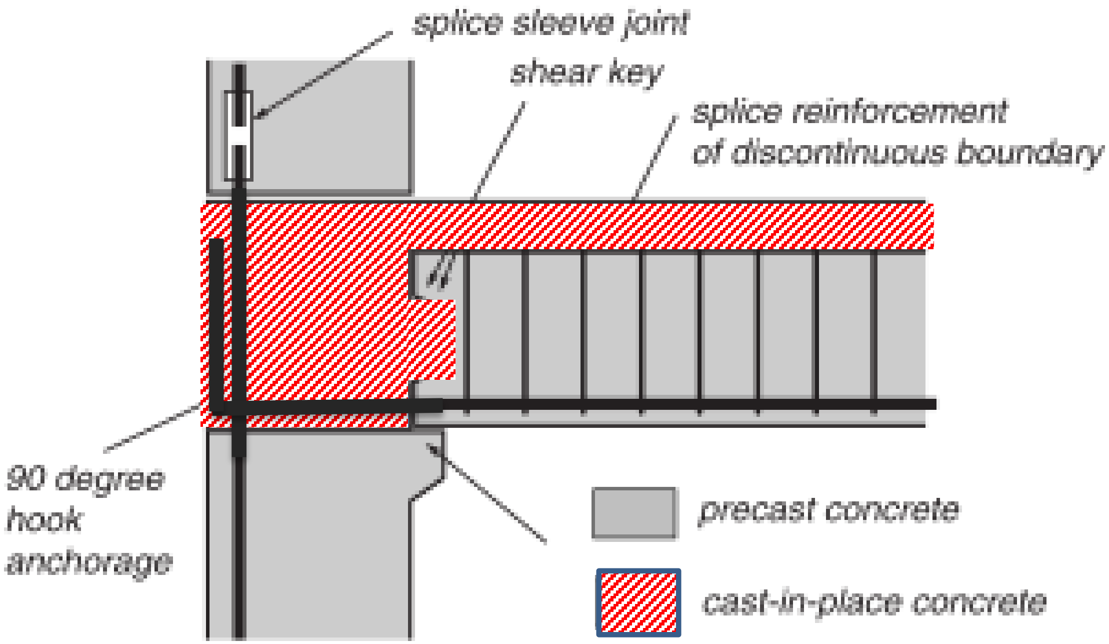
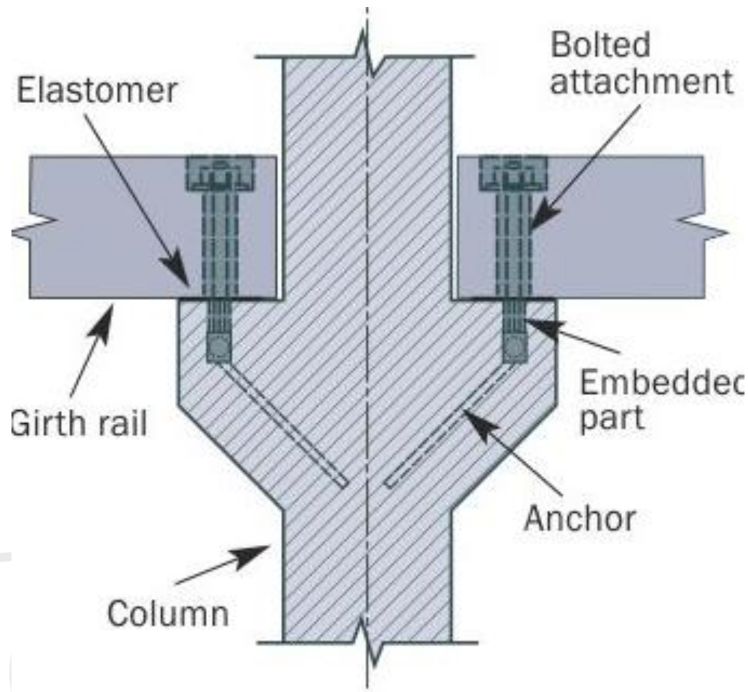


Figure 4: A typical connections at exterior beam column joints and connection elements



Jointed System

Equivalent monolithic system

JOINTED SYSTEM (DRY CONNECTION)

Connections are weaker than the adjacent precast concrete elements. The connections between precast concrete elements of jointed system can be subdivided into two categories:

a) Connections of Limited Ductility:

- Formed by welding or bolting reinforcement bars or plates or steel embedment and dry-packing and grouting.
- These joints do not behave as part of monolithic construction and have limited ductility.
- Structure are designed for elastic behavior.

JOINTED SYSTEM (DRY CONNECTION)

(b) Ductile connection:

- Unbonded post-tensioned tendons are used to connect the precast units together.
- Non-linear deformation occurs at interface of elements, where crack opens and closes.
- The unbonded post-tensioned tendons remain in elastic range.
- These connection have advantage of reduced damage and self-centering (i.e. practically no residual deformation) after an earthquake.

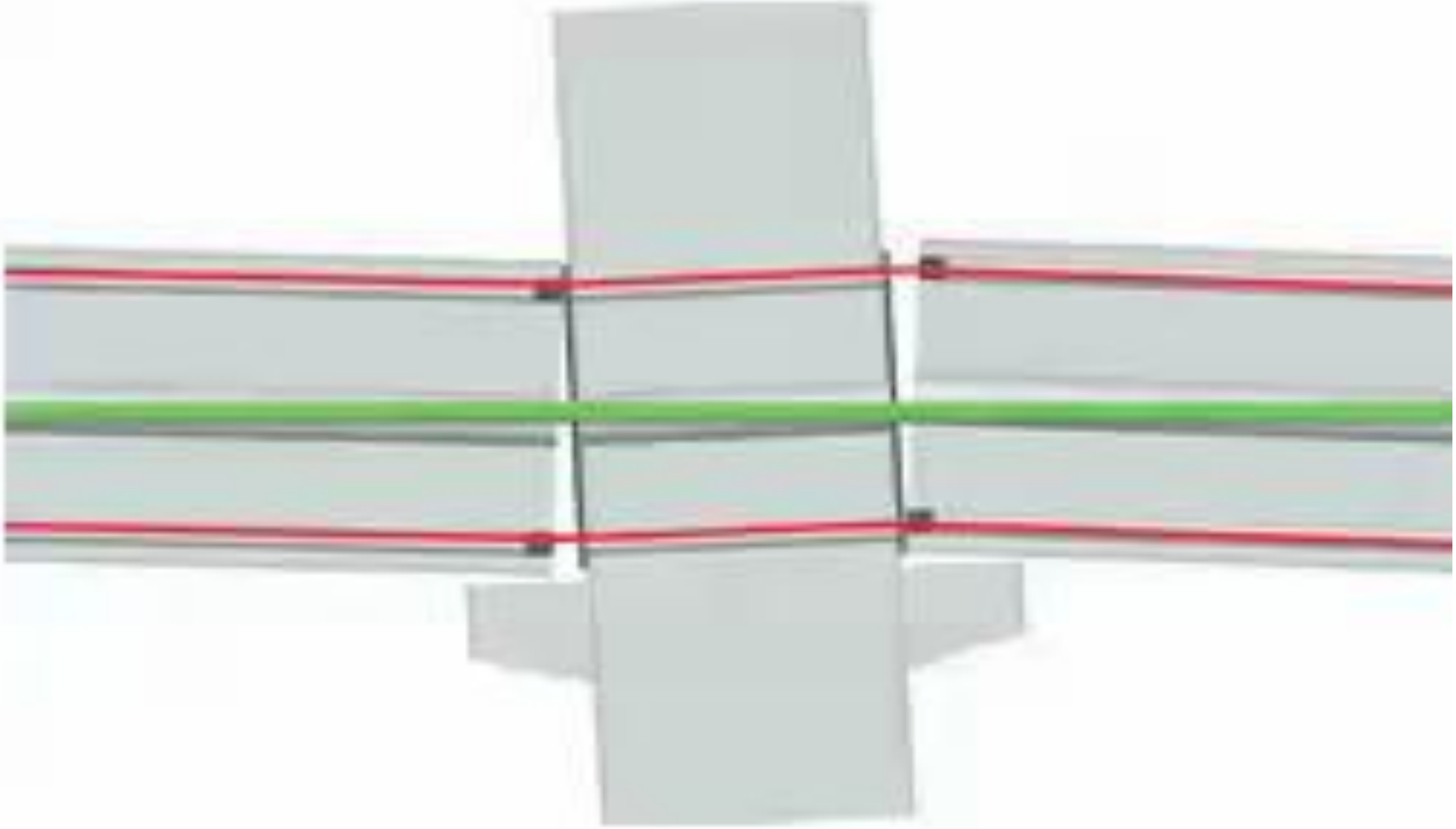
JOINTED SYSTEM (DRY CONNECTION)

MULTILEVEL CAR PARK, INFOSYS, HINJEWADI, PUNE. (Sachin et. al.)

JOINTED SYSTEM (DRY CONNECTION)


Columns
& Beams

JOINTED SYSTEM (DUCTILE DRY CONNECTION)



http://www.ccanz.org.nz/page/PREcast-Seismic-Structural-System-PRESSS.aspx

JOINTED SYSTEM DURING EARTHQUAKE

http://www3.nd.edu/~concrete/1999_duzce_earthquake_reconnaissance/precast.html

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JOINTED SYSTEM DURING EARTHQUAKE

Bhuj Earthquake 2001

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Bhuj Earthquake 2001

EQUIVALENT MONOLITHIC SYSTEM

- Equivalent monolithic system is also known as wet connections.
- Due to limitation of “Dry” connections, “Wet” cast-in-place rein-forced concrete, or post-tensioned joints are most preferred.
- “Wet” connection show excellent performance during earthquakes, they tend to behave monolithically, provide continuity and higher redundancy, and add to the structural integrity.

EQUIVALENT MONOLITHIC SYSTEM

Subdivided into two categories:

(a) Strong Connection of Limited Ductility:

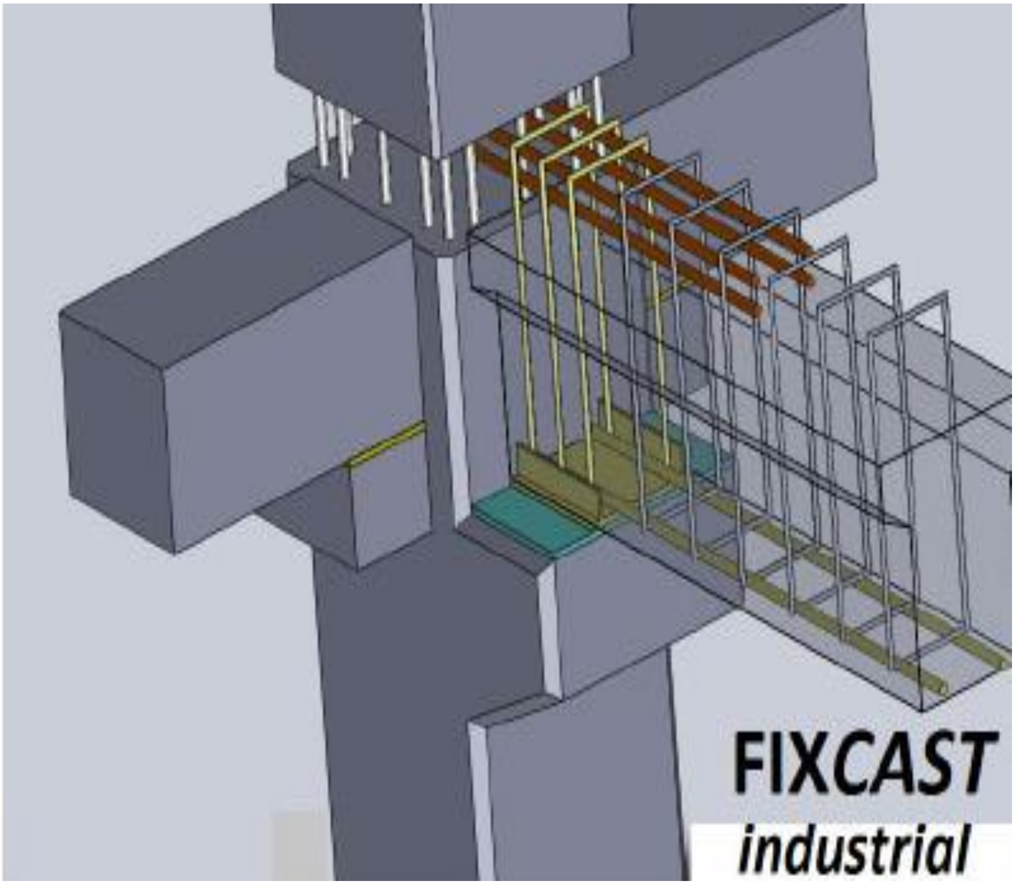
- Longitudinal dowels of precast unit are connected by lap splice in a cast-in-place concrete joint or by non-contact lap splice with grouted steel corrugated duct or by splice sleeves or by welding or by mechanical connectors.
- This type of connections are achieved by capacity design approach, which ensures that **flexural yielding occurs away from connections.**

EQUIVALENT MONOLITHIC SYSTEM

(b) Ductile connection:

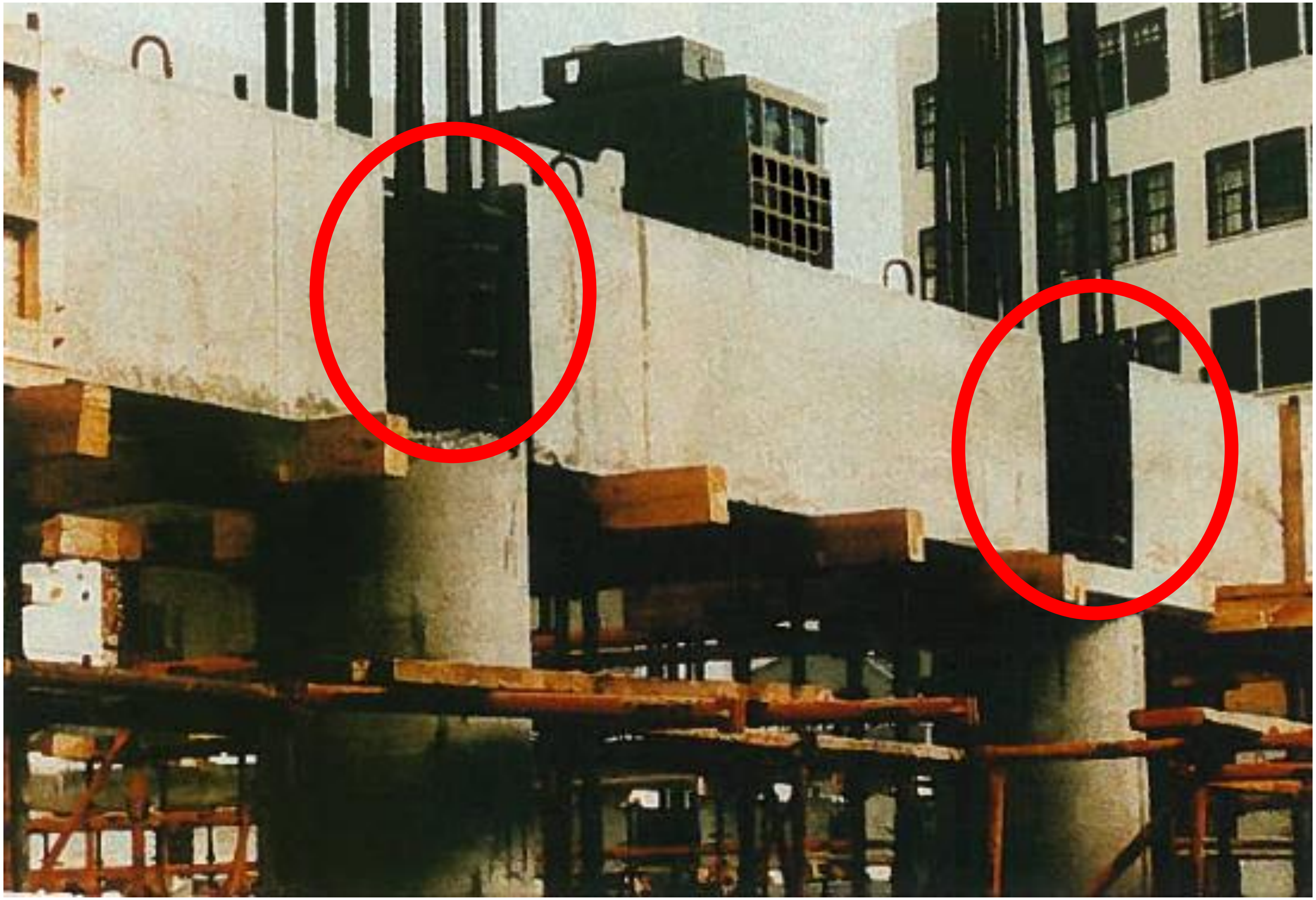
This type of connections are designed for required strength, longitudinal bars or grouted post-tensioned tendons in the connection region expected to enter the **post-elastic range in a severe earthquake.**

EQUIVALENT MONOLITHIC SYSTEM



http://www.emekprefabrik.com/eng/our-construction-system.html

EQUIVALENT MONOLITHIC SYSTEM



EQUIVALENT MONOLITHIC SYSTEM

Peripheral Column-beam joint

Interior Column-beam joint

CUMMINS TECHNICAL CENTRE INDIA, KOTHRUD, PUNE. (Sachin et. al.)

EQUIVALENT MONOLITHIC SYSTEM

LESSONS LEARNT FROM PREVIOUS EARTHQUAKES

- Precast construction has many advantages over conventional construction systems, but there are also many areas where it does not perform well. One major area where precast concrete does not perform well is with seismic loading.
- Due to poor behaviour of precast structures during earthquakes throughout the world, precast is viewed as unsuitable for resisting earthquakes.
- Most of the earthquake related precast construction failures have occurred due to poor design, deficient diaphragm action, inadequate detailing, and/or deformation issues.
- Due to lack of understanding of the basic nature of seismic behaviour, the precast concrete structure are viewed with skepticism in seismic regions.

LESSONS LEARNT FROM PREVIOUS EARTHQUAKES

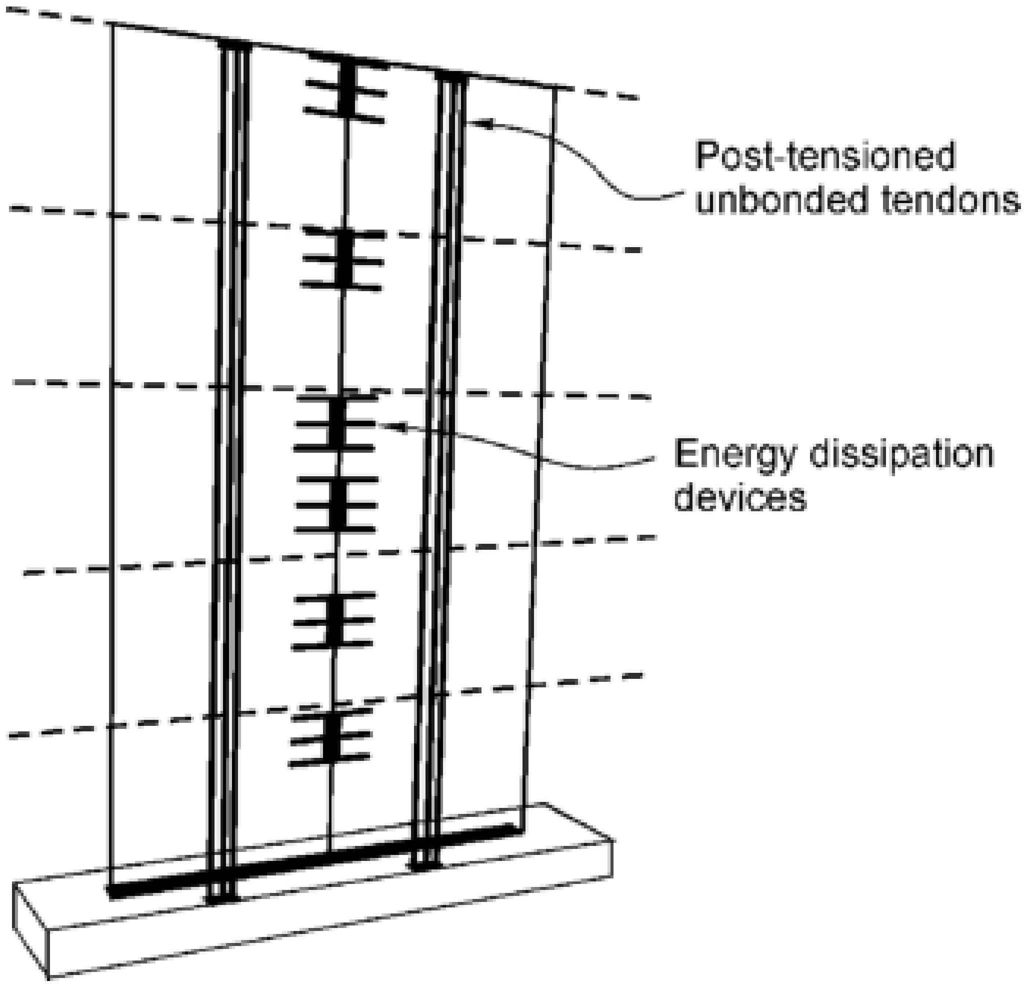
- All equivalent monolithic reinforced concrete construction systems and Column-to-Column and Beam-to-beam Connections tested in Japan and New Zealand under simulated seismic loading, found behaving well as if cast-in-place construction.

TURNING CHALLENGE INTO OPPORTUNITY!

Use the connections between different components for dissipation of energy

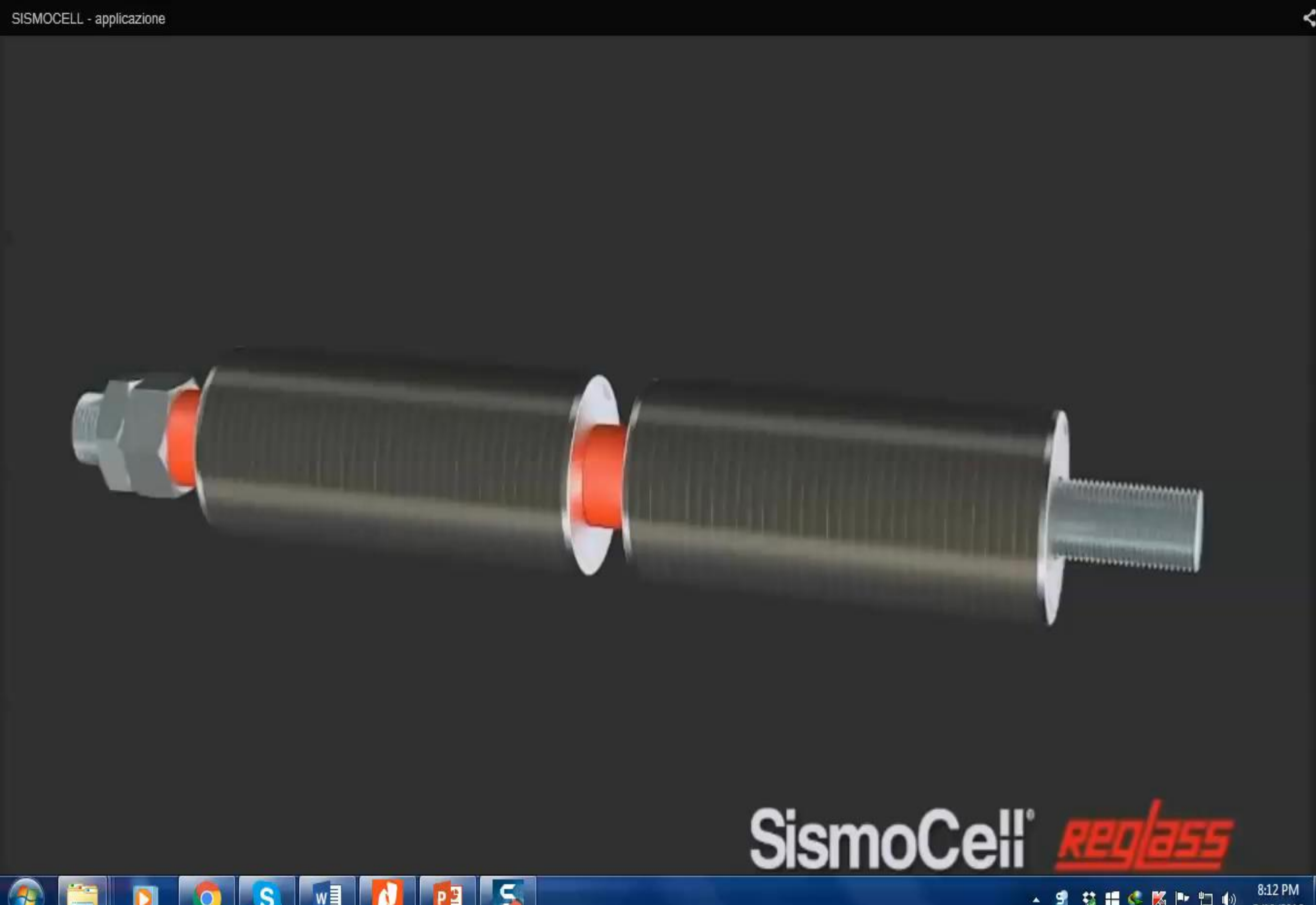
→ Innovative energy dissipation devices

ENERGY DISSPATION BY CONNECTIONS



Hybrid structural wall system (Priestley et al. 1999)

HYBRID STRUCTURAL WALLS


SISMOCELL - applicazione
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reglass
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Thank You !