Structural Issues in Prefabricated Buildings

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Introduction

Prefabrication is the practice of casting components of a structure in a factory or other manufacturing site, and transporting complete assemblies or sub-assemblies to the construction site where the structure is to be erected.

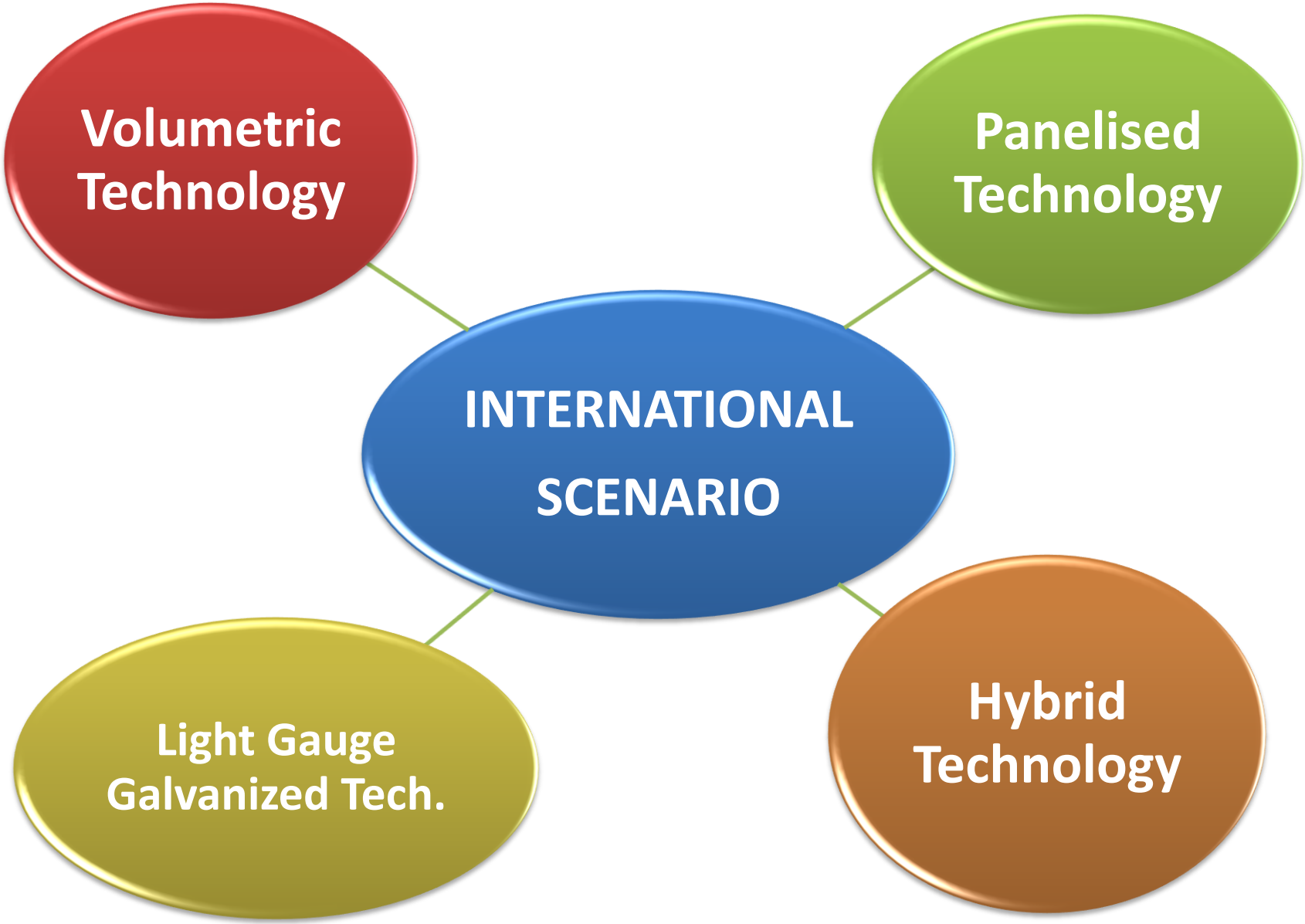
Need for Prefabrication

- Structural efficiency
- Cost Control
- Optimum use of materials
- Speed of construction
- Quality consciousness
- Adaptability
- Protection of the environment

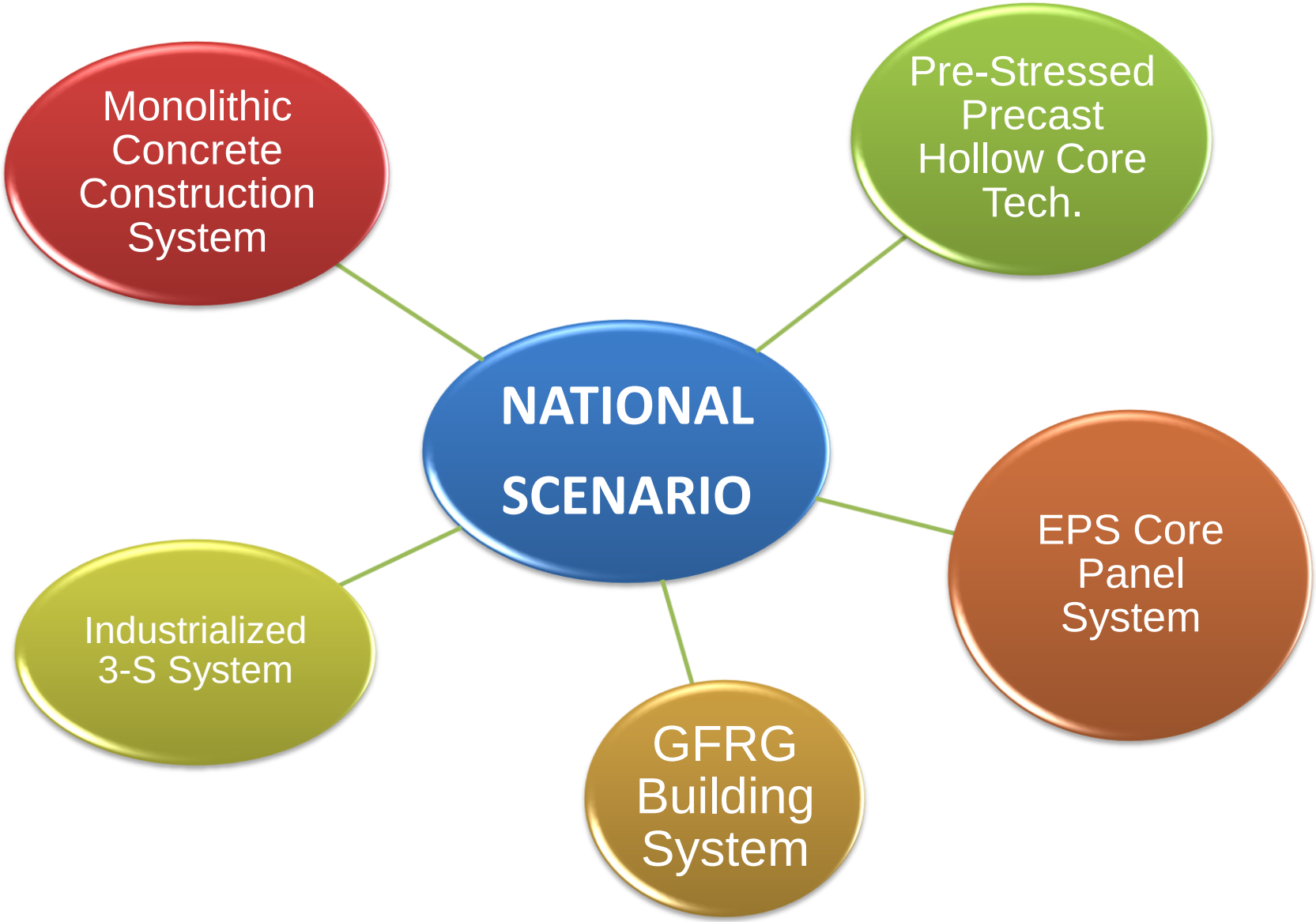
Outline

1. Scenarios
2. Structural Failures
3. Design Concept for Precast Buildings
4. Structural Issues
5. Joints
6. Installation Issues
7. Constructional Issues
8. Life Cycle Design Concept
9. Conclusion

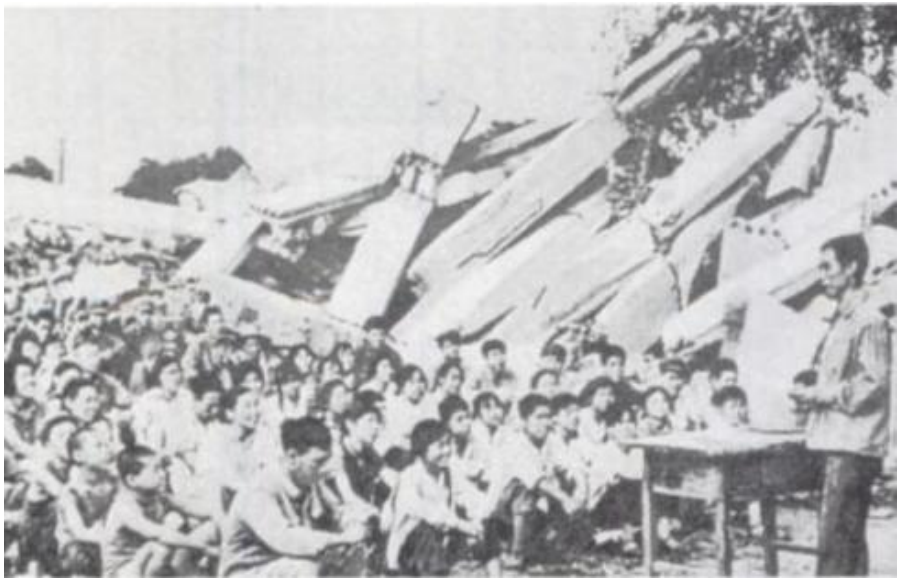
1. International Scenario



National Scenario



2. Structural Failures



Collapse of precast buildings in Tangshan, China 1976

Collapse of precast concrete parking structure due to pounding against adjacent structure in Mexico City, 1985 Michoacán Earthquake (due to inadequate separation)

Ref: fib bulletin 27

Structural Failures contd.

Collapse of Precast Concrete Hollow Core Floor; 1994 Northridge Earthquake, California

Failure of Flexible light-gauge metal diaphragm; 1999 Kocaeli Earthquake, Turkey

Ref: fib bulletin 27

Structural Failures contd.

Failure of a poorly detailed beam-column connection (1976 Tangshan Earthquake, China)

Beam-Column joints of moment – resisting frames with precast have often failed in earthquakes due to poor details

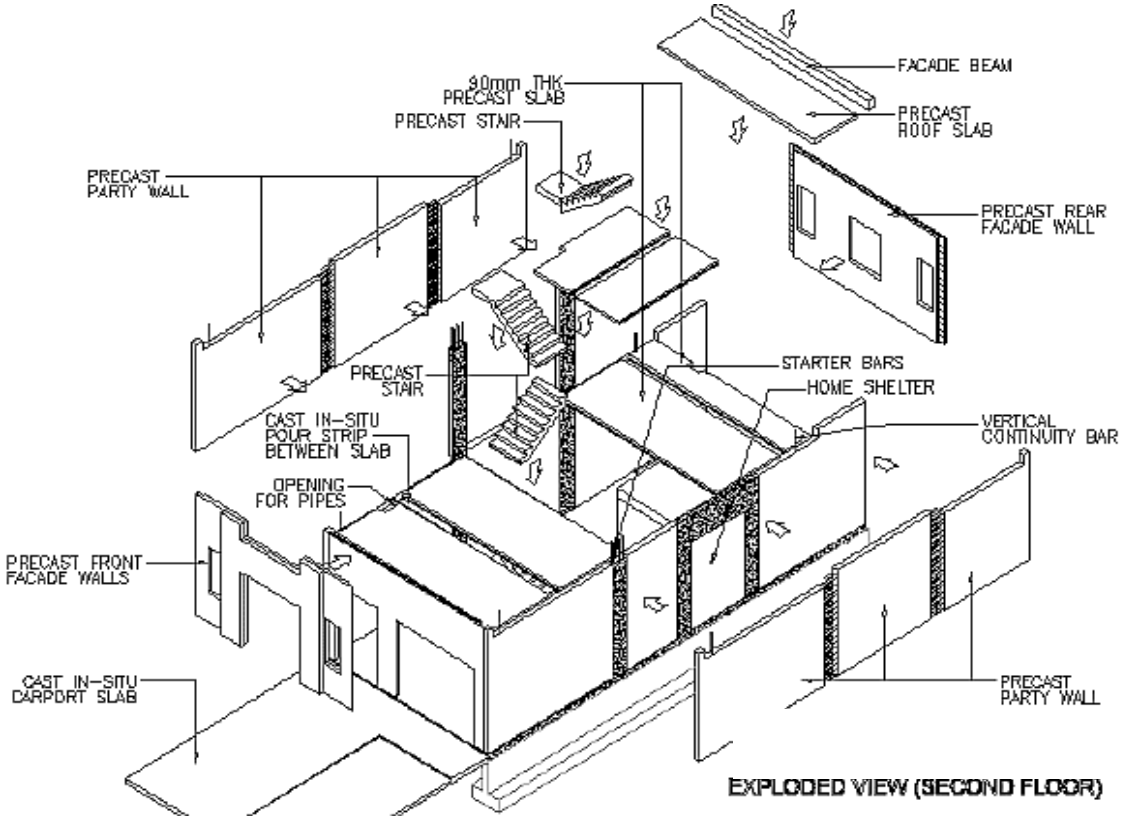
Failure of a poorly detailed beam-column connection (1976 Tangshan earthquake, China)

Ref: fib bulletin 27

3. Design concept for precast concrete buildings

The design concept of the precast buildings is based on

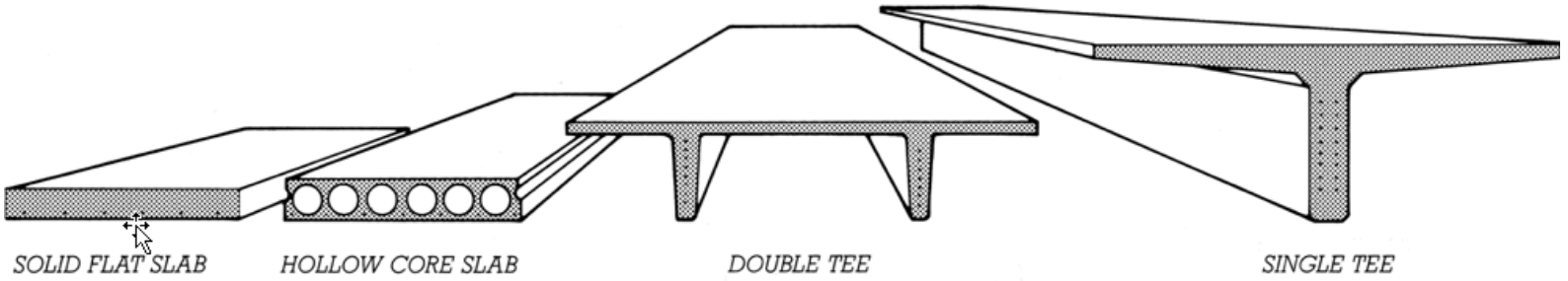
- Buildability
- Economy
- Standardization of precast components.



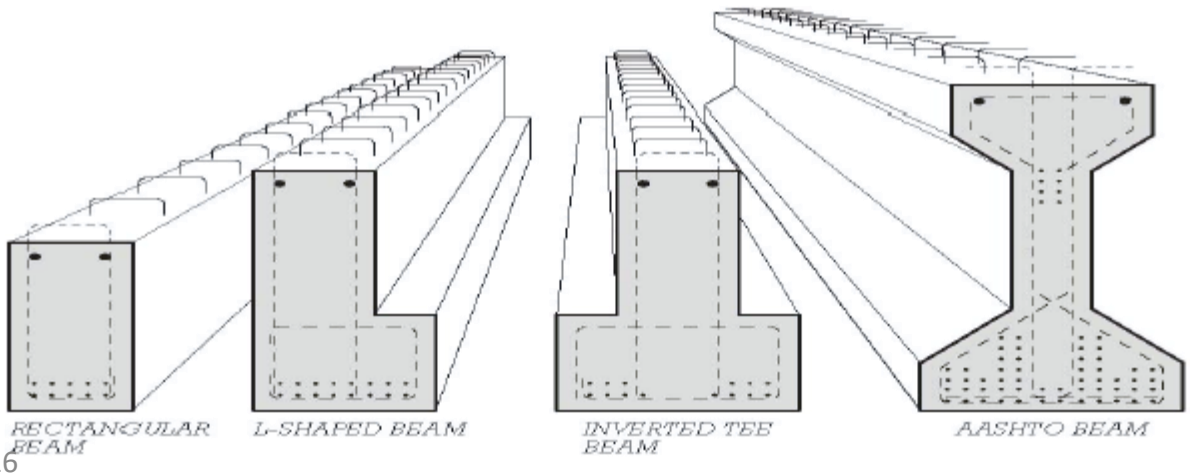
Isometric View

Precast concrete structural elements

Precast slabs



Precast Beam & Girders



Precast concrete structural elements....contd.

Precast Columns

Precast Walls

Precast concrete structural elements....contd.

Precast stairs

Precast concrete Stairs

Steel plates supported on 2 steel beams

4. Structural Issues

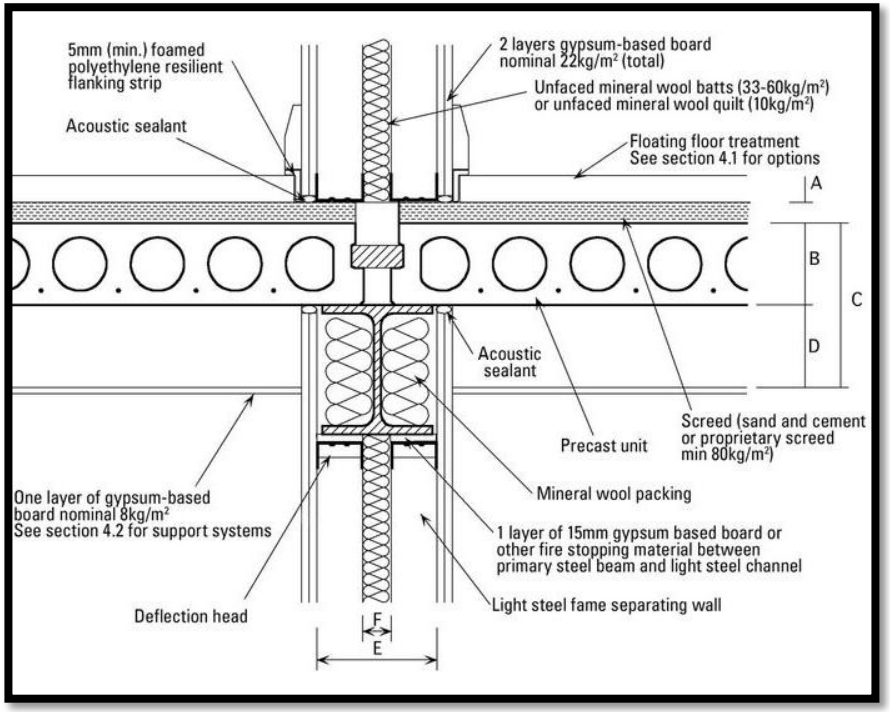
- Limited research on different types of precast structural systems.
- In code-based design of structures to resist earthquake loads, one needs to determine the response reduction factor (R).
- R factor would have different values for different types of precast buildings depending on their proven performances.
- Less flexible against future structural modifications

Major Design Codes

COUNTRY	CODES
New Zealand	Standards New Zealand 1995 covers many aspects of seismic designs, Precast R.C. structures
U.S.A.	Design Guides and Manuals by Precast/ Pre-stressed Concrete Institute
Canada	CPCI (Canadian Pre-stressed Research Institute) Design Handbook; NBCC (National Building Code of Canada)
Japan	Design and construction of Precast R.C. buildings by AIJA (Architectural Institute of Japan)
Mexico	Mexico City Building Code.

Further Structural Issues

- Inadequate Diaphragm Action
- Vulnerable in seismic prone areas due to semi rigidity at joints
- Issues due to different foundation level
- Issues due to changes in design plans during construction (not recommended).



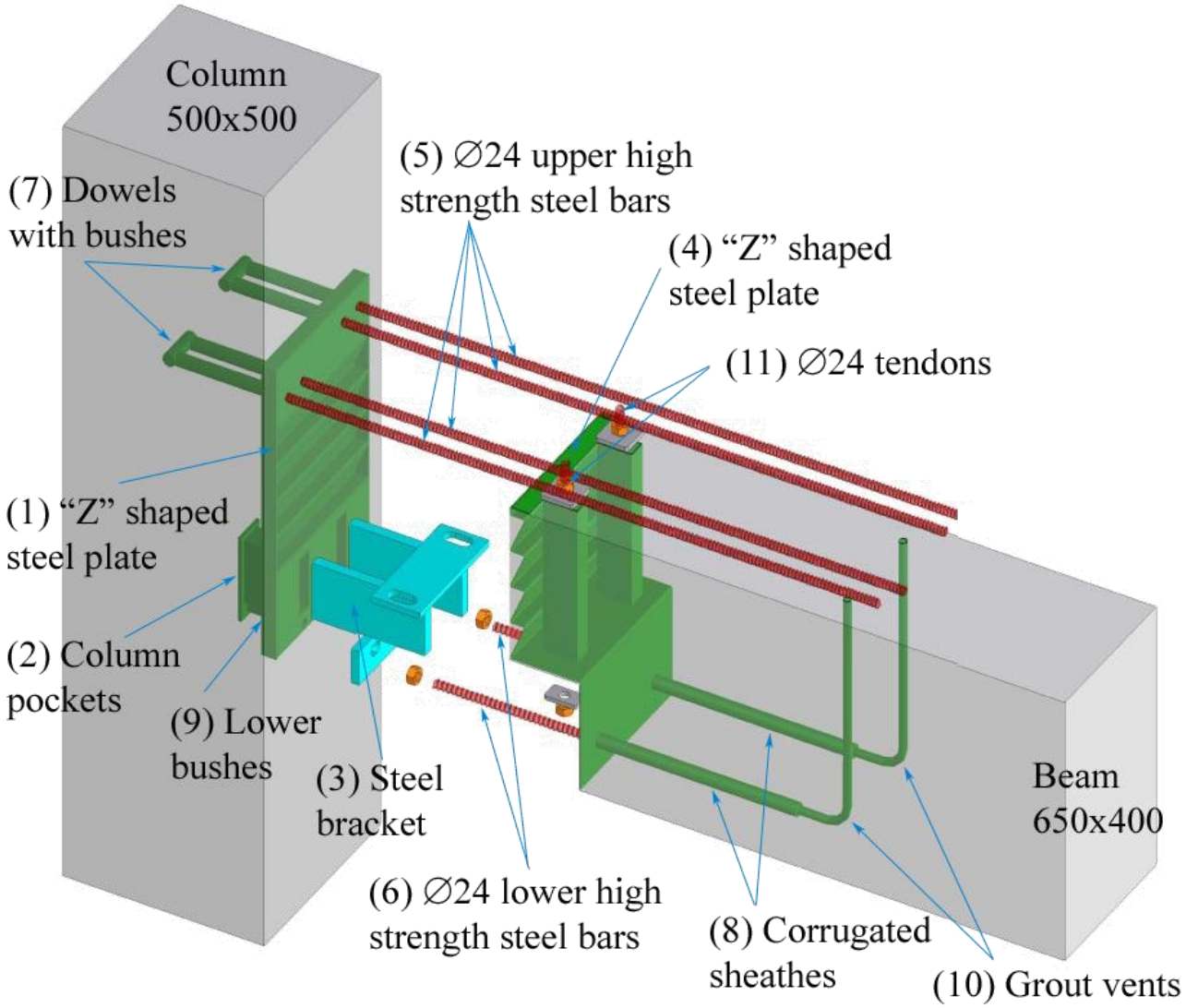
Achieving floor diaphragm action in Precast structures

5. Joints

- Problem faced by the precast industry is finding a reliable and economic method to join prefabricated members.
- Locations of high stress are weak point in structural system.
- Types of joint connection :
  - ❖ Dry Connections- Must be designed as strong connection maximum height of 18 m or 4 storeys is allowed.
  - ❖ Wet Connections- Must satisfy ACI-318-11 specially for anchorages and splices.

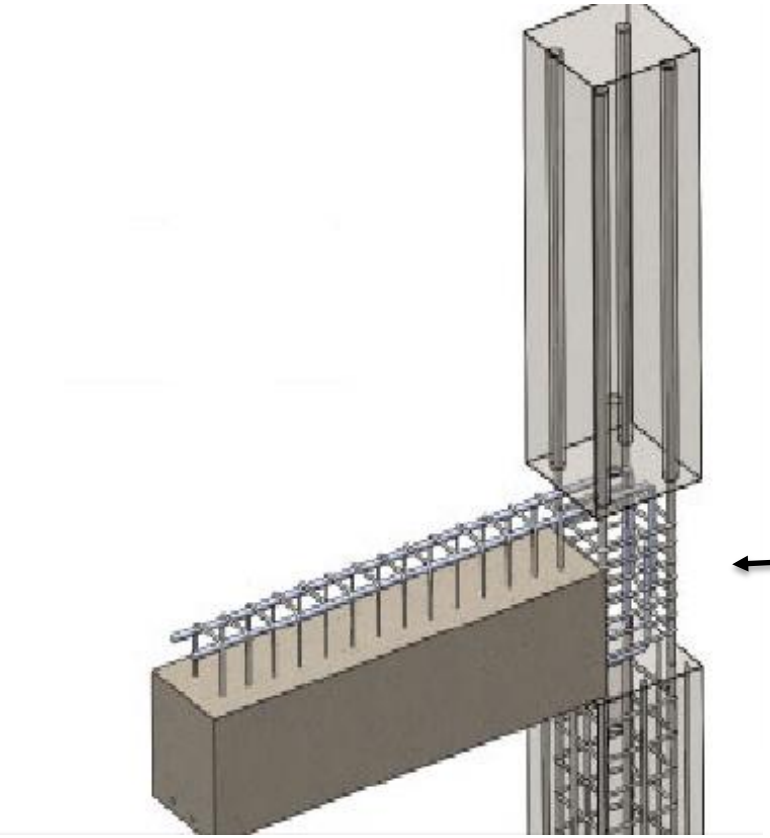
Ref: Englekirk 2003

Typical Precast Beam-Column Dry Joint



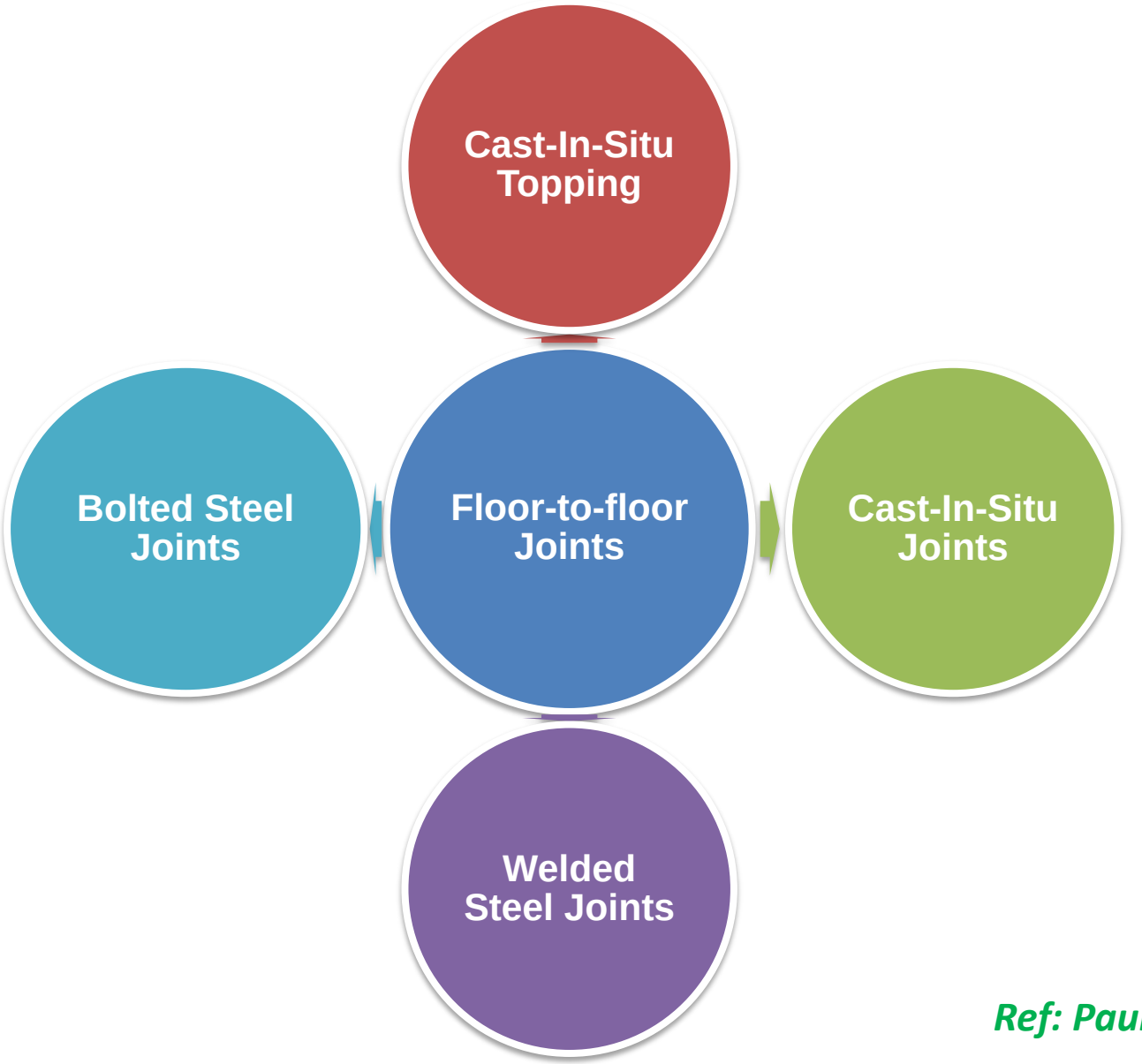
Edilmatic system components for typical beam-column joints in precast reinforced concrete structures *(Ref: Metelli G 2008)*

Typical Precast Beam-Column Wet Joint



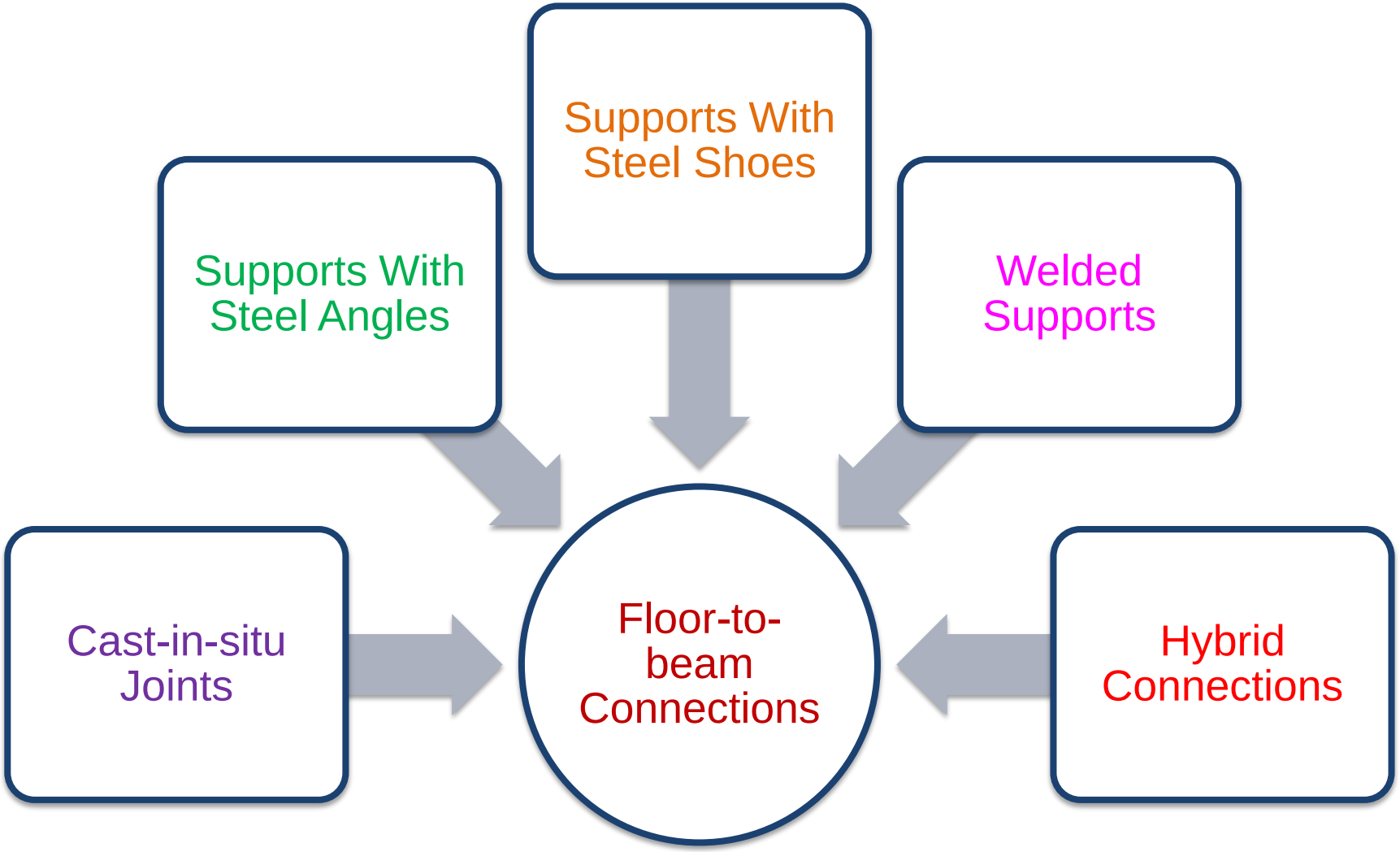
(Ref: Emek Prefabrik)

Floor-to-floor Connections for Precast Structures



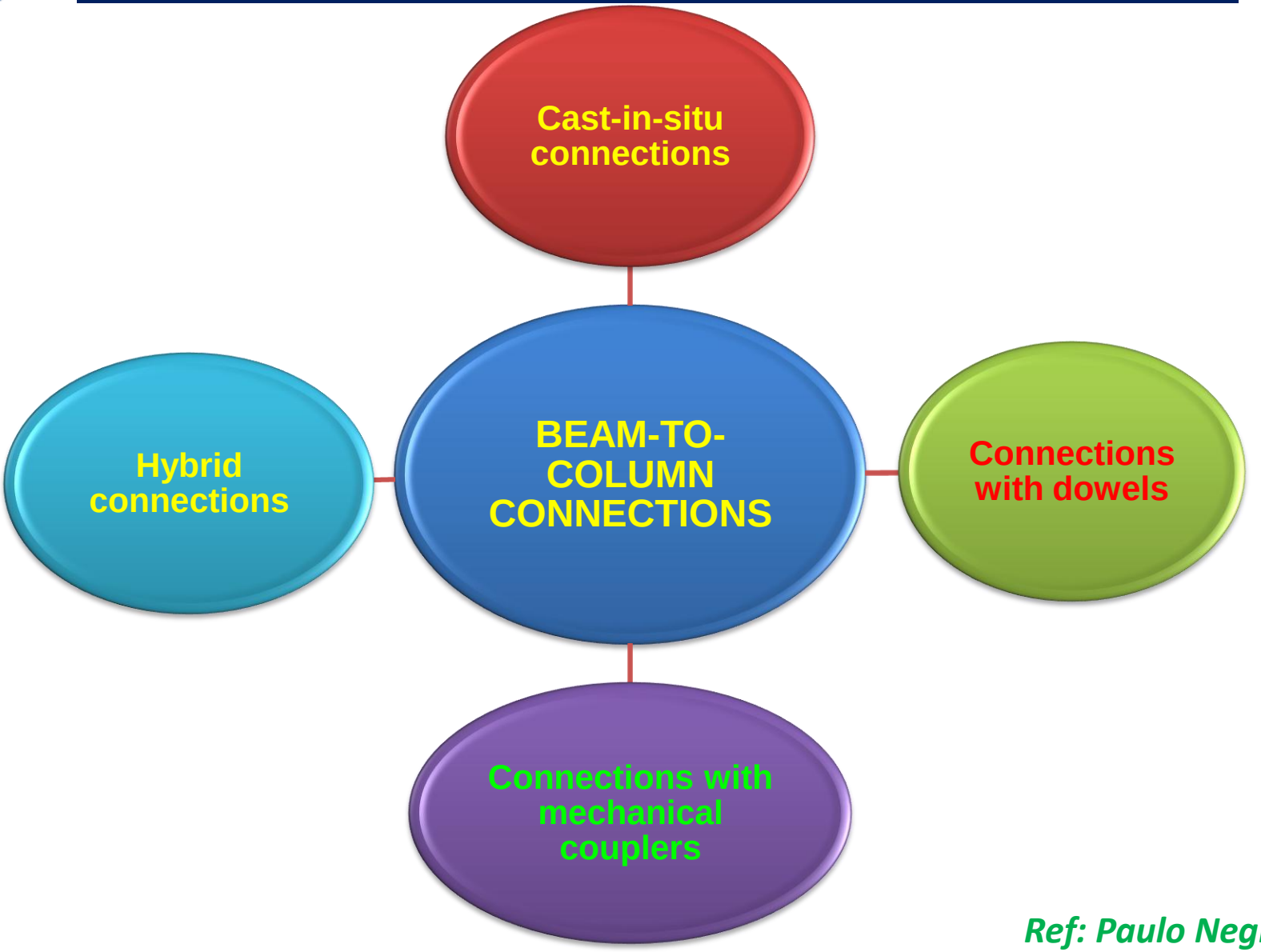
Ref: Paulo Negro 2012

Floor-to-beam Connections for Precast Structures



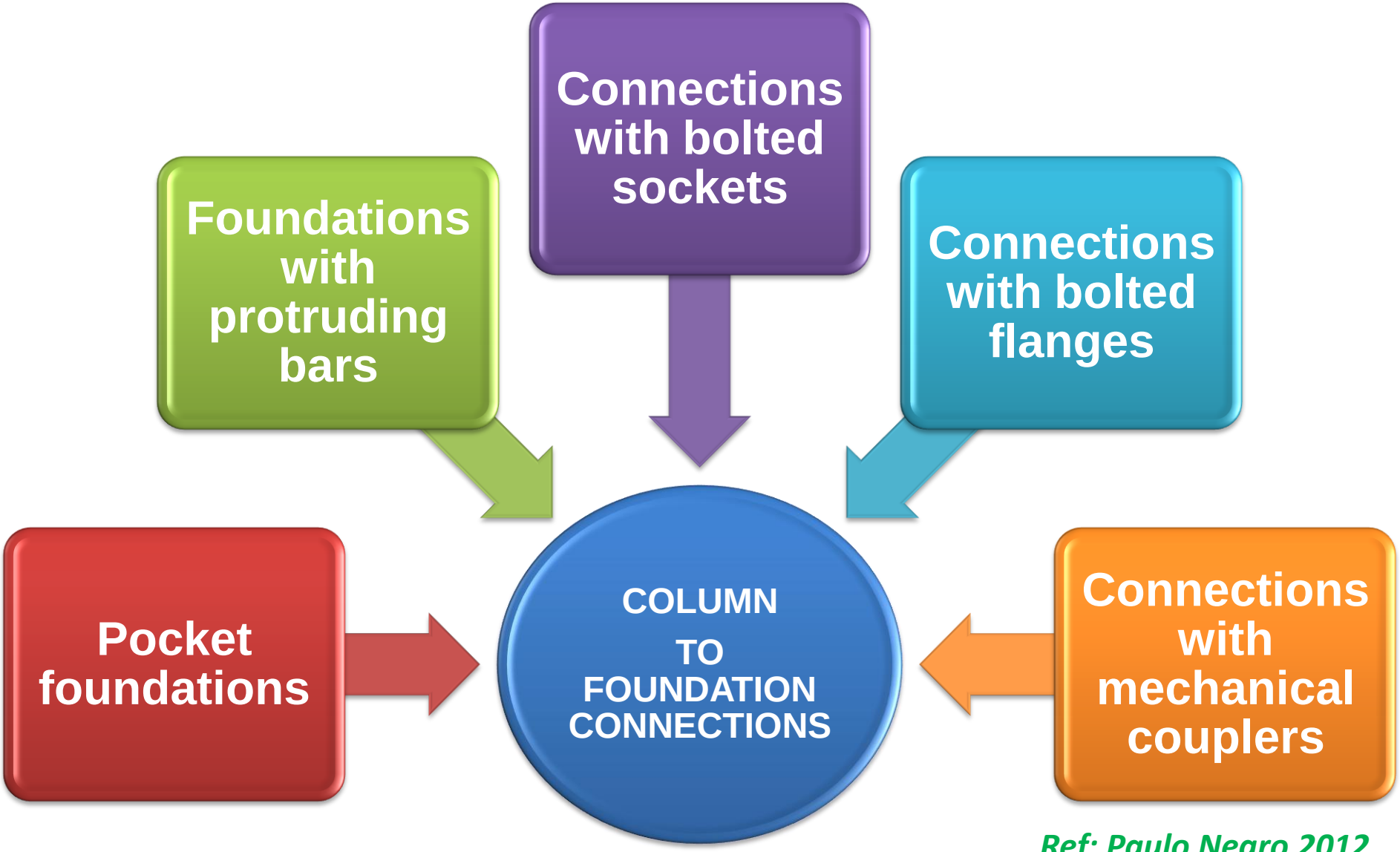
Ref: Paulo Negro 2012

Beam-to-column Connections for Precast Structures



Ref: Paulo Negro 2012

Column-to-foundation Connections for Precast Structures



Ref: Paulo Negro 2012

Joint Issues

- Adequate joints to transfer diaphragm forces
- The joints of the core structure and the components should be strong to transfer tension compression and vertical loads.
- FE modeling of precast buildings is complicated because of the variety of joint and support types with unknown load-deformation properties.
- Joints must have adequate strength to transfer gravity and lateral load between panels.
- If joints are not well accomplish it results in leakage.

6. Erection and Installation Issues

- Damages during erection or transportation.
- Heavy machineries are required for large size prefabrication.
- Difficulty in transportation of precast components.
- Aligning of heavy precast components becomes difficult at site
- Erection and installation becomes very cumbersome in crowded area.

Erection at Site

Installation of a Slab

7. Construction Issues

- Requirement of skilled labour at site.
- Lack of onsite automation in the construction sector
- Durability aspects due to leakage problem.
- General maintenance manual of these structures is extremely challenging.

8. Life Cycle Design Concept

- Design for deconstruction
- Flexible and demountable precast building systems would result in efficient use of resources
- Inventory of relevant energy and material inputs and environmental releases
- Repair and maintenance

9. Conclusions

- Government of India's ambitious Mission of "***Housing for ALL by 2022***" can only see the light of the day using prefab technologies in the housing sector.
- The partial prefabrication technologies developed by CSIR-CBRI has been successful in rural areas and has been implemented at a large scale in various housing projects.
- The quality achieved in construction using CBRI technologies has been proved to be better.
- There is a need for development of training modules, quality control/ assurance guidelines including general maintenance requirements, SOR etc.

Conclusions

- Research need to carried put for identifying the response reduction factor (R) for different precast structural systems.
- For wide acceptability design codes are needed to be formulated for different precast structural systems.
- R & D in automation for construction sector needs to be encouraged for greater acceptability of precast structural system

Reference

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4. Negro, P and Toniolo G., “Design Guidelines for Connections of Precast Structures under Seismic Actions, European Commission (2012)

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Thank You