Hyderabad 9th March 2013

Conference on precast concrete Structures

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Architecture in Precast

Planning and Design of Precast Buildings

Contents of the presentation:

1. Introduction
2. Why precast?
3. Design process
4. Architectural design aspects
5. Structural design aspects
6. MEP services aspects
7. Manufacturing aspects
8. Construction aspects

Purpose of this presentation

To introduce the audience to the design aspects and planning aspects of precast concrete construction methods for residential and commercial buildings.

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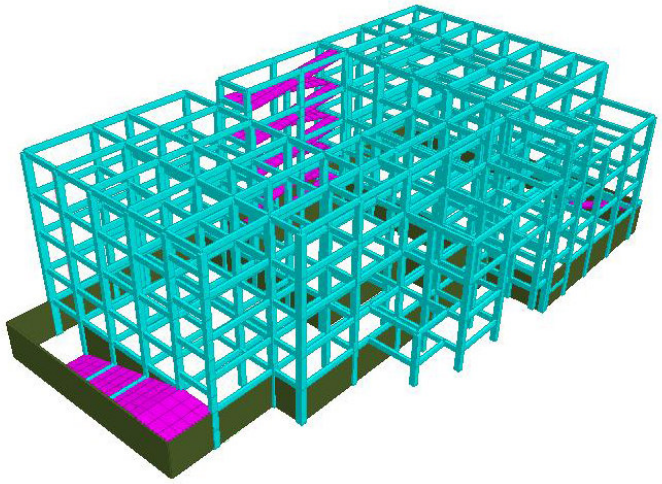
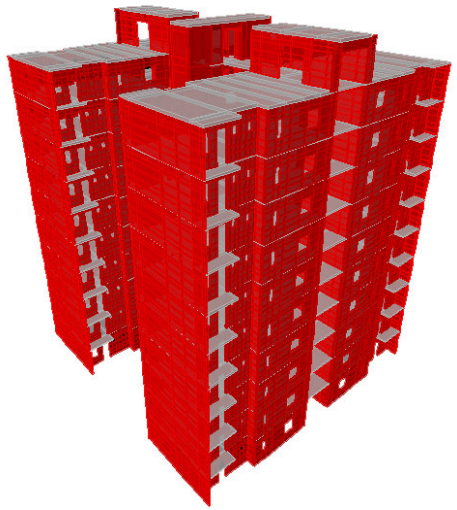
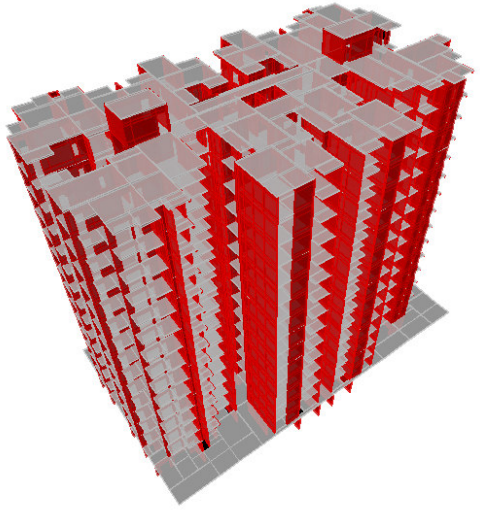
Our companies

- Structural engineering consultancy.
- Structural analysis and design of buildings.







Our companies

- Head office in the Netherlands, founded in 1969.
- Since January 2005 also office in Gurgaon, India.
- Since 2009 precast concrete design services for the Indian market.

Why precast?

Decision making – why precast?

Factors to be considered when deciding to implement precast concrete construction:

- Quality
- Unique capabilities with precast
- Speed of construction
- Building site
- Construction aspects
- Costing

Quality in Precast

- Controlled environment
- High quality precast products
- Less wastage
- Skilled labor force
- High strength concrete (M40 to M60)
- Ordinary reinforcement and prestressing steel
- Specialized design engineers

Examples : high quality finishing

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Examples : high quality finishing

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Unique capabilities with precast

- Mechanization – mass production
- Customization – small production
- Prestressing
- Fair faced concrete (exposed)
- Colored concrete and Graphic concrete
- Natural stone / marble / tiling / bricks
- Sandwich panels with insulation

Examples : mass production of standard elements

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Examples : customization

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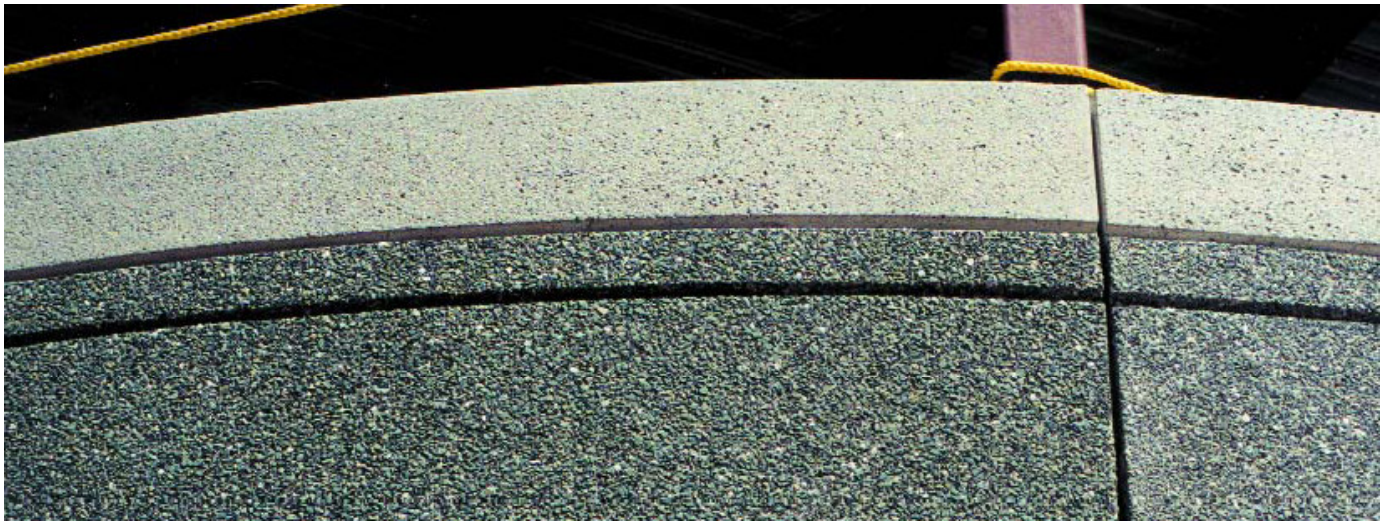
Examples : exposed aggregates



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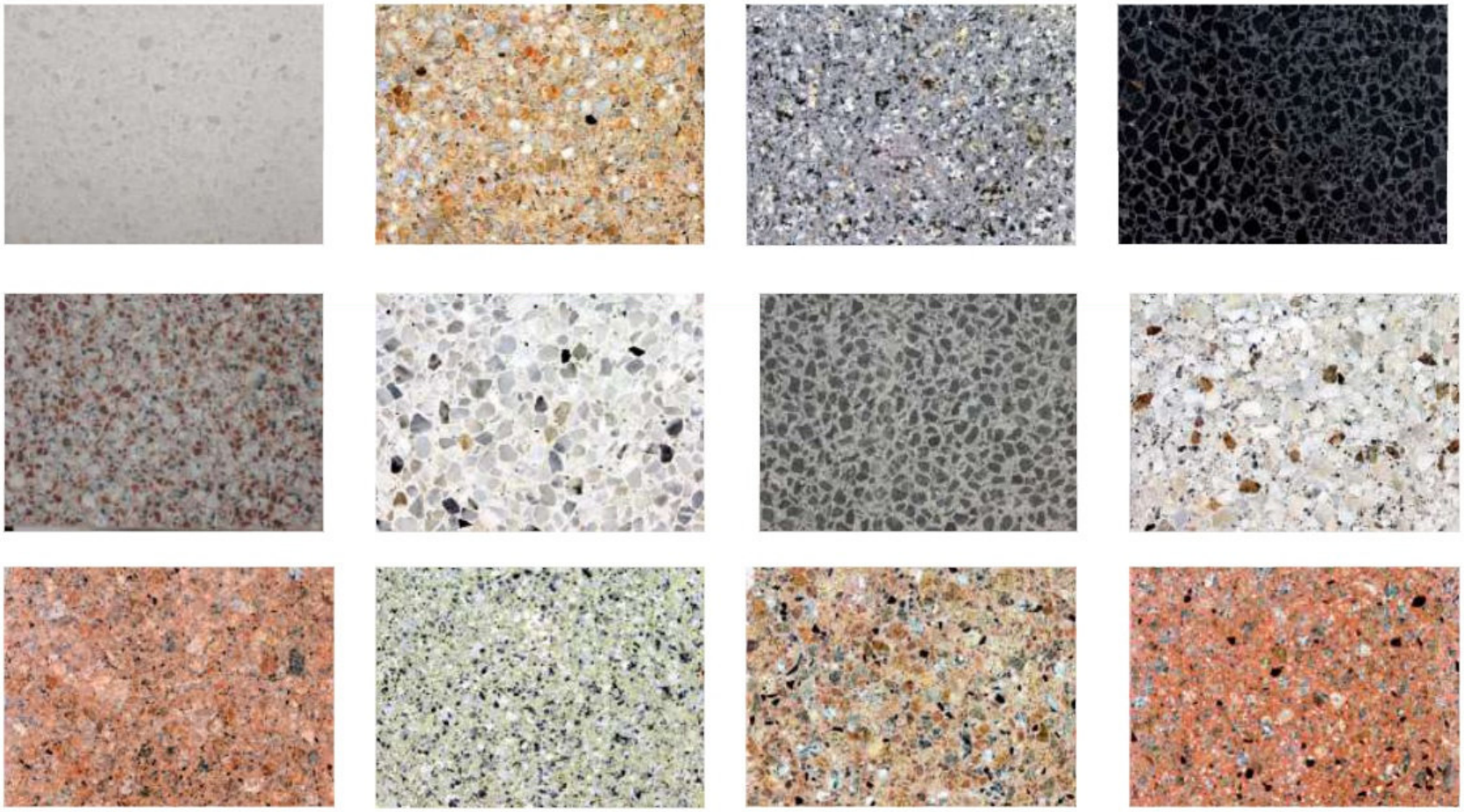
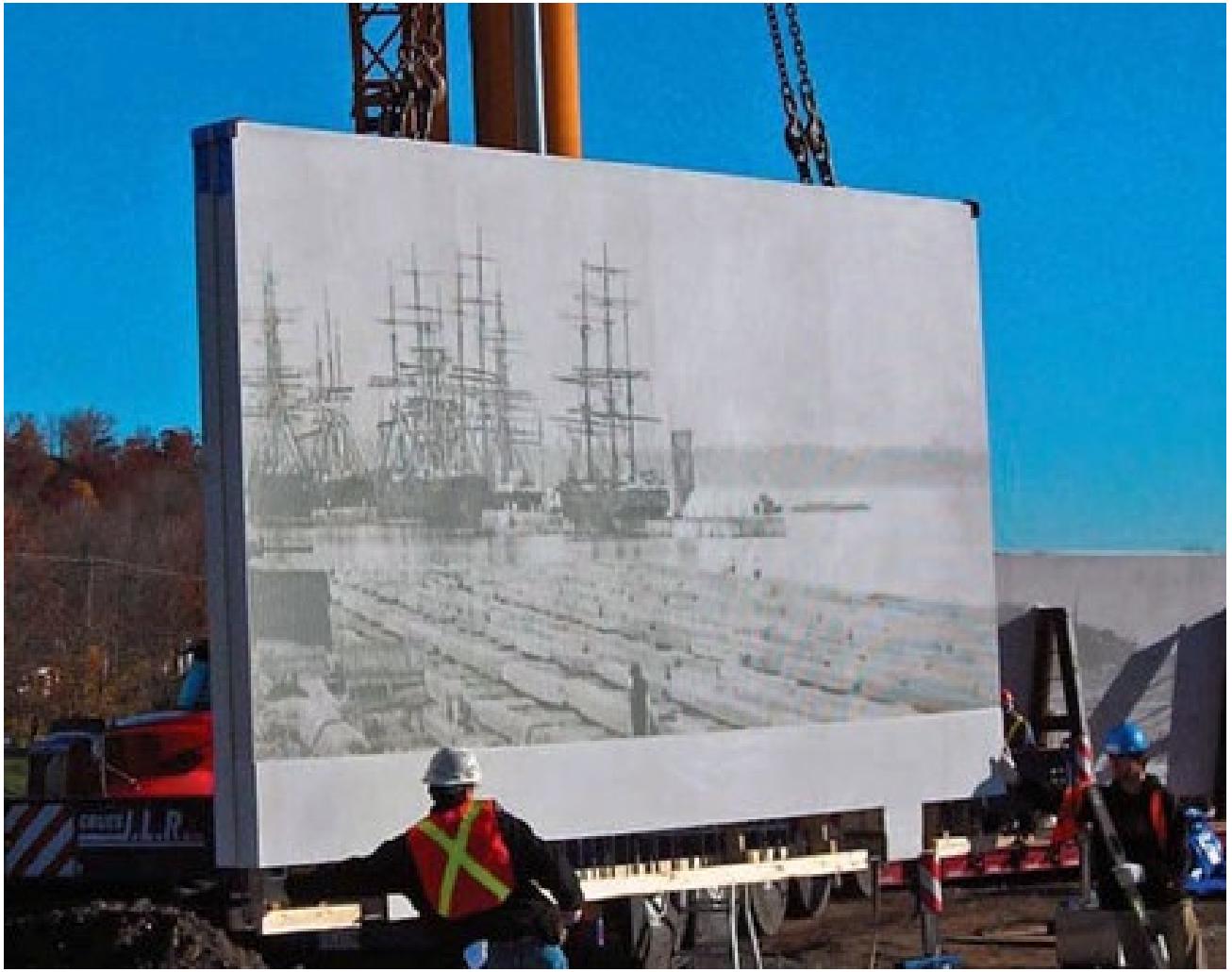
Examples : polished concrete samples



Examples : formliners

Examples : graphic concrete



Examples : sandwich panels

Speed of construction

- Very short erection time
- Small team for execution
- Long lead time
- Longer design process
- Planning and logistics are crucial
- Overall shorter construction time

Examples : planning and logistics

Decision making – why precast?

Examples : planning and logistics

Examples : planning and logistics

Examples : small team for execution

Building site

- Size of the construction site
- Availability of nearby land
- Access for transportation
- Just in time delivery of precast elements
- Site casting vs factory casting
- Possible crane positions
- Clean and neat construction site

Decision making – why precast?

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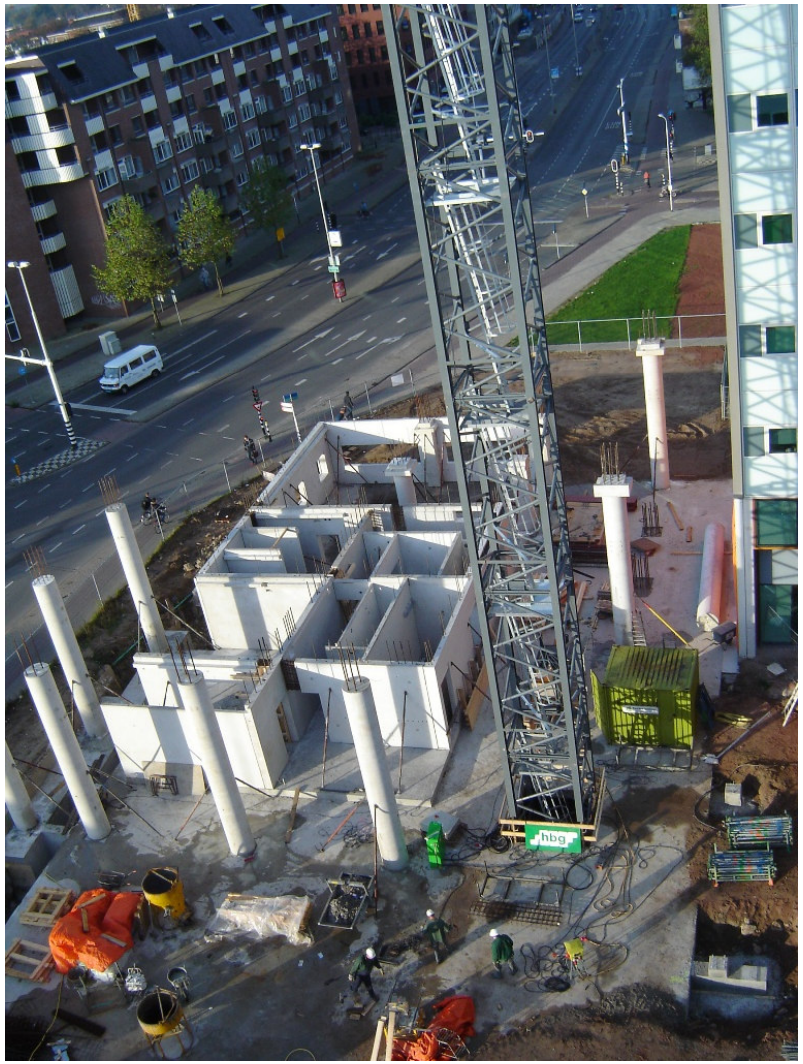
Examples : small site in urban areas



Examples : clean and neat construction site

Construction aspects

- Availability of labor
- Availability of precast equipments
- Health and safety standards
- Ease of construction
- Project management

Examples : Small team / health and safety

Examples : Small team / health and safety

Cost of precast

- Consider total costs
- Simplicity = cost saving
- Time = Money
- Price vs Quality
- Think precast from the start
- Long term strategy

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Examples : Simplicity in precast design

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Examples : Simplicity in precast design

Major advantages of precast concrete

- High Quality
- Fast construction
- Reduction in manpower
- Less wastage
- Large floor spans possible
- Good health and safety standards
- Durable construction material

Major disadvantages of precast concrete

- Large initial investment required
- Heavy lifting equipment
- Longer preparation time required
- Limited flexibility
- Transportation problems
- Taxation

Why precast? – key decision making aspects

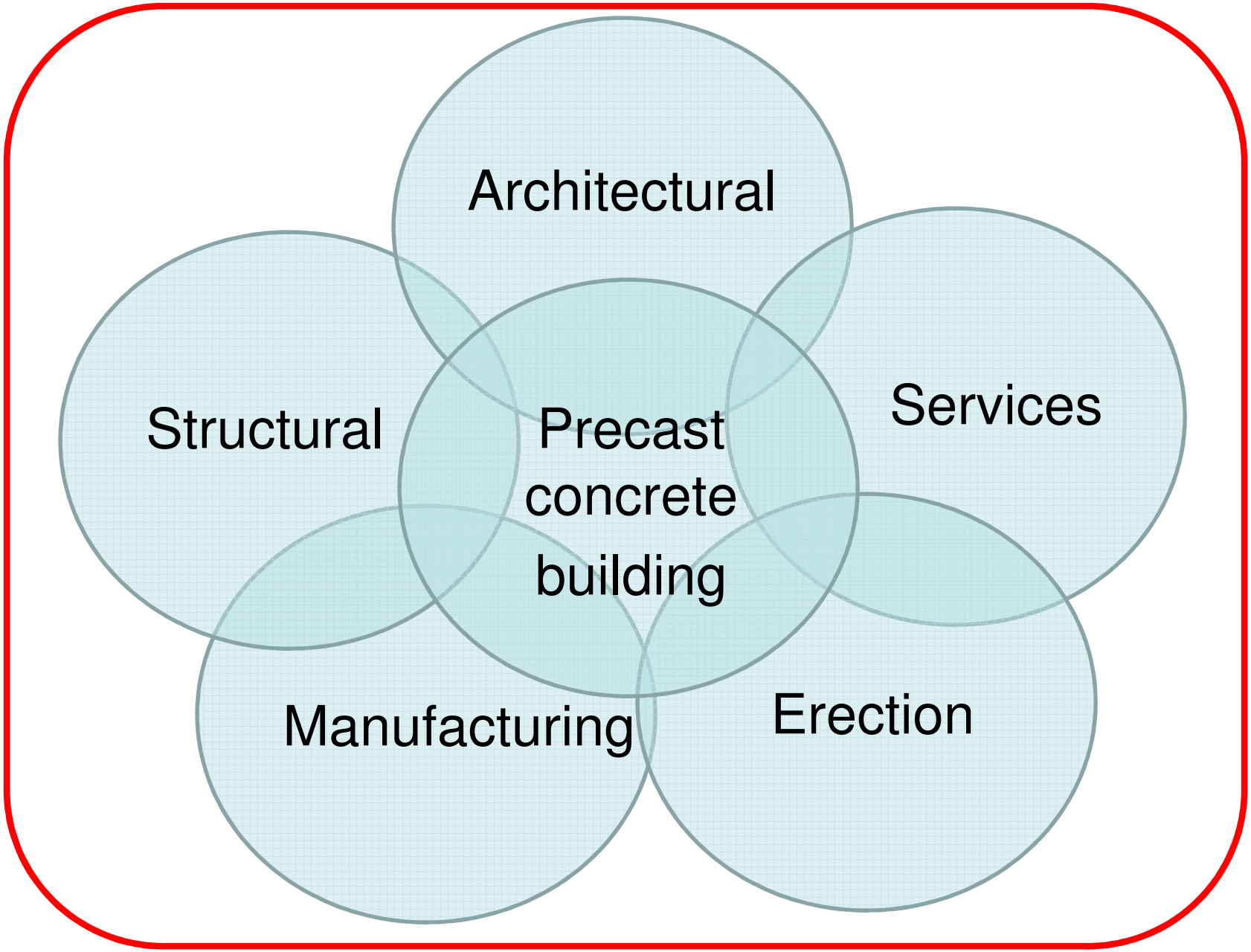
- Unique capabilities with precast
- Total building cost
- Time = money
- Availability of labor
- Price vs Quality
- Building site constraints
- Building design constraints
- Government initiatives

Design process for precast buildings

Aspects

- Team
- Tasks and responsibilities
- Design brief
- Design process
- Challenges

Design process of precast buildings



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Team

- Client
- Architect
- Structural engineer
- Services consultant
- General contractor
- Precast manufacturer
- Precast contractor
- Precast design engineer

Tasks and responsibilities

- Decisions have to be made early
- One party has to coordinate
- Strict planning has to be followed
- Work closely together
- MEP design required at early stage
- Early completion of detailed design
- Avoid last minute changes

Design brief

- Precast system
- Maximum weight and size of pc elements
- Aesthetics – finishing and joint locations
- Design Codes
- Structural connections
- Manufacturing limitations
- Tolerances of the precast components

Design process of precast buildings

Design brief

↓

Architect sketch plan

↓

Concept design

↓

Final design

↓

Shop drawings

↓

Erection drawings

Challenges during design phase

- Time pressure
- Lack of information
- Coordination
- Lack of experience

Architectural design aspects of precast buildings

Design approach:

- Modular design
- Design with larger floor spans
- Minimize joints
- Restrict maximum weight of pc elements
- Integration with MEP services
- Integration with structure
- No conversion of cast in-situ design
- Not everything has to be precast concrete

Architectural design aspects

Layout

- Simple and symmetrical layouts
- Alignment of load bearing elements
- Strategic location of shafts for services
- Minimize cantilevers and offsets

Floor to floor height

- Transportation restrictions → height of panels
- Minimum required clear height
- Minimum space for services

Architectural design aspects

Simple layout

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Simple precast villas

Modular design system

- Important for standardized production methods
- Grid size: multiple of 300mm
- Multiple of 1200mm for standard precast slabs
- Modular system is guided by the standard slabs
- Alignment of other precast elements
- Walls and columns are more flexible than slabs

Repetition of precast elements

- Evaluate per project
- Depending on production methods
- Depending on design requirements
- Small project → minimize number of moulds
- Outer size of mould can be fixed (basic mould)
- Positions of windows and doors can vary
- Use symmetrical precast elements

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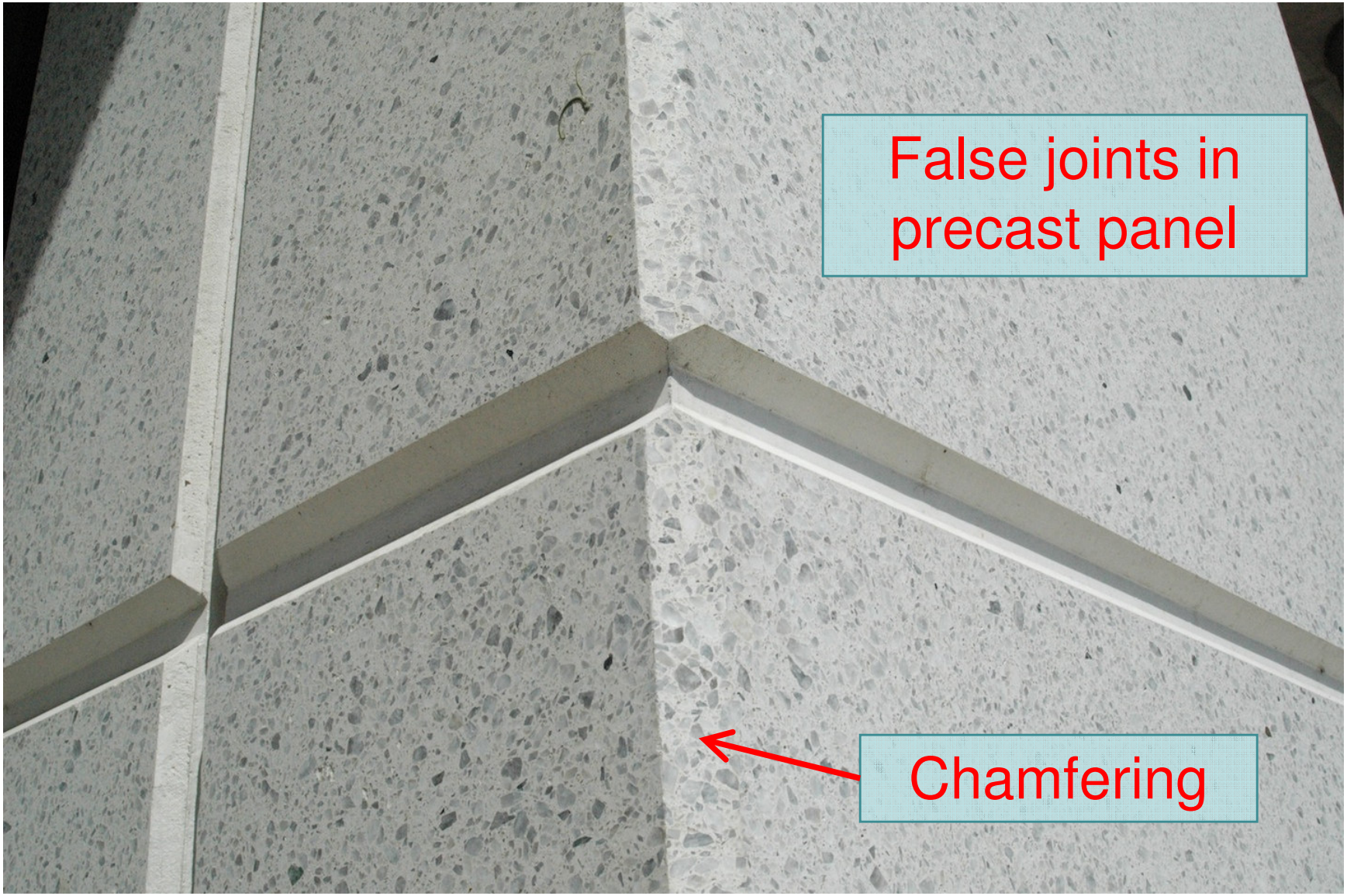
Repetition in large scale precast project

Detailing

- Integration of architectural features in the precast concrete elements.
- Standard concept with simple customization
- Tolerances between elements
- Building should be water proof
- Location of panel joints and false joints
- Deep recesses under 10º angle
- Chamfering at corners

Architectural design aspects



Architectural design aspects

Structural design aspects of precast buildings

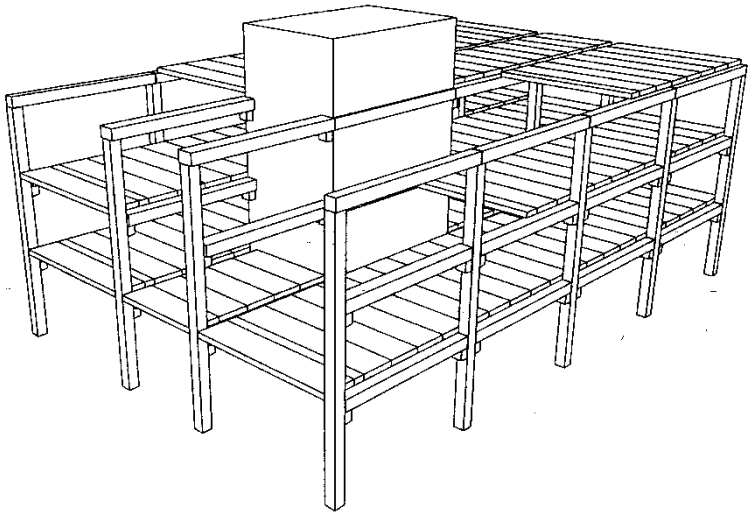
Structural system:

Seismic design of precast concrete structures

- Precast structure has to withstand earthquake forces.
- Structural integrity and connections between the precast elements are important.
- Ductile behavior and detailing.

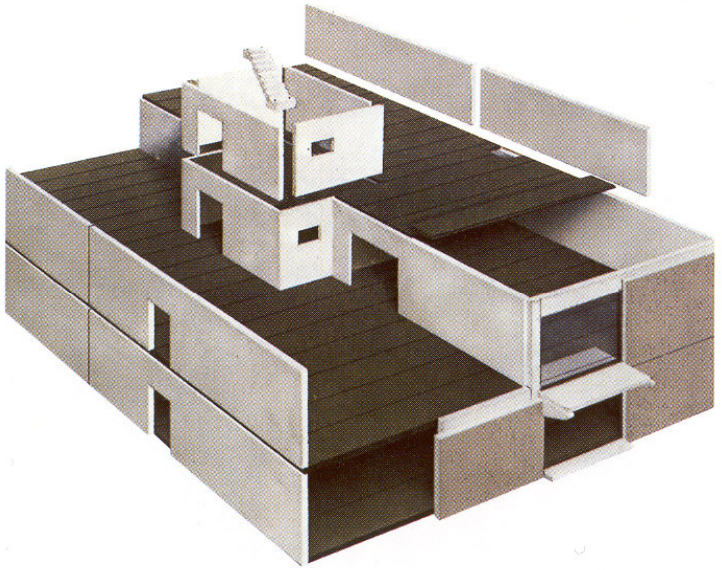
Structural design aspects

- Frame structures



- Moment resisting frame
- Gravity frame with core

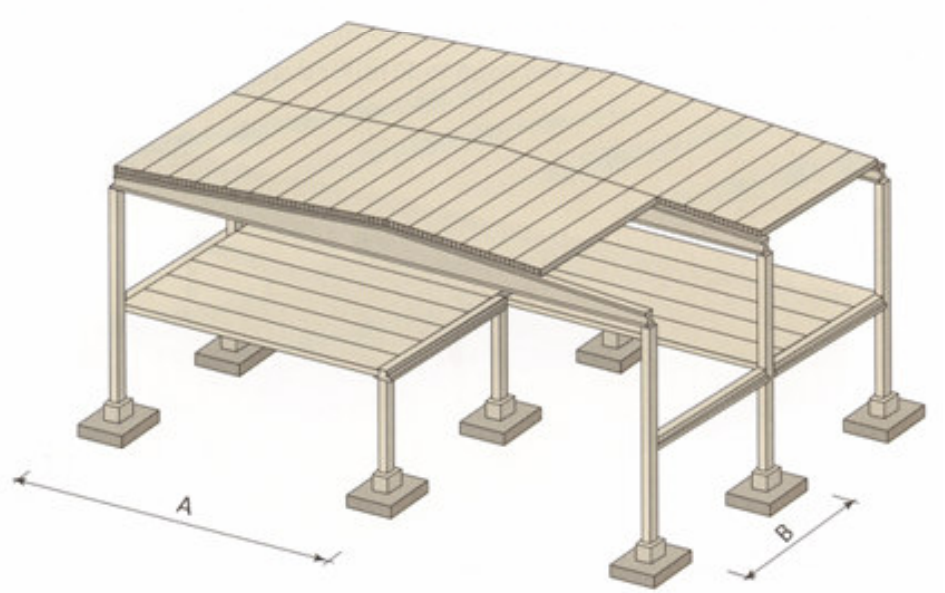
- Wall structures



- Shear walls
- Coupled shear walls

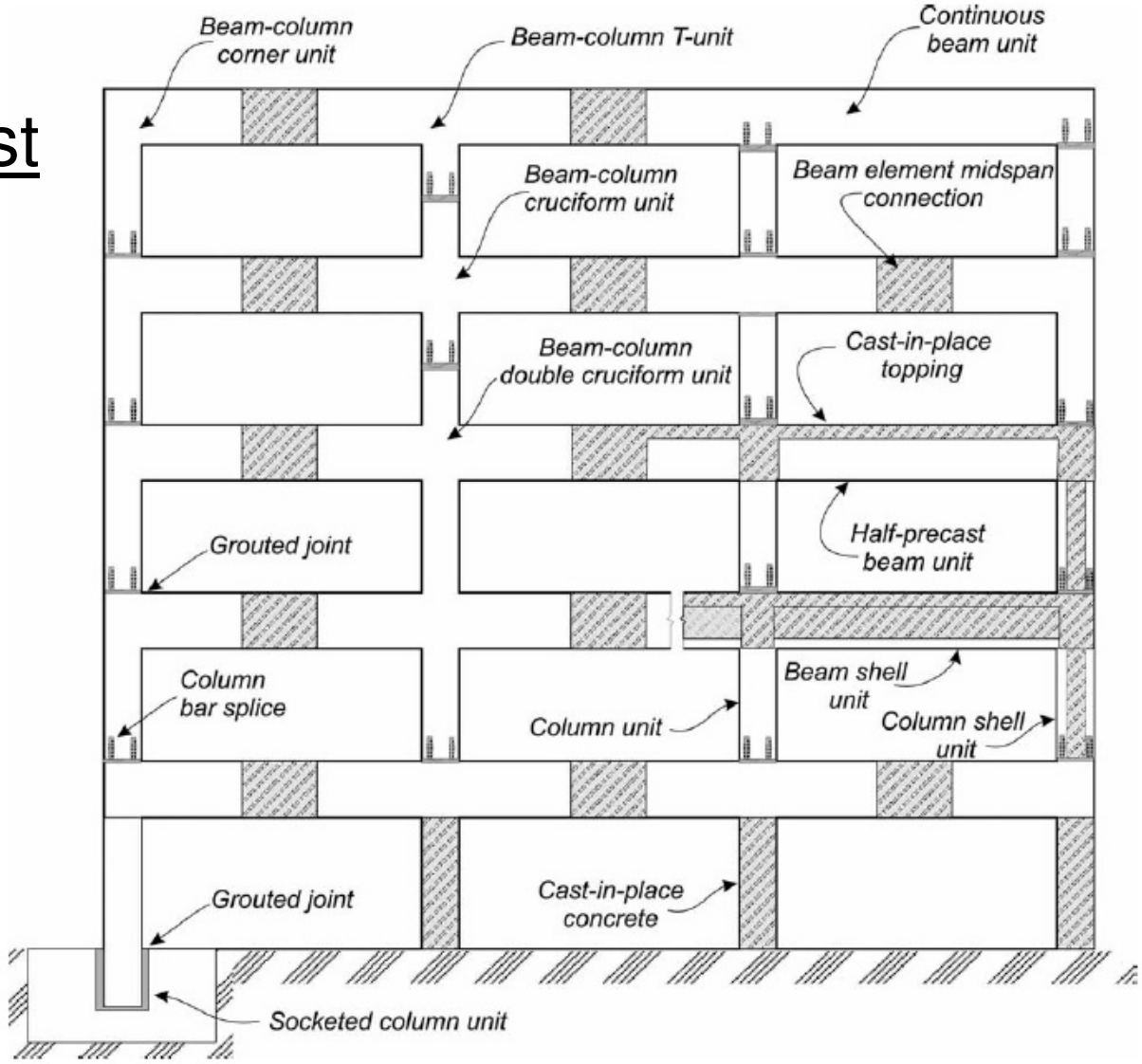
Low rise precast frame structures

Low rise frames with columns fixed in the foundation.

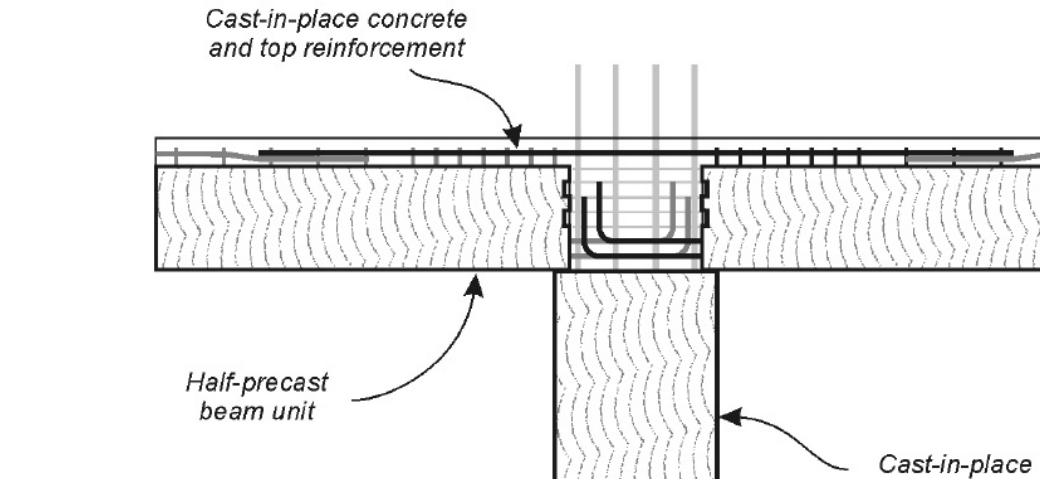


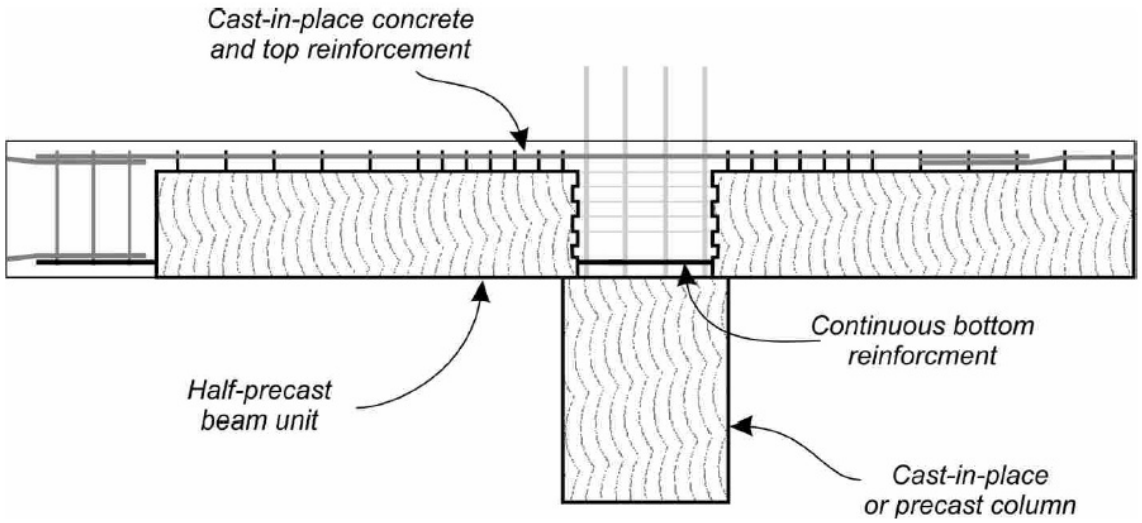
Multistoried precast frames

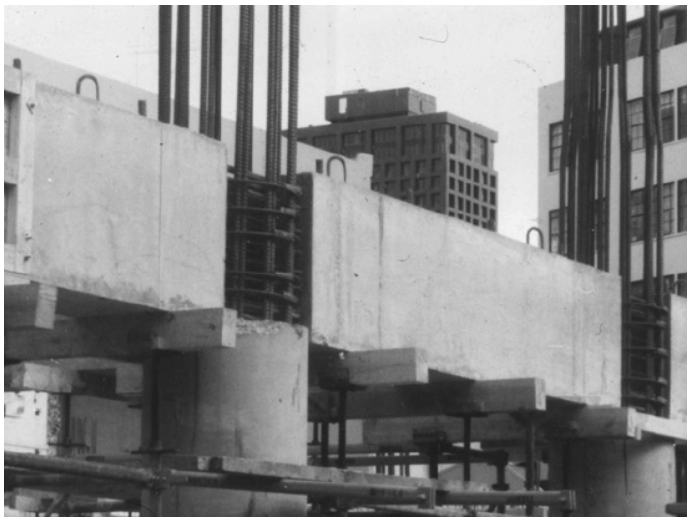
Possible arrangements of connections for precast concrete moment resisting frames in seismic zones.



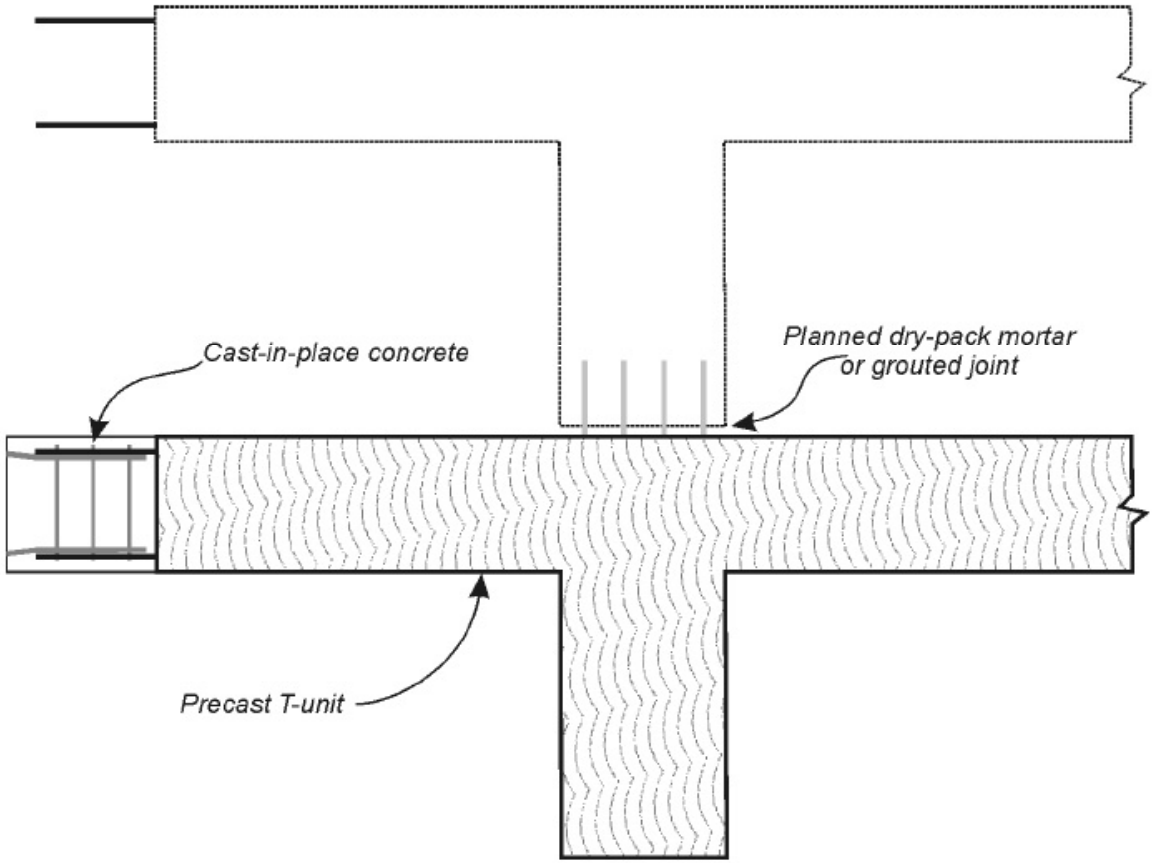
Precast beams between columns







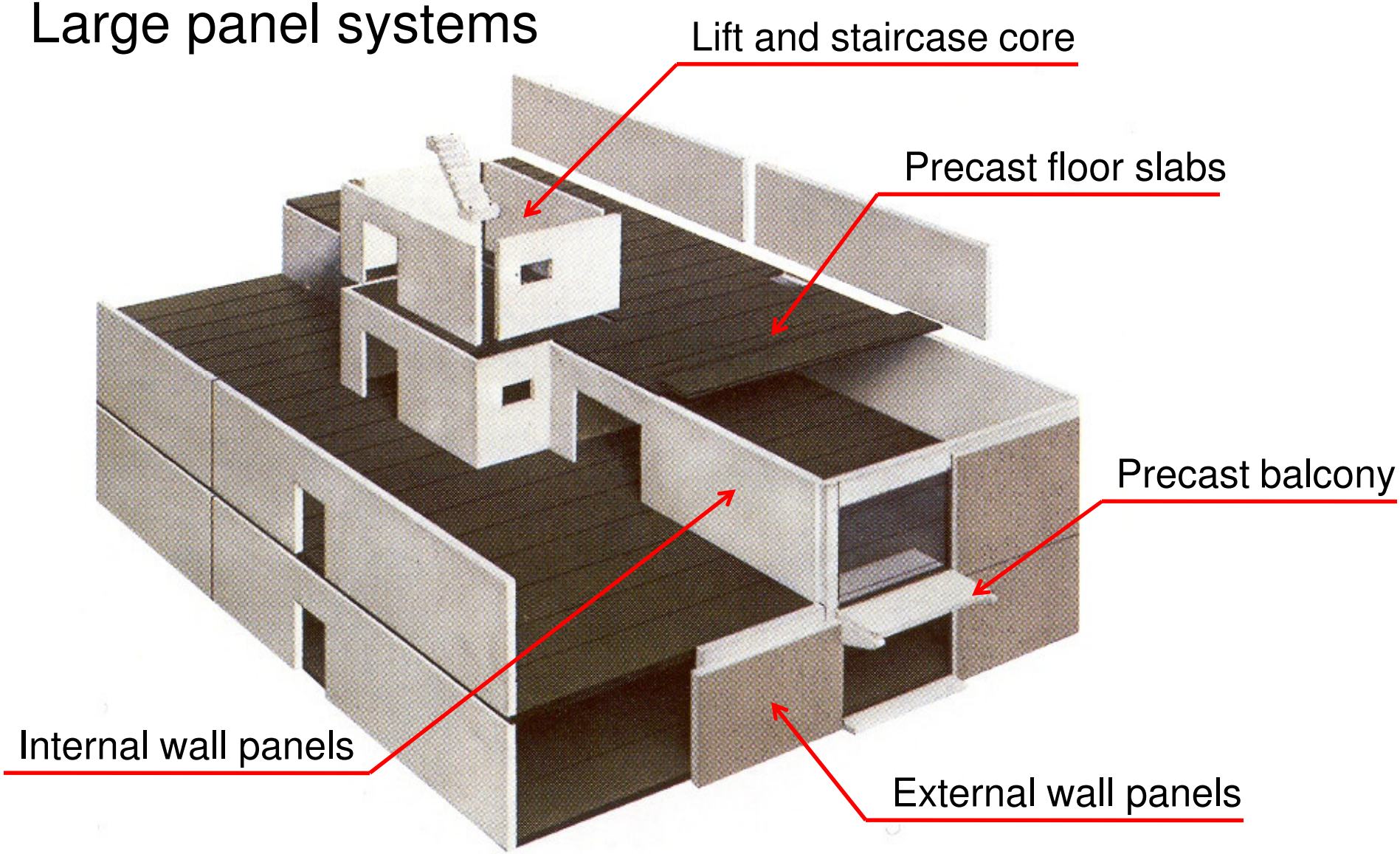
Precast T or cruciform units



Structural design aspects

Example of precast T units

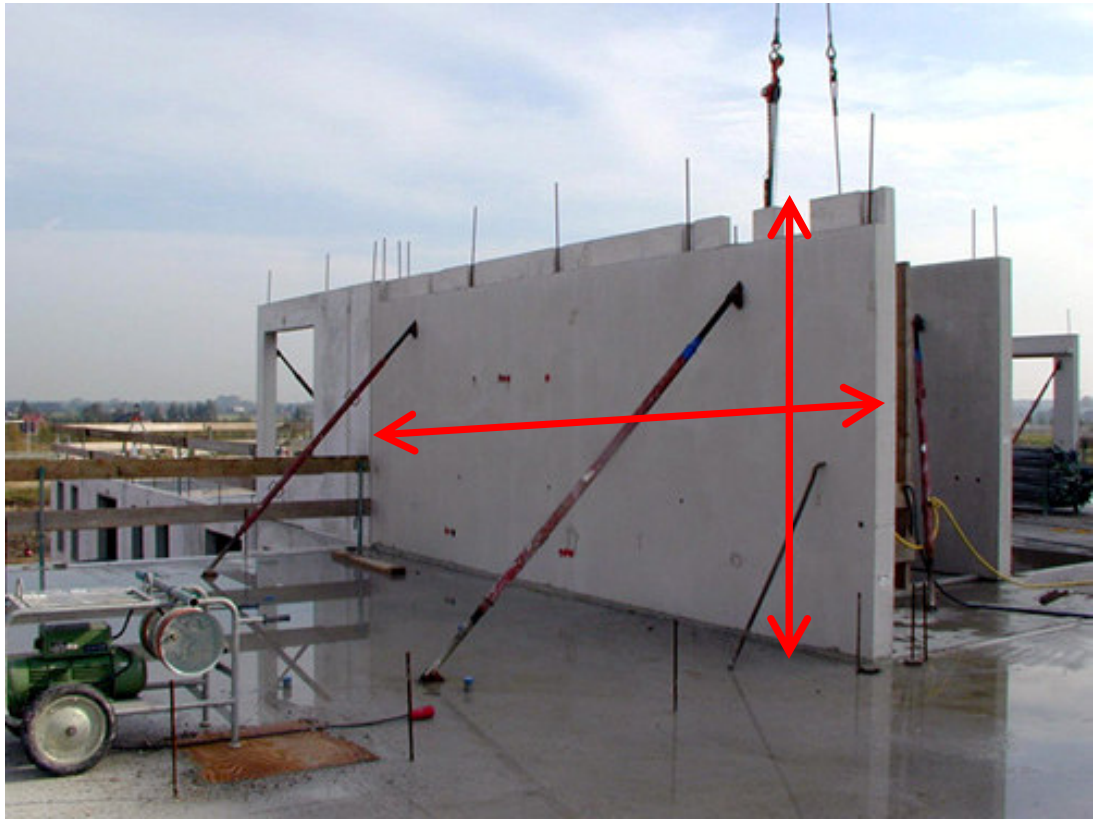
Large panel systems



Structural design aspects

Erection of wall panels

Large wall panels



Advantages precast wall structure compared to rcc frame structure:

- No brickwork infill walls required
- Precast has superior quality of finishing
- No plastering is required
- Saves time and reduces manpower
- Thin walls increase the carpet area
- Precast concrete is more durable than clay brick
- Better health and safety standards

Structural design aspects:

- Configuration of the building
- Vertical load path
- Lateral load path
- Structural connections
- Structural integrity

Configuration of the building:

- Simple and symmetrical layout is required for earthquakes
- Structures with precast shear walls are stiff which results in less damage during heavy earthquakes.
- Avoid soft stories.
- Avoid torsion.

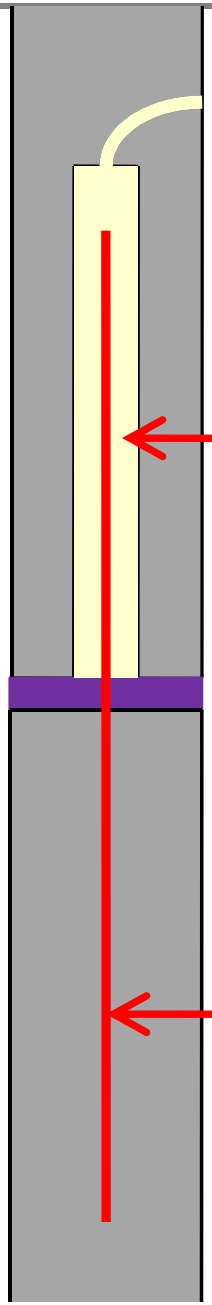
Vertical load path:

- Achieve proper transfer of vertical loads.
- Grouted joints.
- Corrugated steel sleeves filled with grout.
- Welded and bolted connections

Structural design aspects

Vertical load path:

Wall to wall connection with grouting

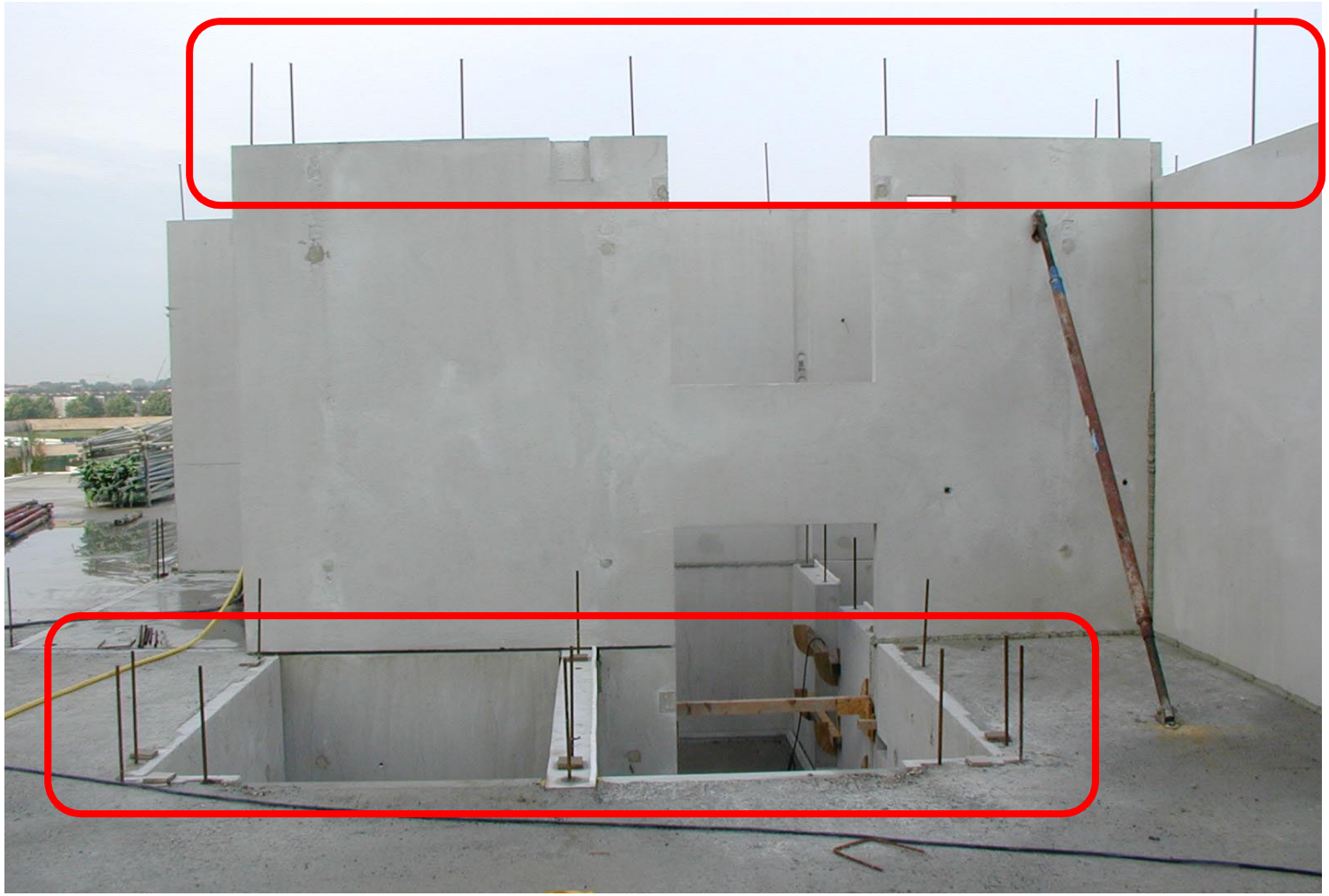


Corrugated steel sleeve filled with grout.

High strength non-shrink grout

Reinforcement bar

Dowel bars in wall panels:

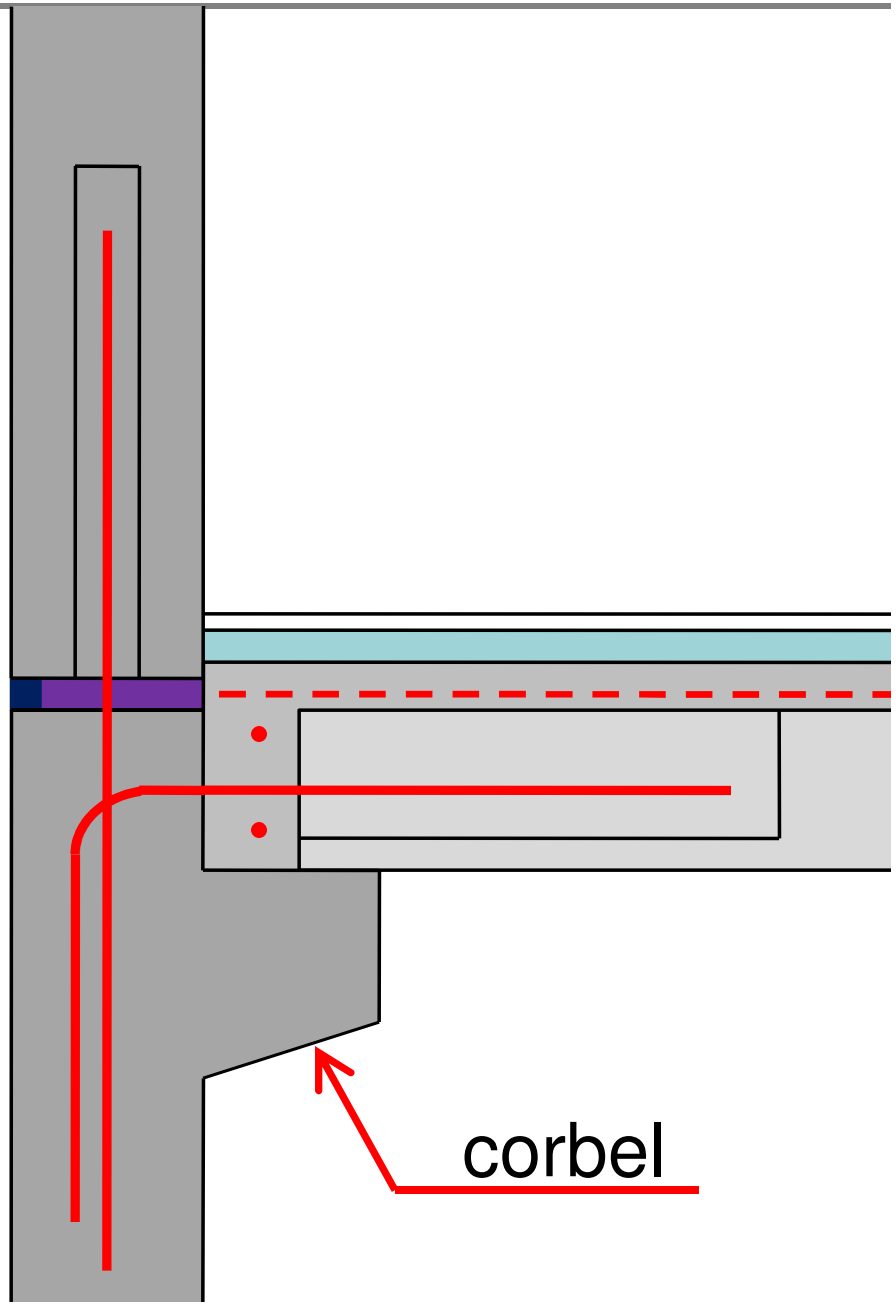


Vertical load path:

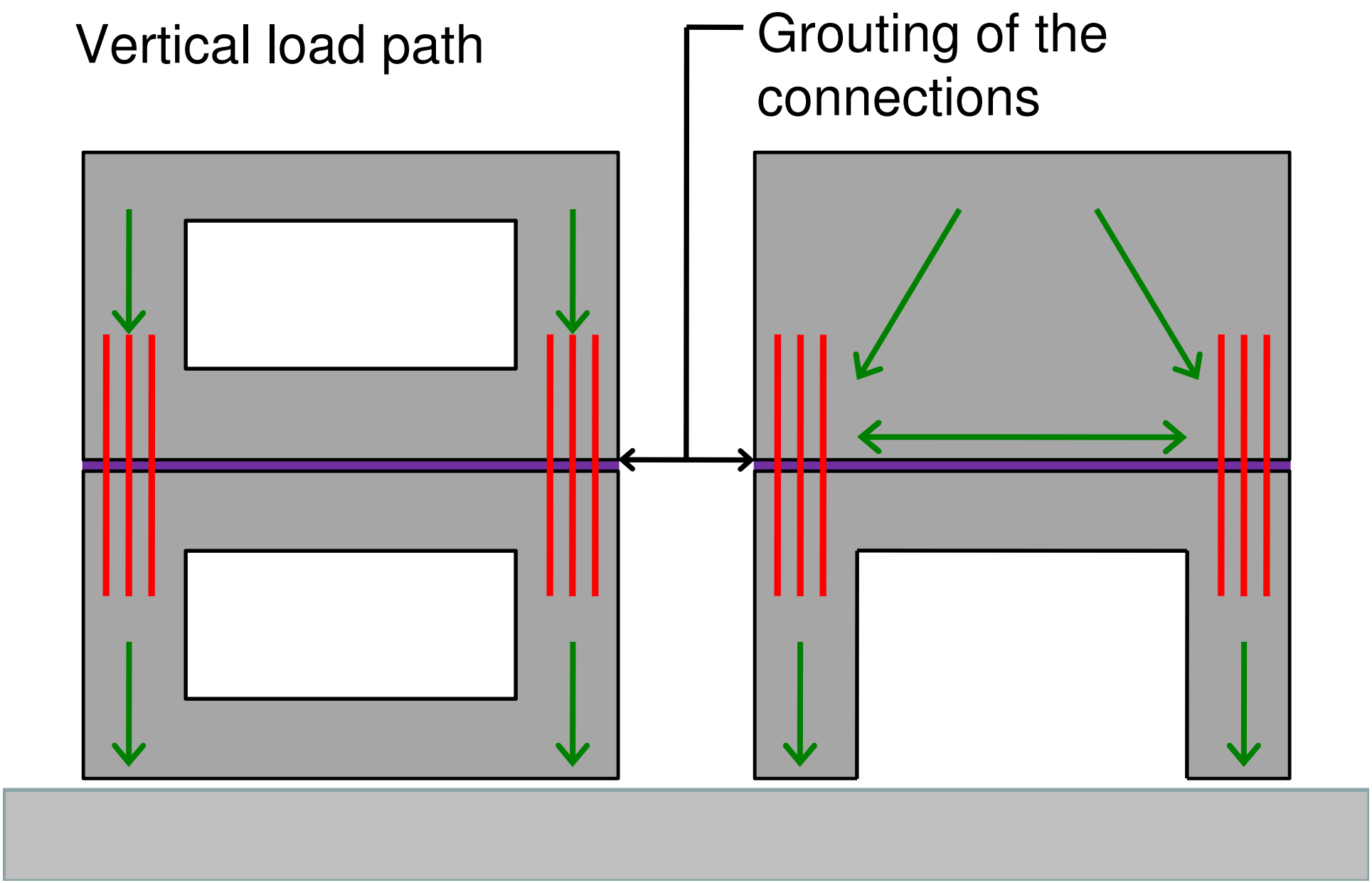
No disturbance in vertical load path. Direct load transfer between walls.

Enough bearing length for floor slab.

Enough space for tie reinforcement and wall to floor connection.



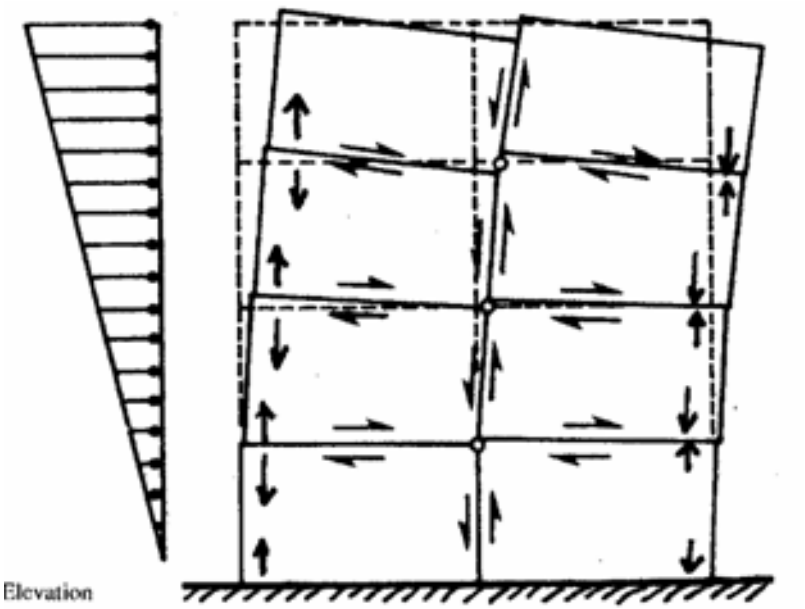
Structural design aspects



Lateral load path:

- Wind loads and Earthquake loads
- Shear walls required in two directions
- Floor diaphragm action
- Structural integrity

Structural design aspects



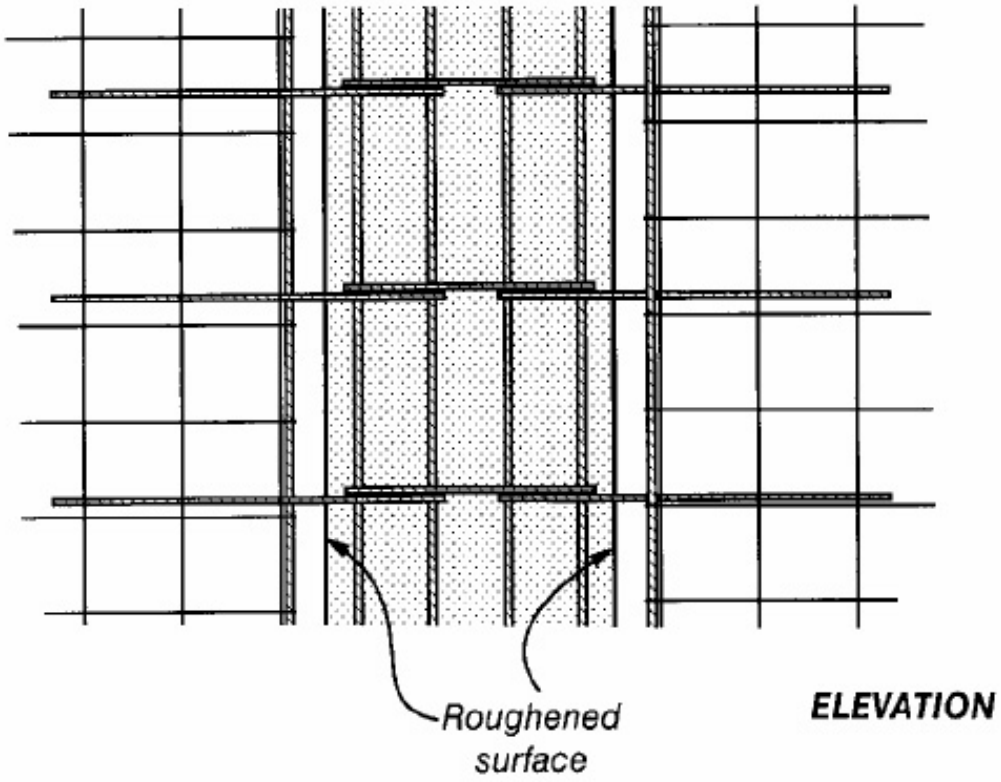
Shear walls structure:

Shear walls are cantilevered from the foundation.

Bottom walls are will develop yielding areas during heavy earthquake.

In the yielding areas ductile reinforcement detailing is required.

Structural design aspects



Monolithic wall to wall connection:

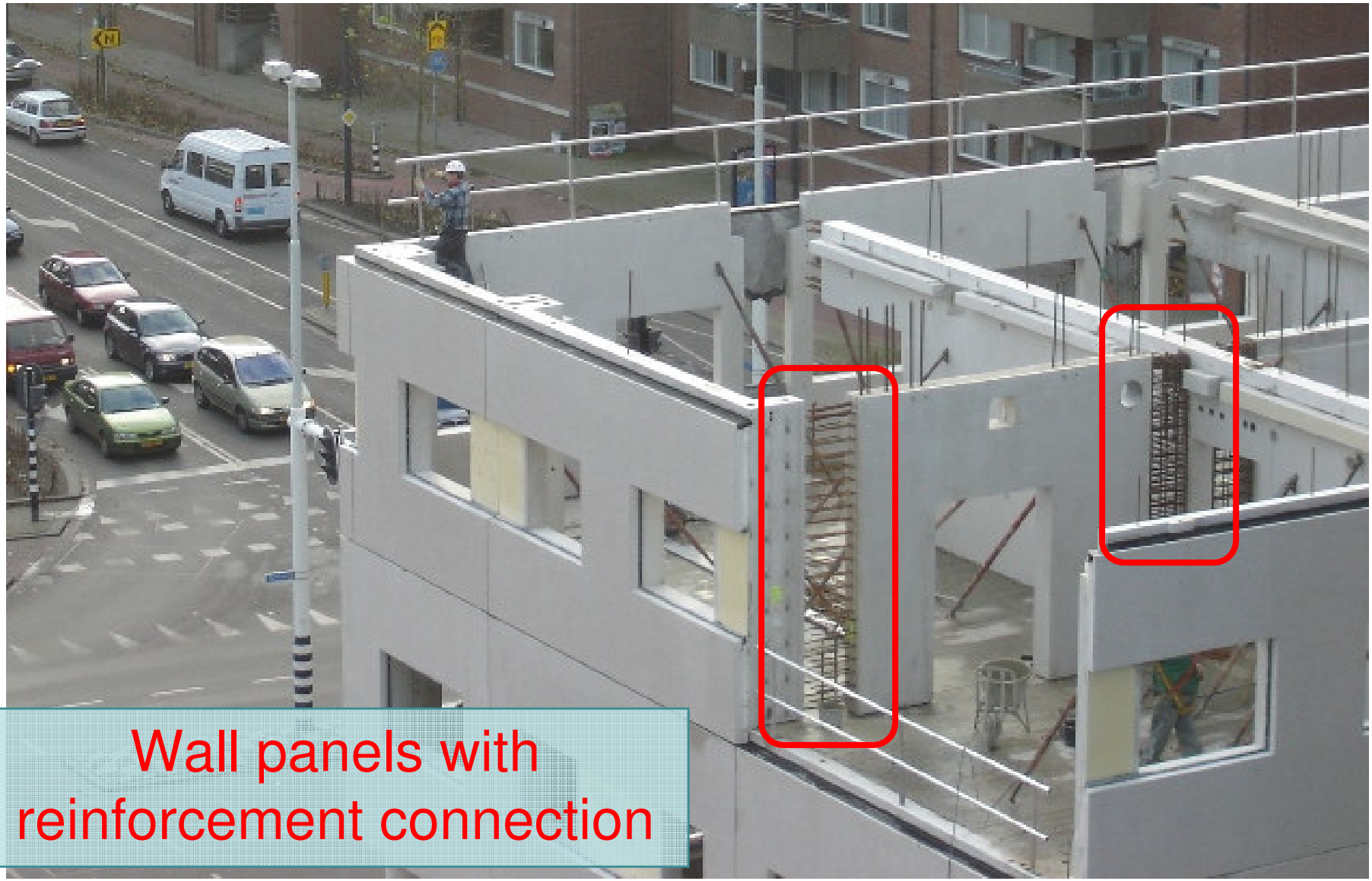
Only use at critical locations

Preferred for inner wall panels because of finishing

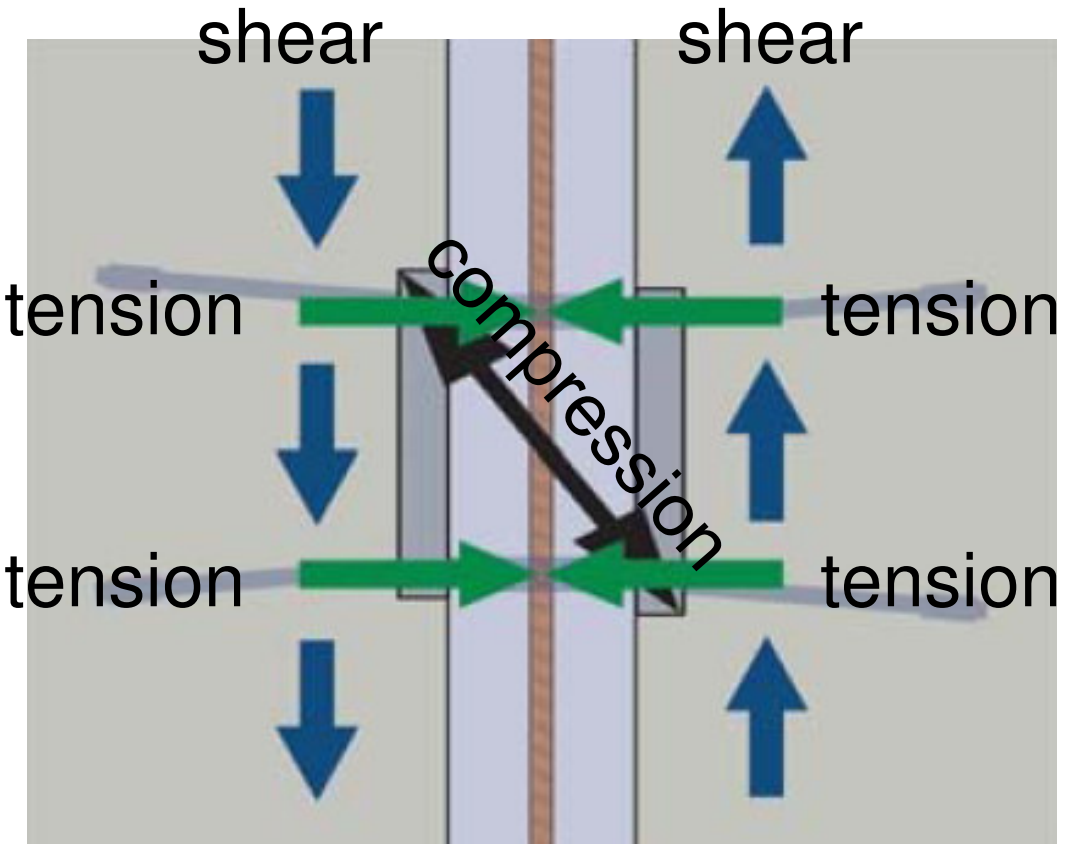
Structural design aspects

Wall panels with reinforcement connection

Structural design aspects

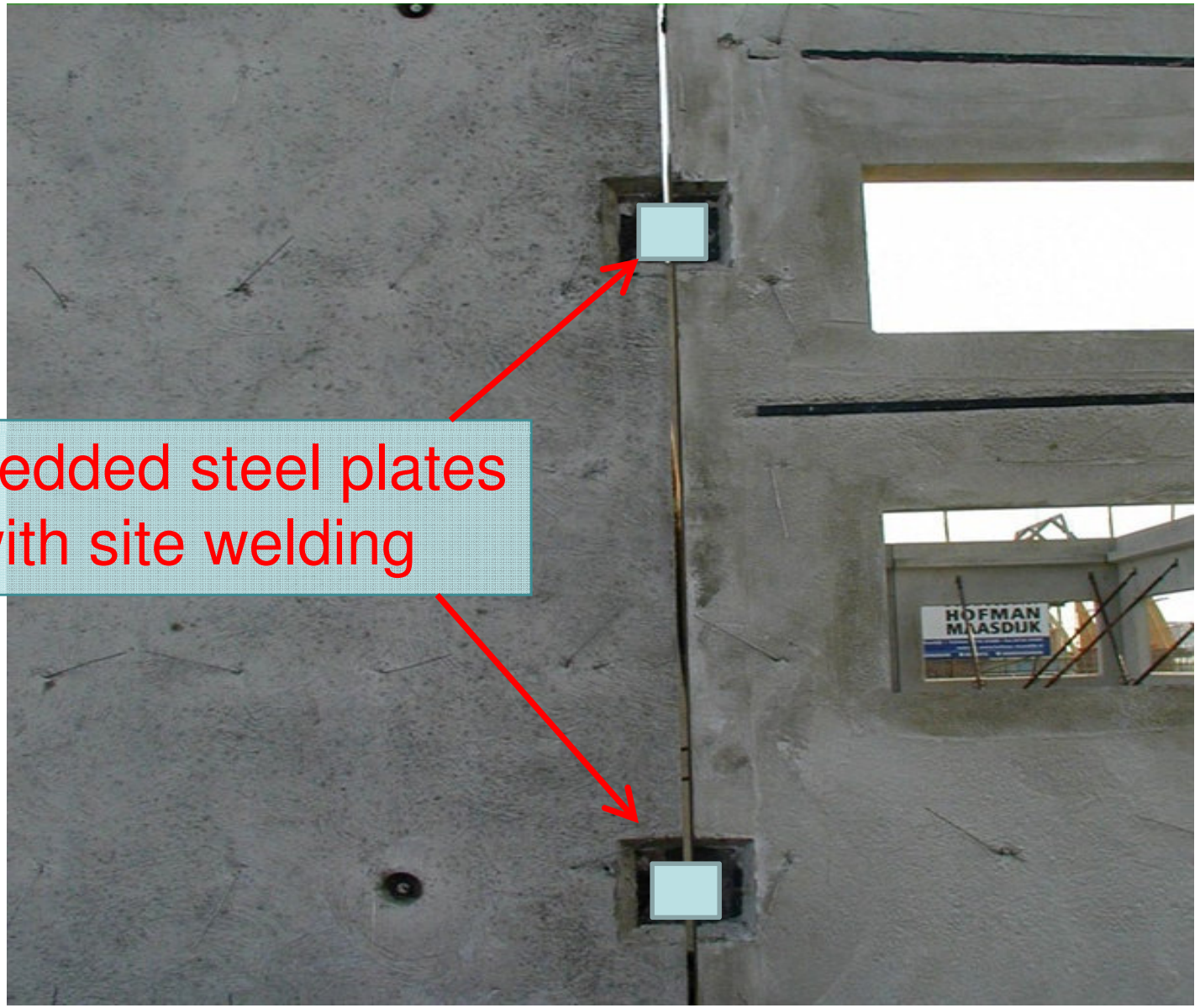


Double wire loop connection

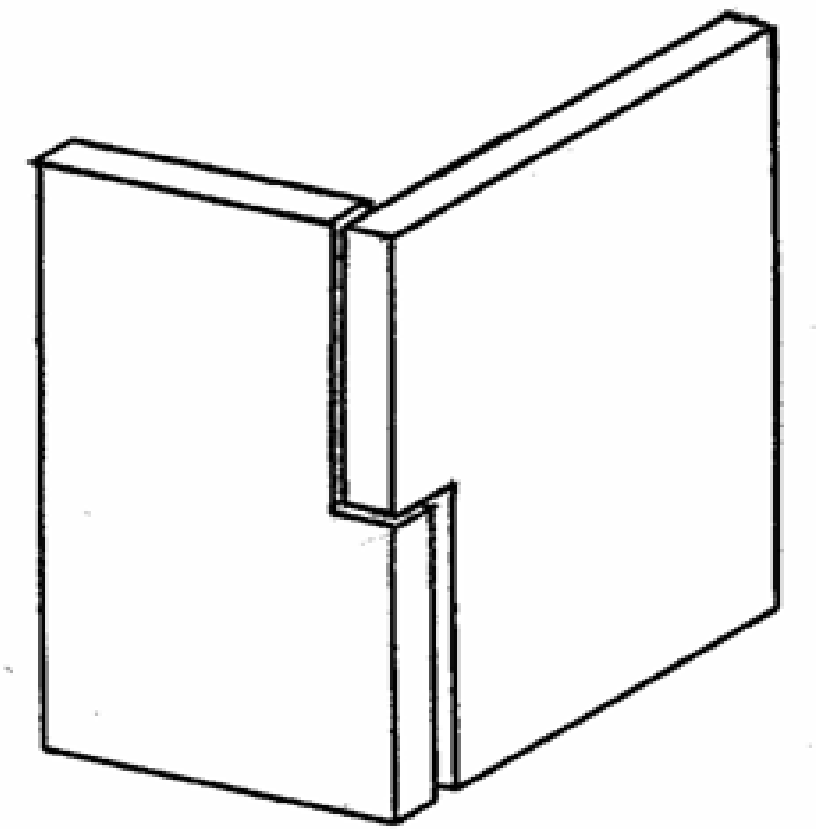


Connection can take load in both directions

Structural design aspects



Overlapping corner wall connections:



Simple connection

Suitable for inner walls

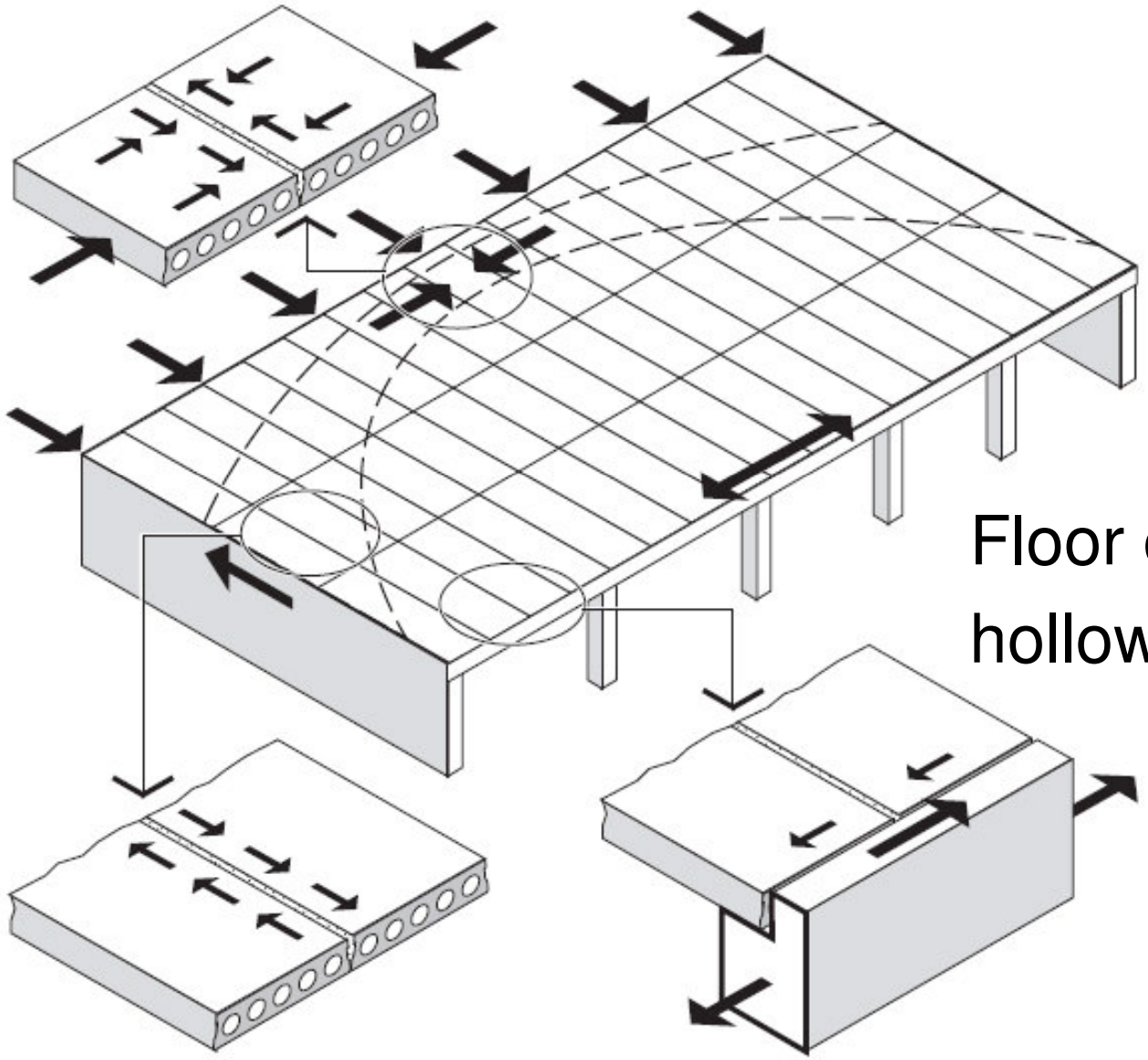
Not suitable for outer walls because of exposed joints

Ongoing research about structural behavior.

Floor diaphragm:

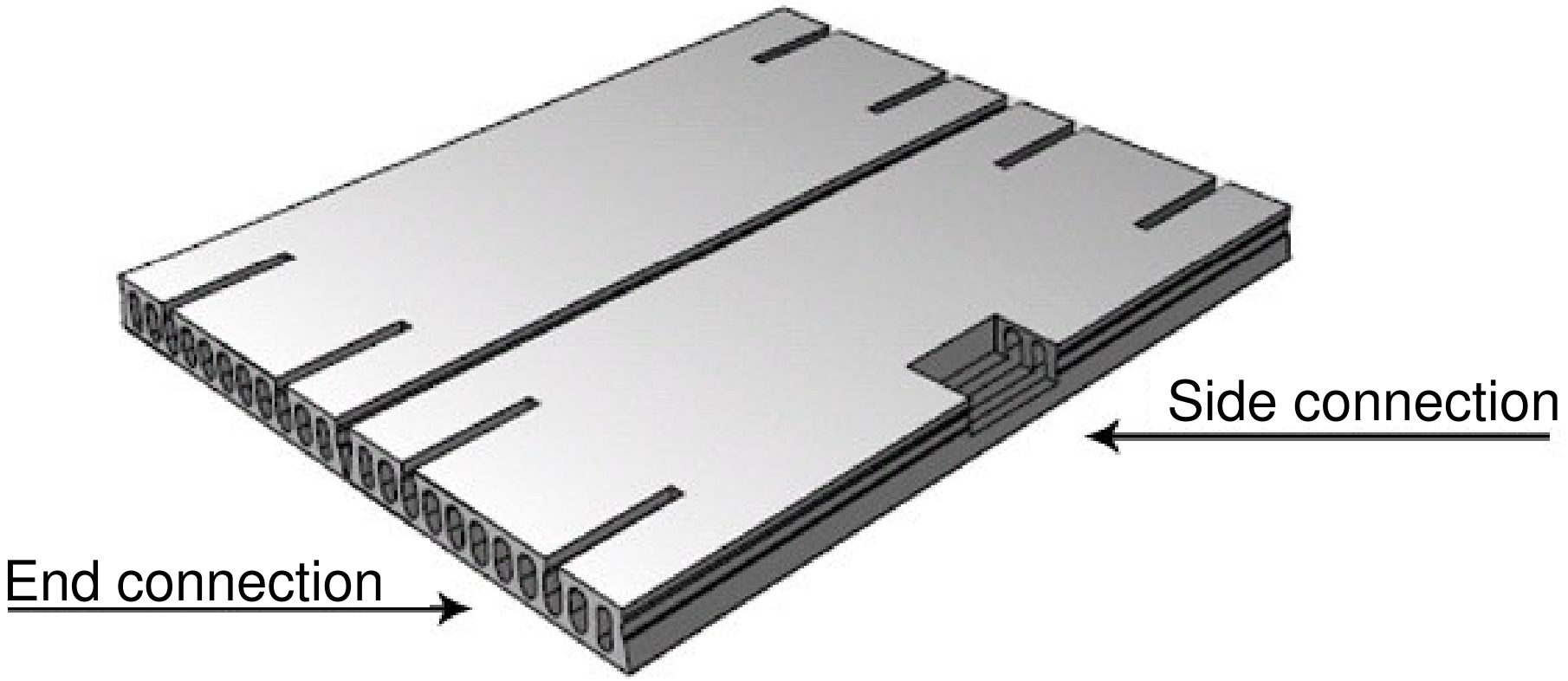
- Adequate connections to transfer diaphragm forces and adequate support of the pc floor units are the basic requirements.
- Tying the individual floor slabs.
- Tie reinforcement at the edges.
- Connection of floor diaphragm to shear walls.

Structural design aspects

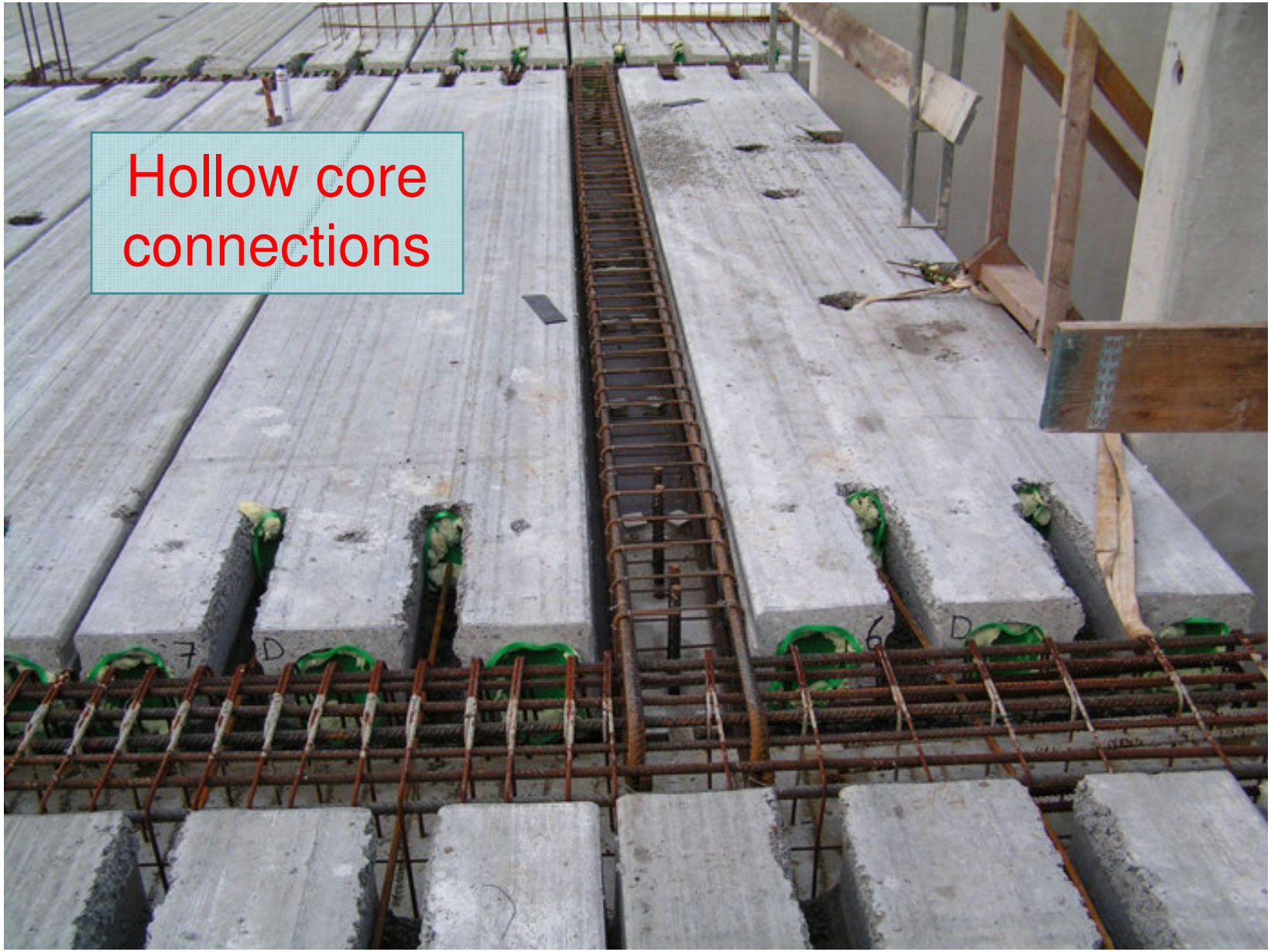


Floor diaphragm
hollow core slabs

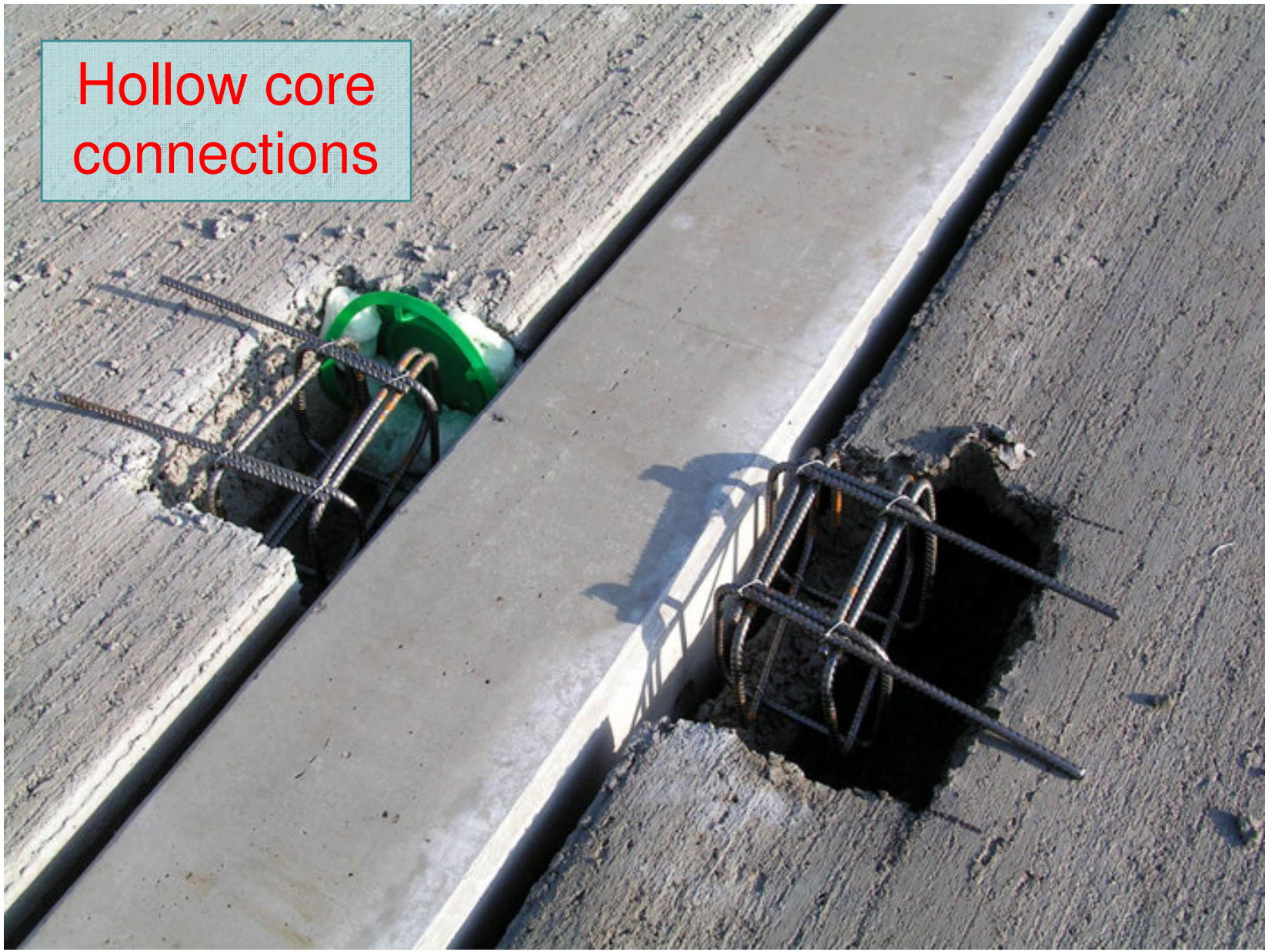
Connections to achieve diaphragm action



Structural design aspects

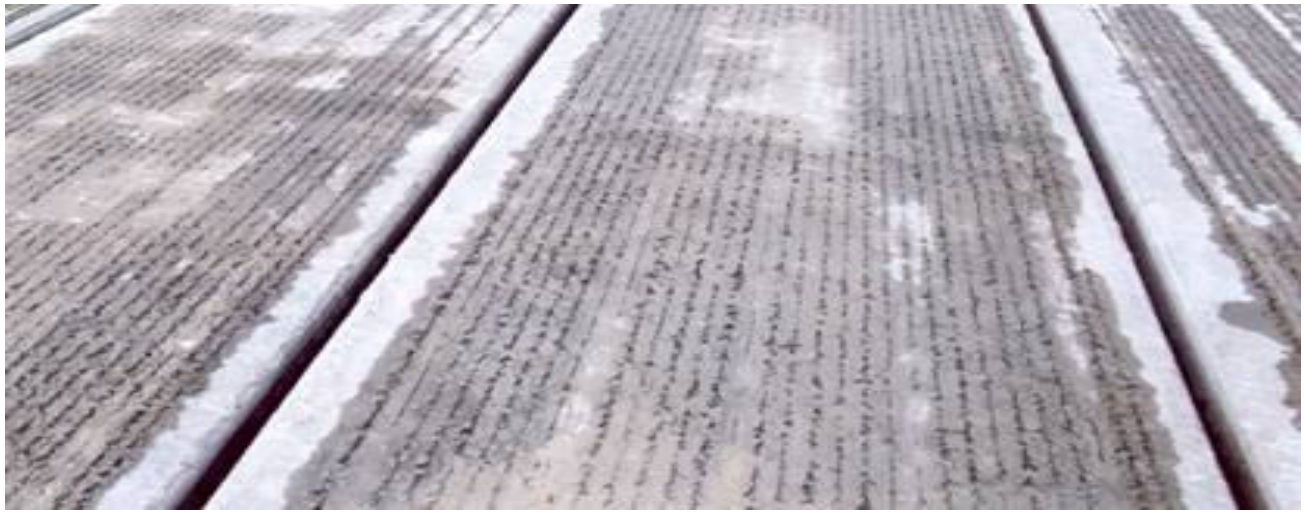


Structural design aspects



RCC topping on hollow core slabs:

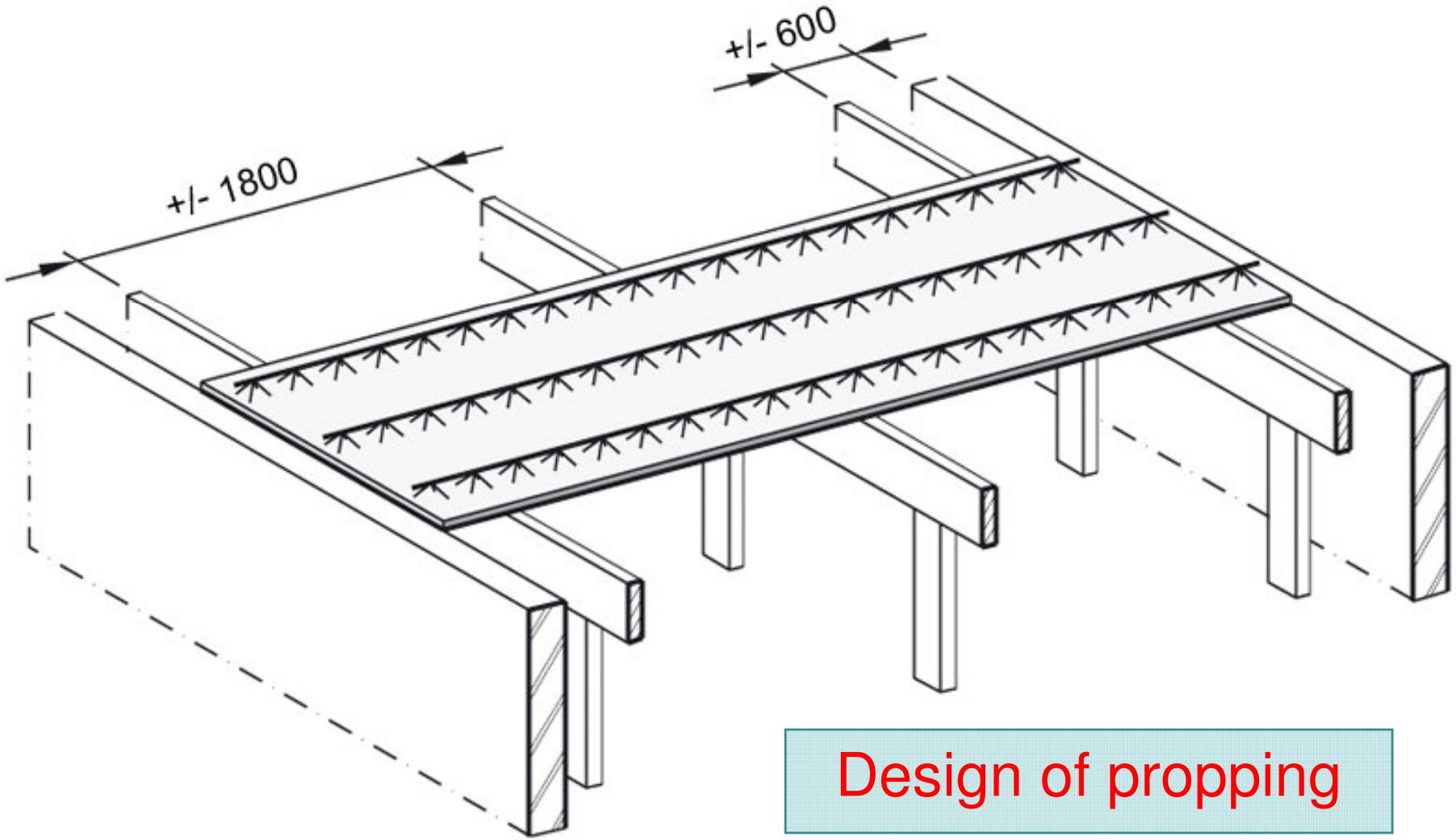
- Tying the individual members.
- Improve the waterproofing.
- Minimum 60mm thick
- Rough top surface of hollow core required



Structural design aspects

Precast plank floor with lattice girder and rcc topping

Precast plank floor with lattice girder and rcc topping



Design of propping

Precast plank floor with lattice girder and rcc topping

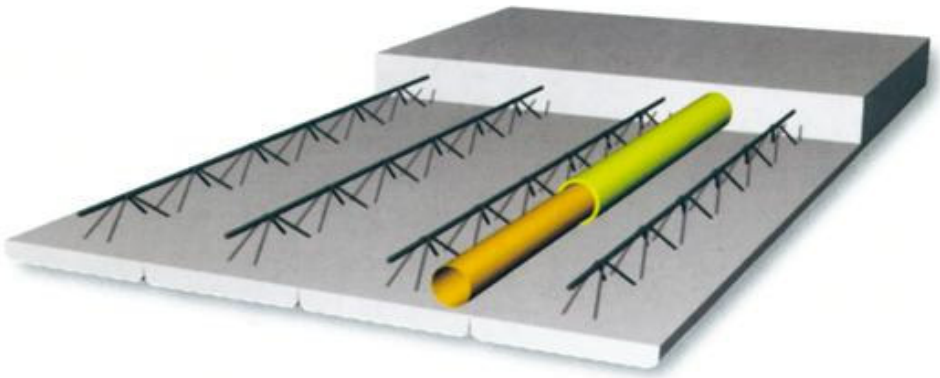
MEP Services

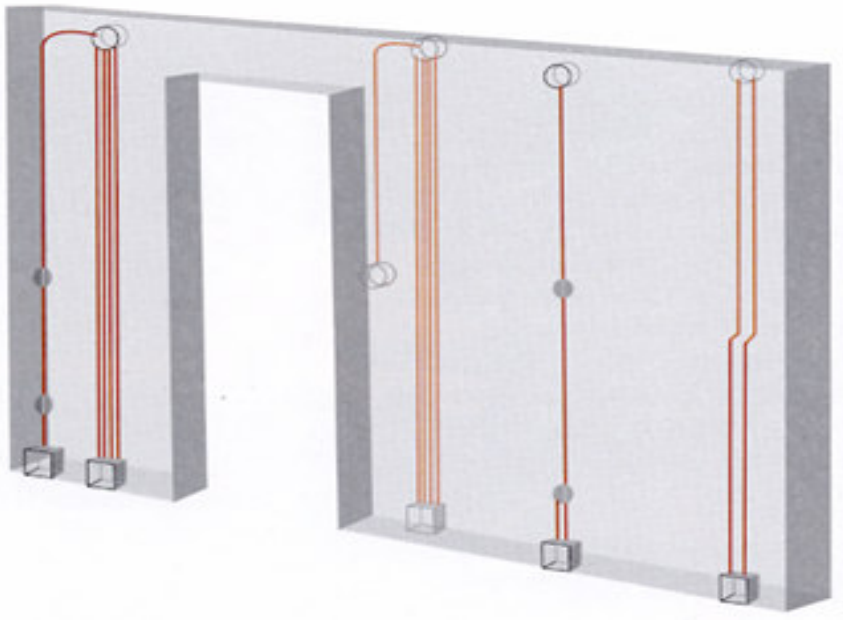
Some important points:

- Services consultant and vendors have to be part of the design team.
- Integration of services in the precast elements.
- Coordination between the various consultants is very important.

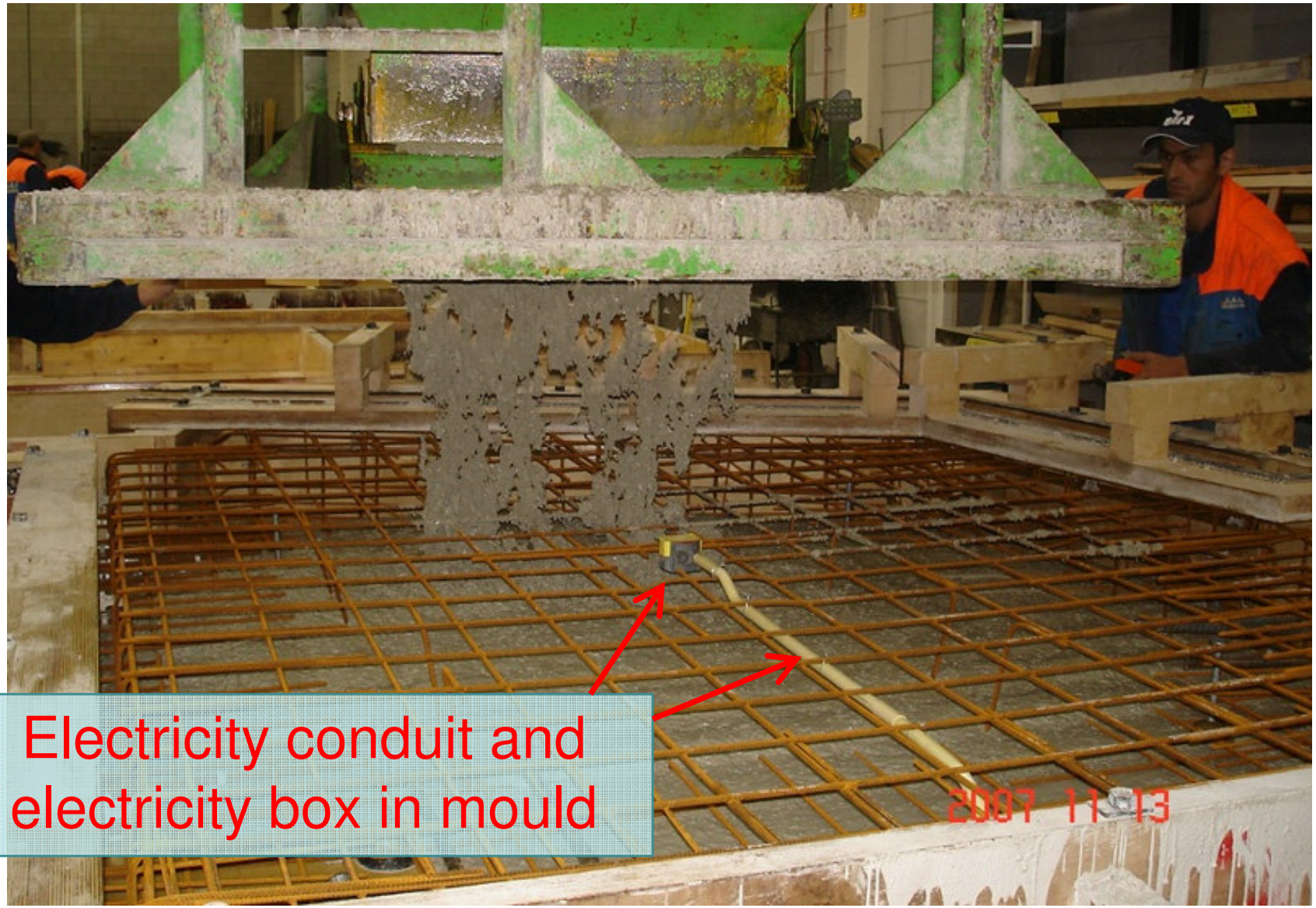
Electrical wiring:

- Conduits inside RCC topping on slabs.
- Conduits inside precast wall panels

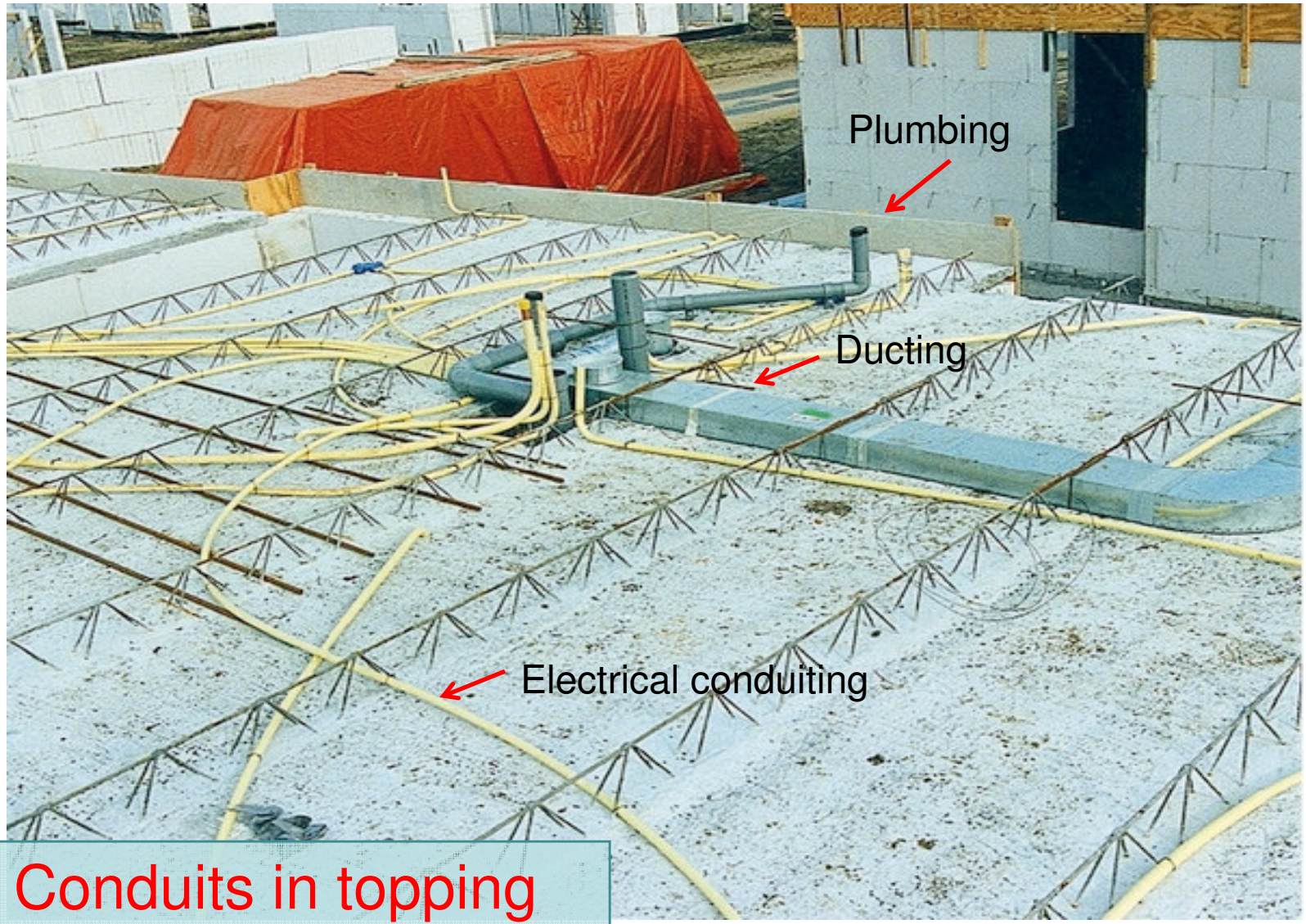




MEP services



MEP services



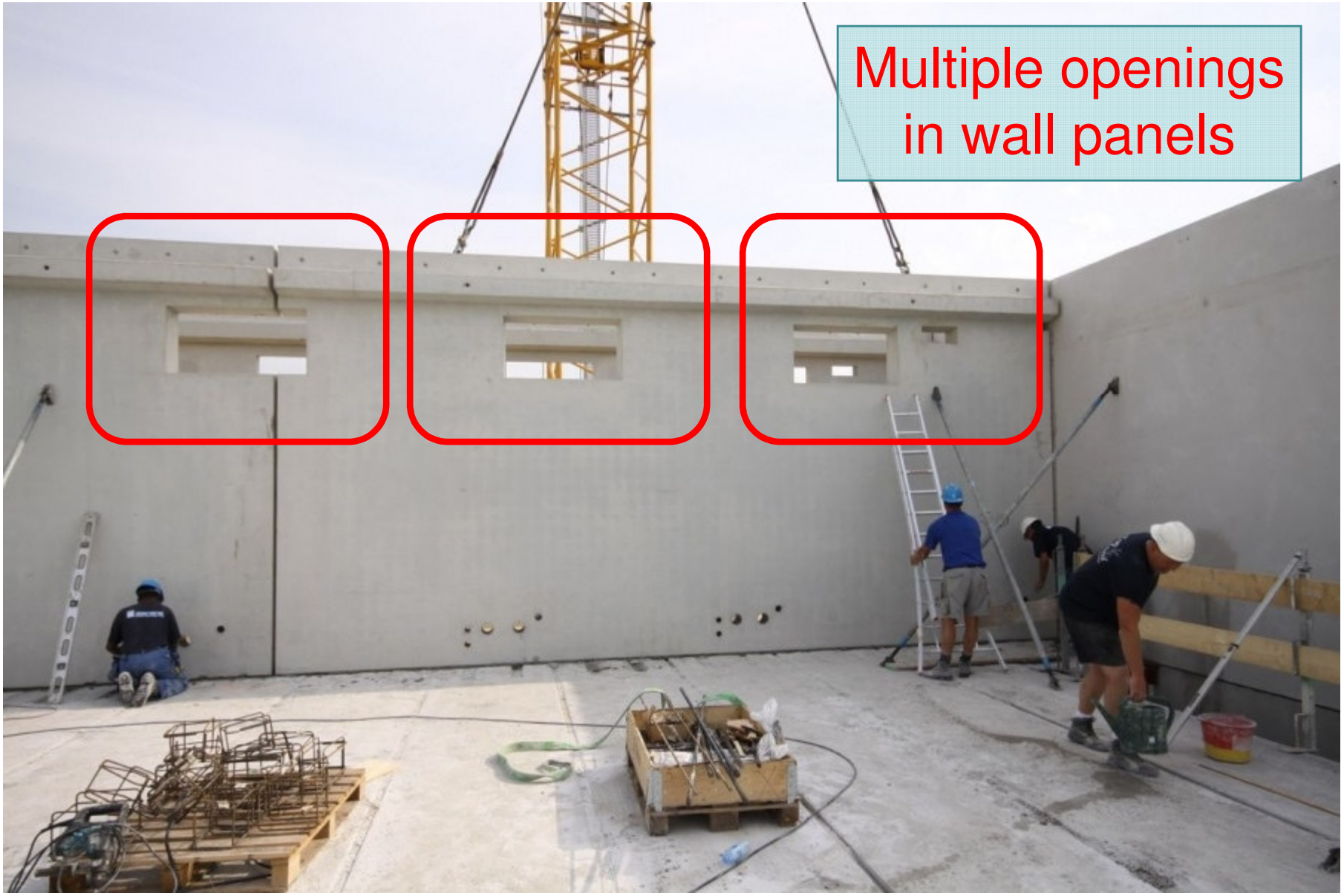
Conduits in topping

Provisions for air-conditioning

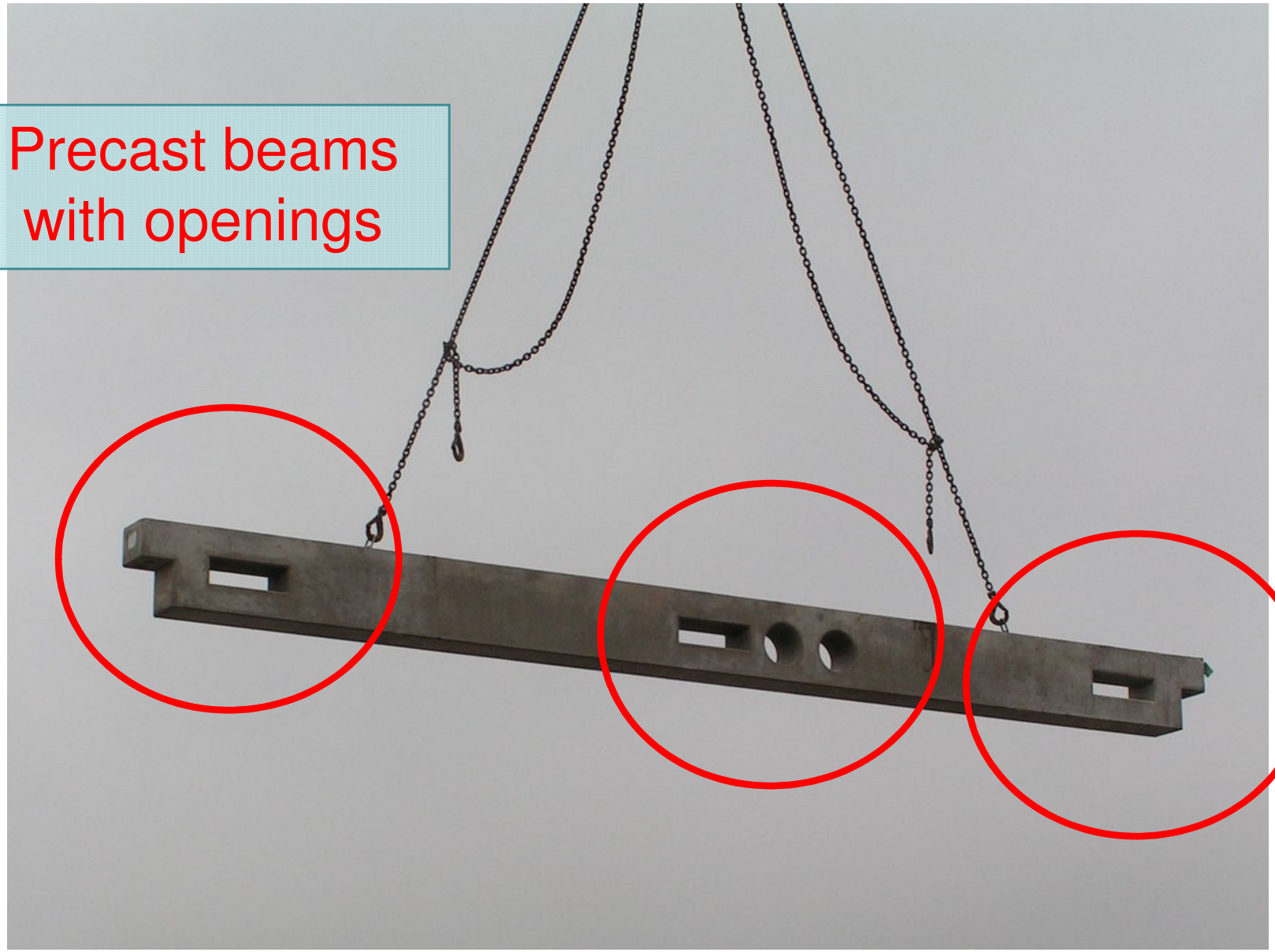
- Location of shafts
- Openings in walls and beams
- Hanging support for ac system

Shaft opening

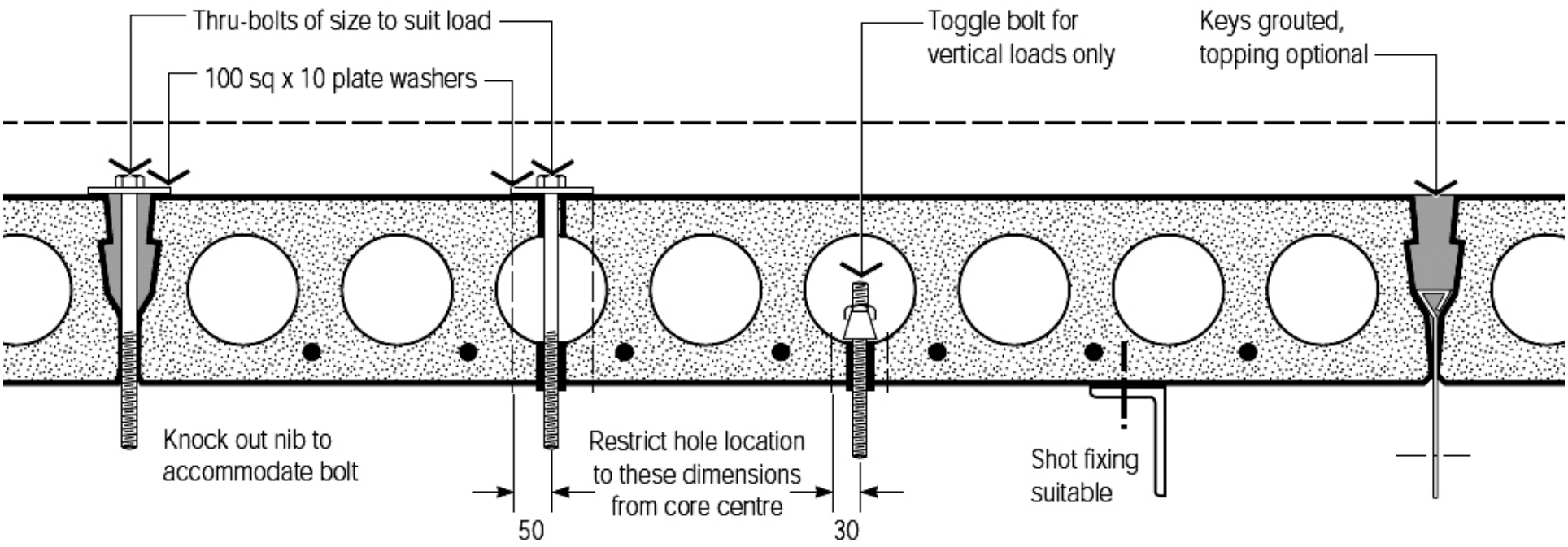
MEP services



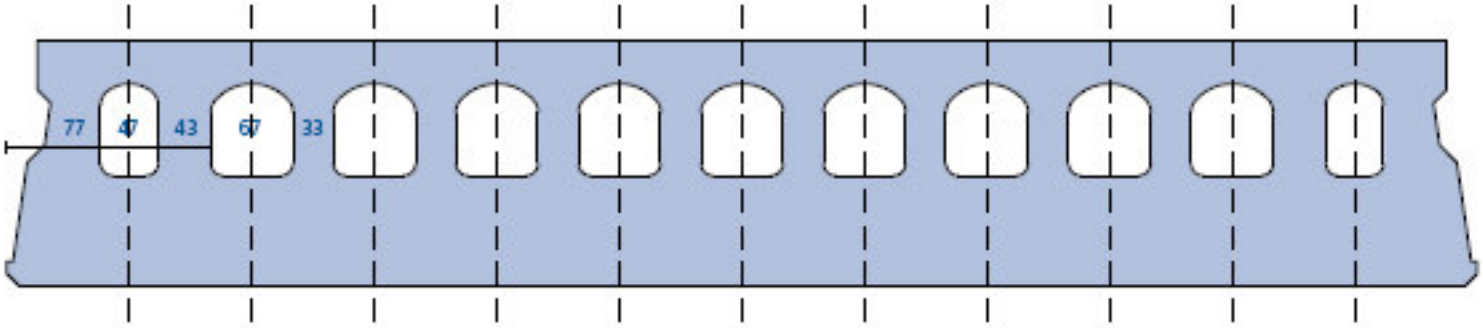
MEP services

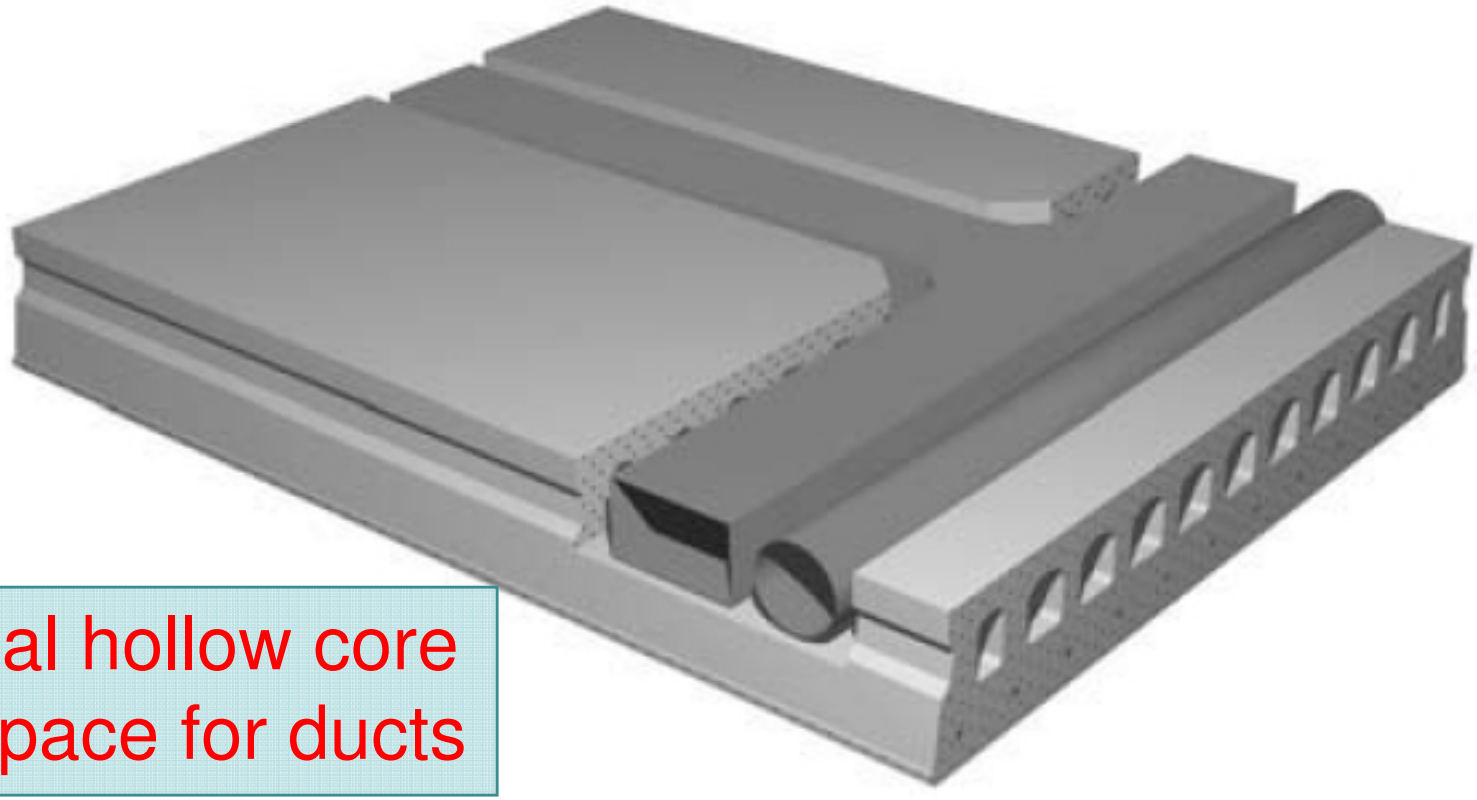


Typical hangers for hollow core slabs



MEP services



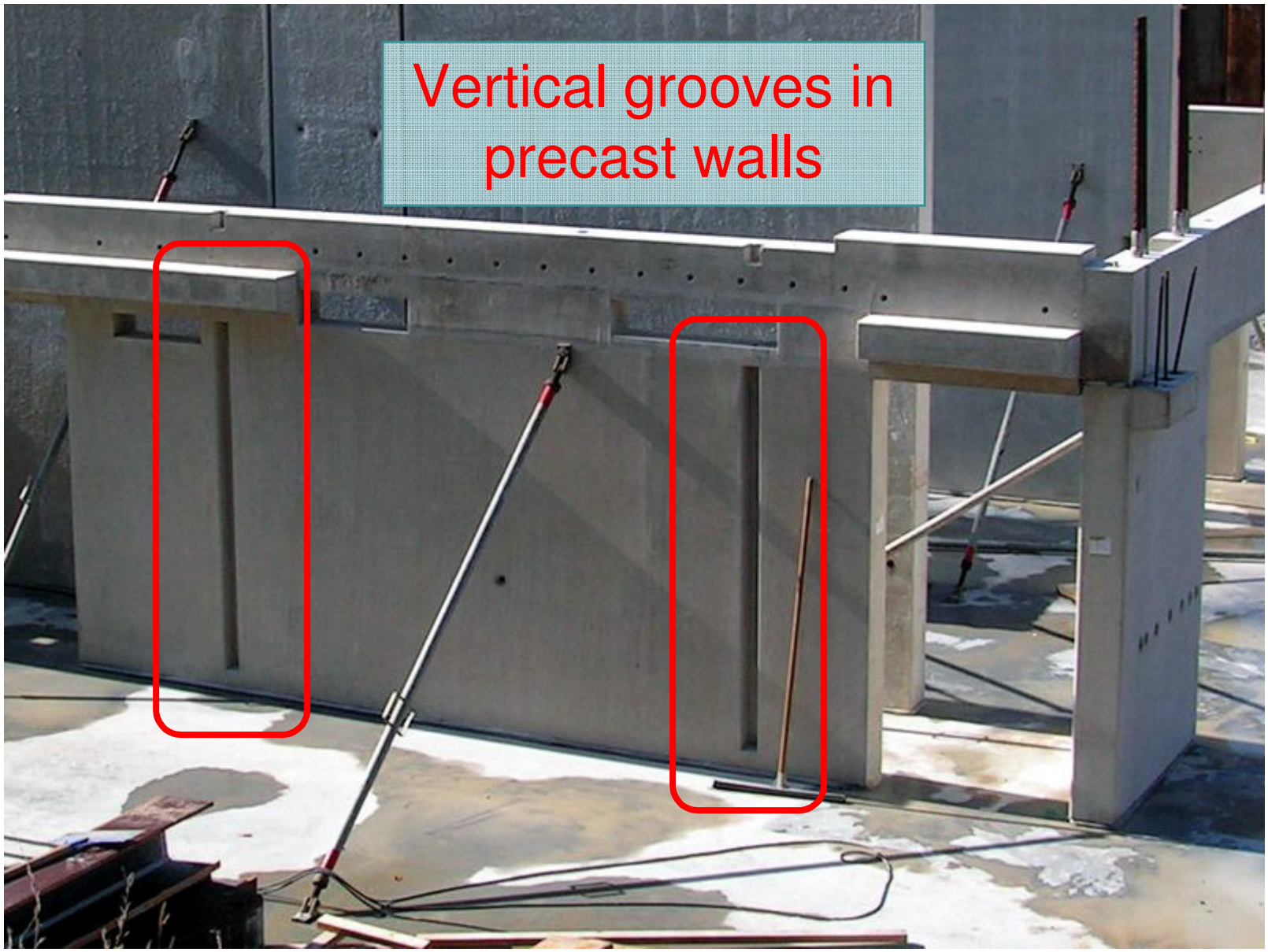


Special hollow core with space for ducts

Plumbing

- Exposed plumbing
- Plumbing in recess in walls
- Ledge wall
- Plumbing inside topping

MEP services



MEP services

Manufacturing aspects

Different precast plants:

- Site plant (casting yard)
- Permanent plant

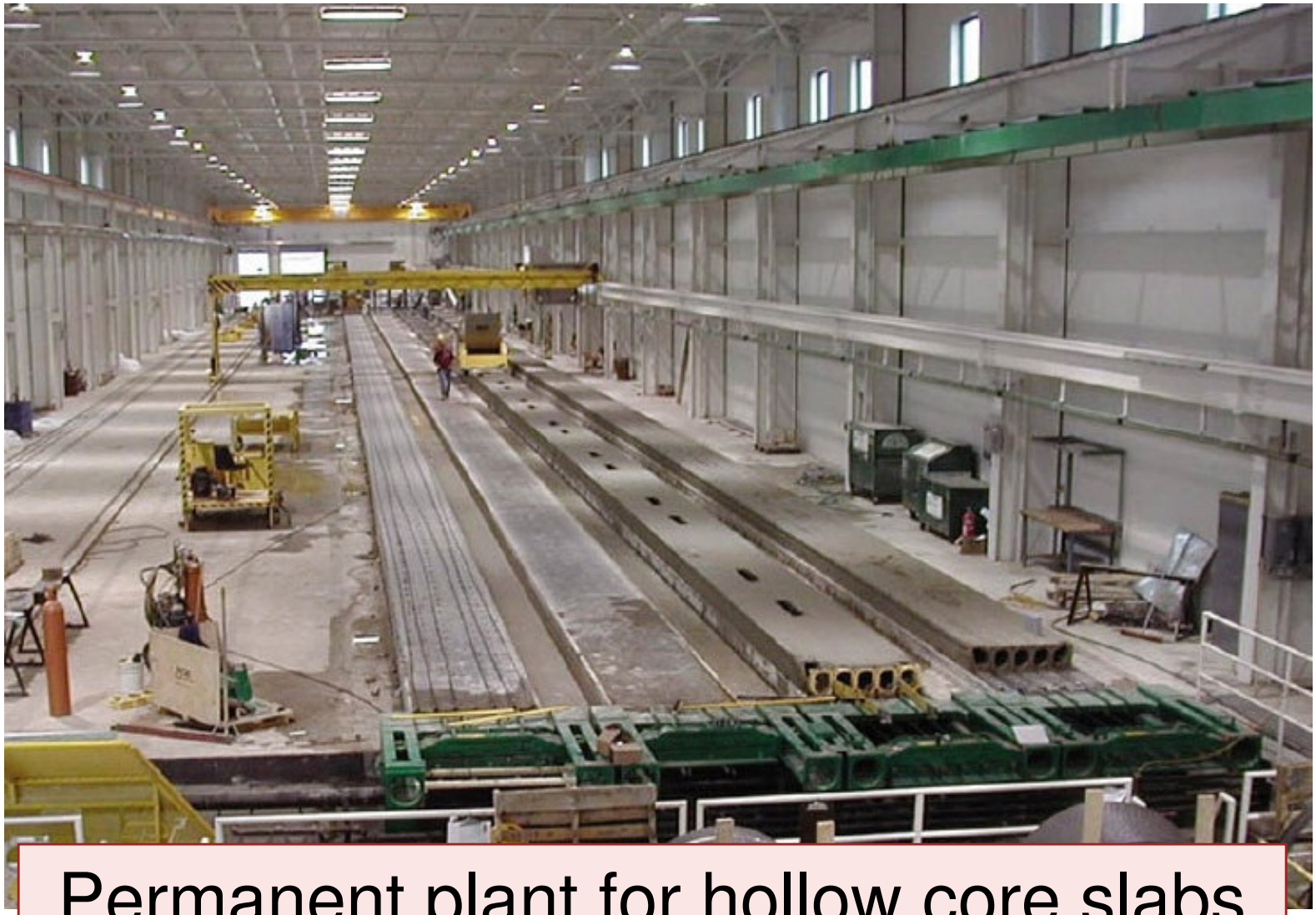
Different precast elements:

- Ordinary reinforced concrete elements
- Prestressed concrete elements

Manufacturing aspects

Site plant

Manufacturing aspects



Permanent plant for hollow core slabs

Manufacturing aspects

The design team has to understand the capabilities of the manufacturing unit.

Type of precast factories:

- Conventional precast factory.
- Semi Automated precast factory.
- Fully Automated precast factory.
- Hollow core slab manufacturing process
- Precast plank floor manufacturing process

Generally precast members are made as flat 2D elements.

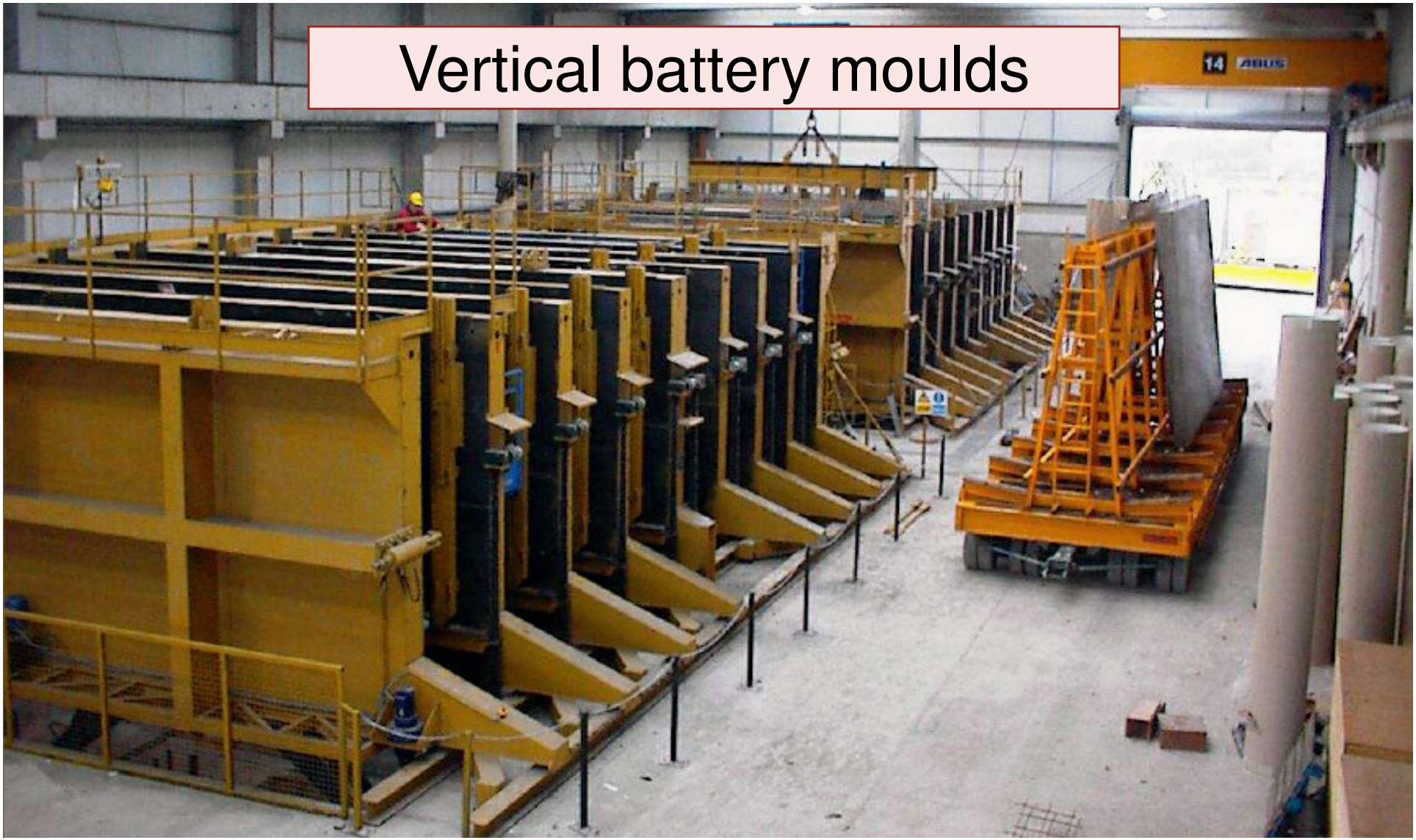
Vertical moulds:

- Battery mould
- Column mould

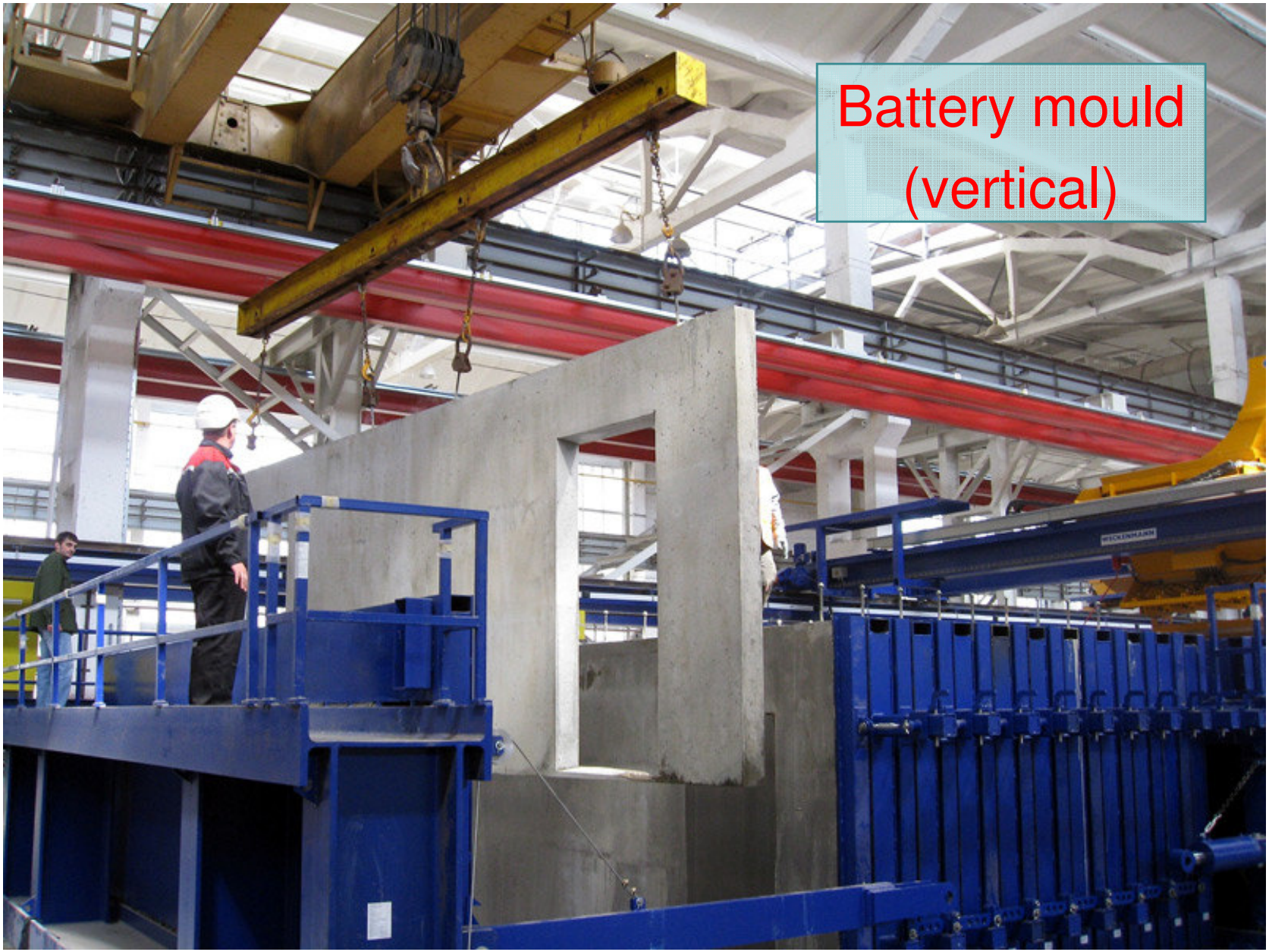
Flat moulds:

- Stationary flat moulds
- Circulating pallet system
- Tilting tables
- Prestressing beds

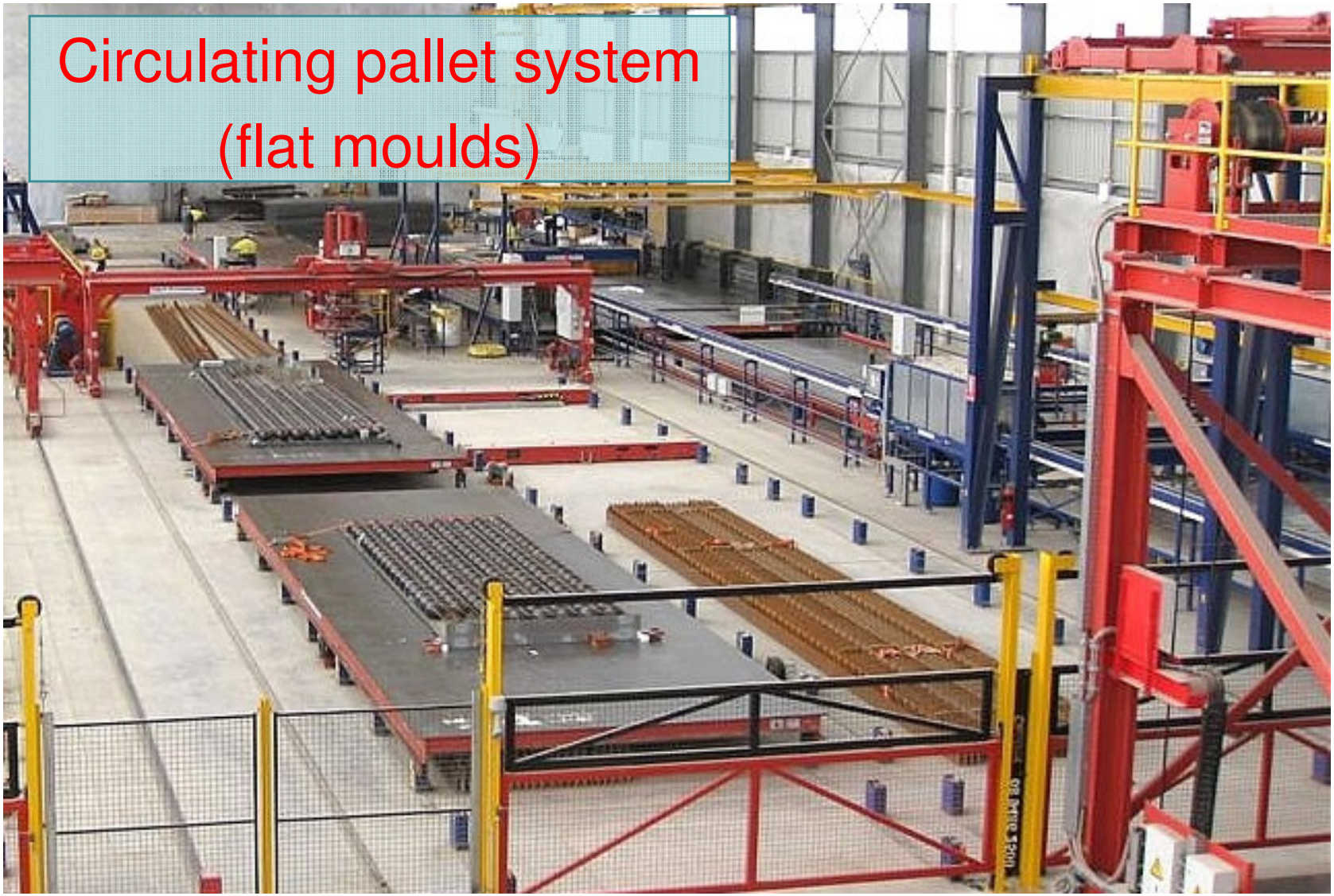
Vertical battery moulds



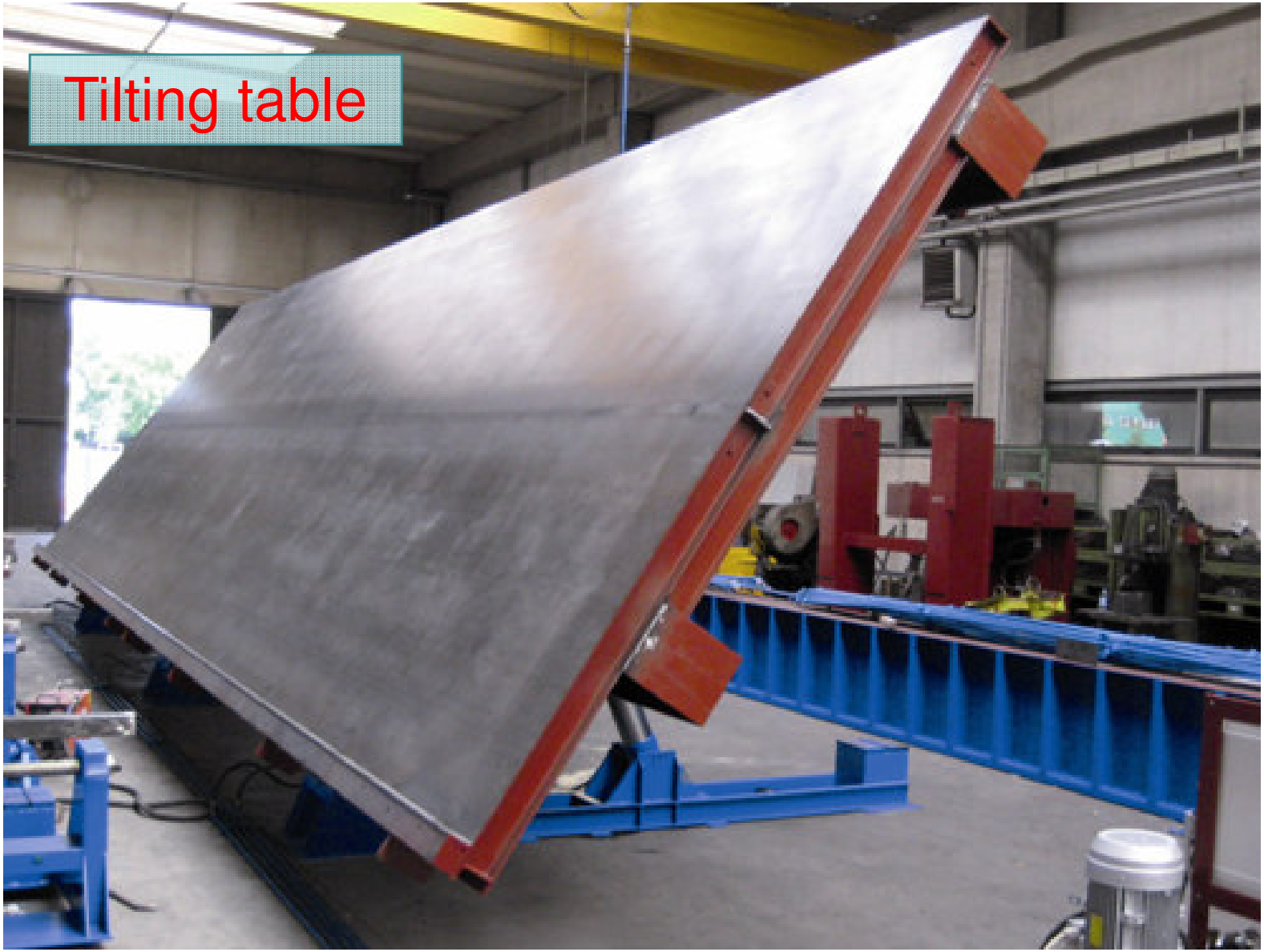
Manufacturing aspects



Manufacturing aspects



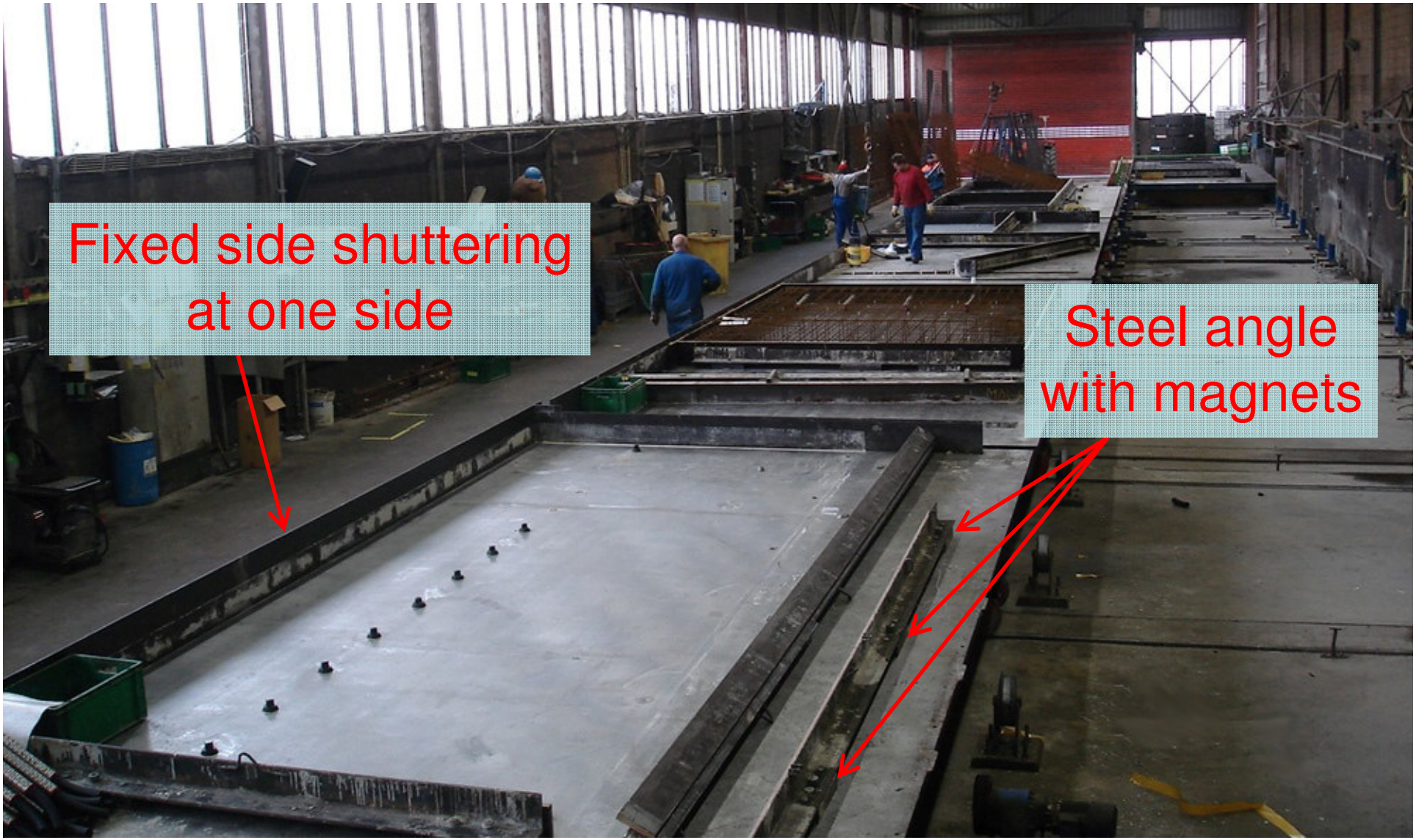
Manufacturing aspects



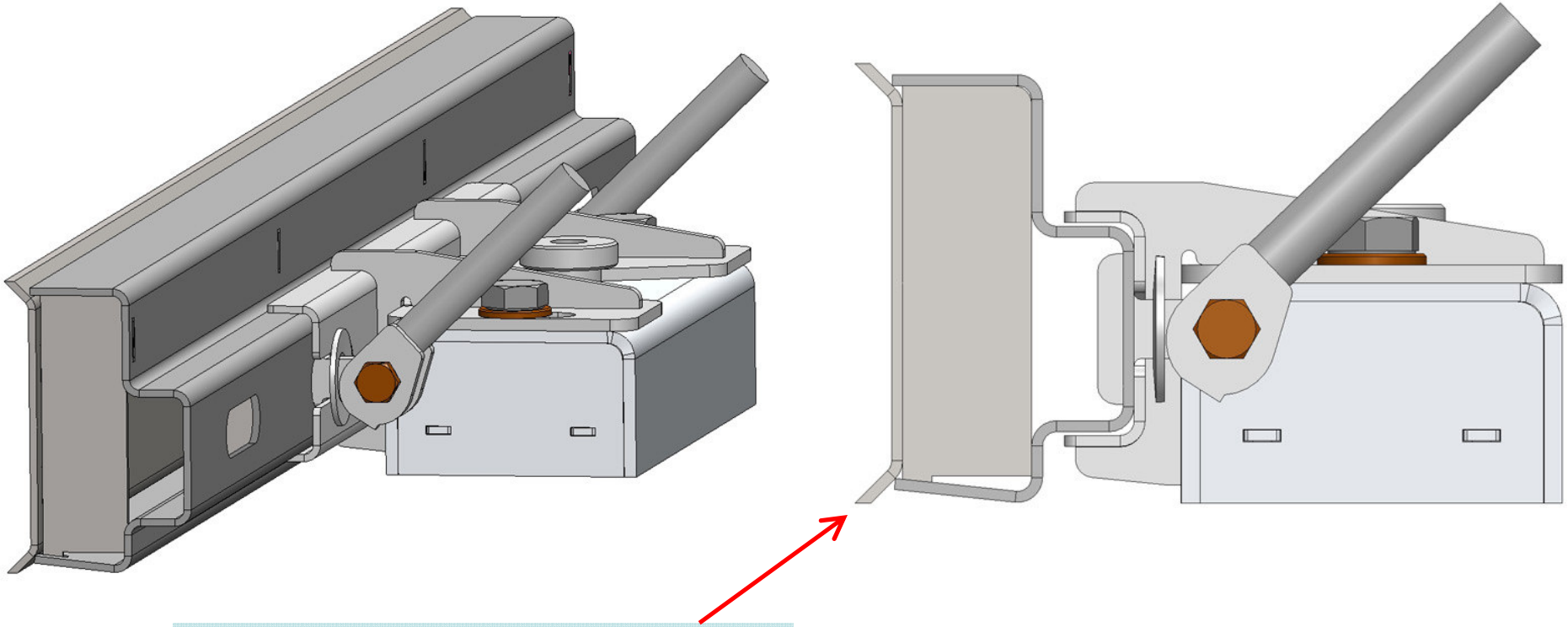
Design aspects regarding moulds:

- Size of mould
- Type of shuttering
- Finishing methods
- Curing methods
- Stripping methods
- Details like: chamfering, drip holes, block outs, water proofing etc.

Manufacturing aspects



Standard steel side shuttering with magnets:



Chamfer at edges

Manufacturing aspects

Wooden moulds:

- Custom made wooden moulds
- Highly skilled carpentry work
- High flexibility
- Time consuming

Manufacturing aspects

Manufacturing aspects

Manufacturing aspects

Embedded parts in precast:

- Standard products
- Minimum variation in embedded parts
- Avoid penetrations through the mould

Reinforcement:

- Use prefab reinforcement
- Detailing → check if reinforcement fits

Manufacturing aspects

Corrugated steel ducts

Manufacturing aspects

Manufacturing aspects

Manufacturing aspects

Steel angle connected to embedded anchors

Manufacturing aspects

Manufacturing aspects

Manufacturing aspects

Maximum size and weight of the elements?

Wall panels:

- Depends on vertical transport on road
- Depends on crane capacity
- Depends on size of mould

Floor slabs:

- Depends on maximum span
- Generally slabs are lighter than walls

Execution / Erection

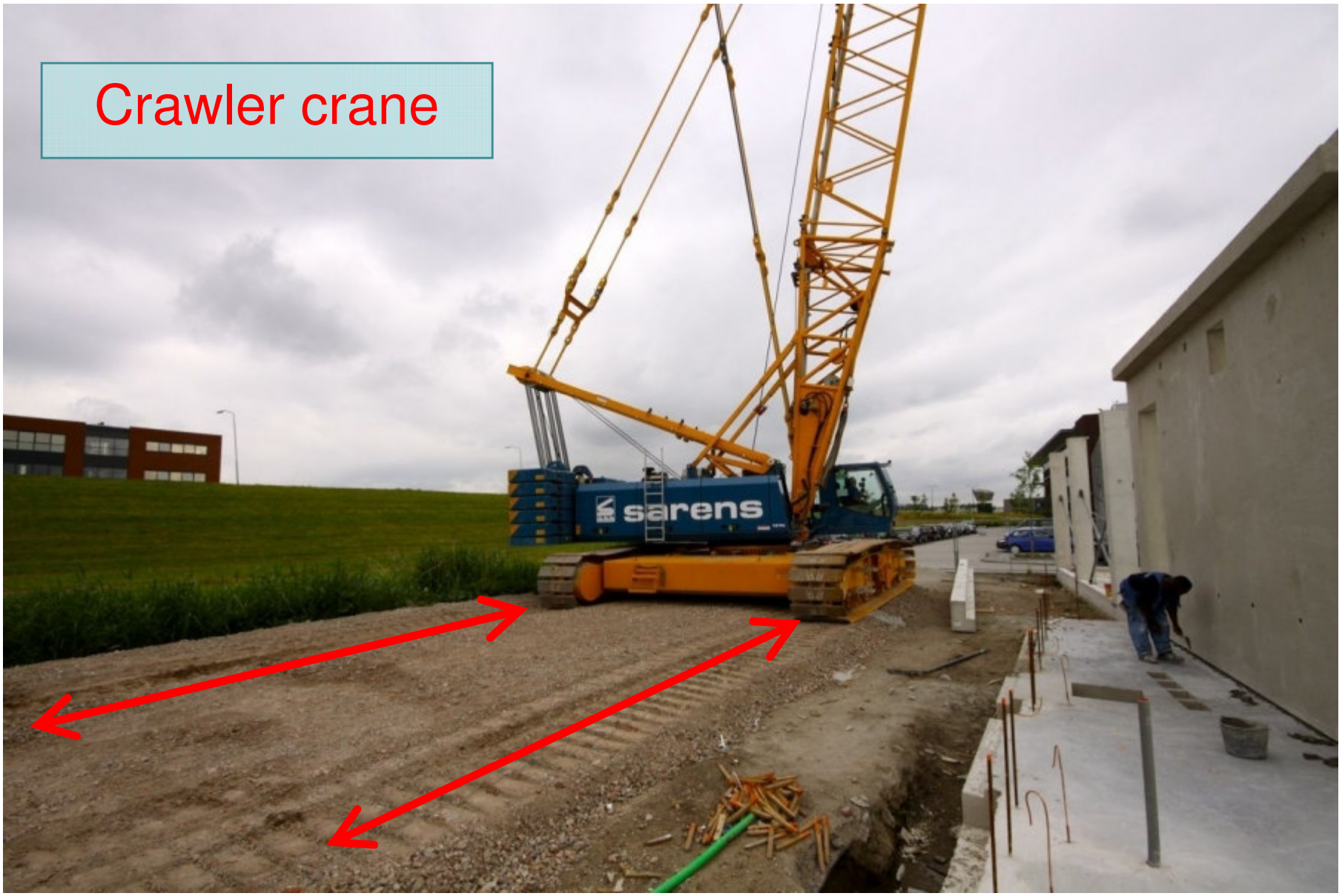
Design aspects:

- Transportation restrictions
- Crane position and lifting capacities
- Easy access to connections
- Clean connections
- Tolerances
- Easy and fast erection
- Position of props and supports
- Casting of rcc topping

Execution / erection aspects

Execution / erection aspects

Execution / erection aspects

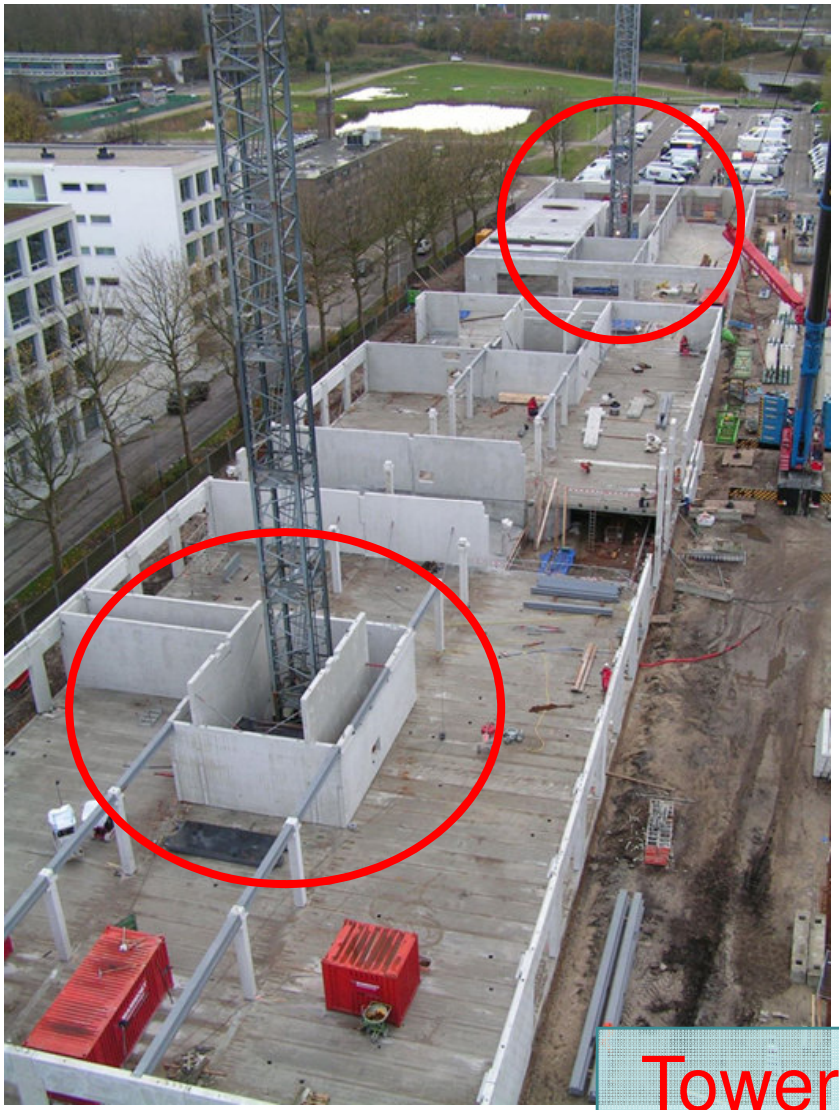


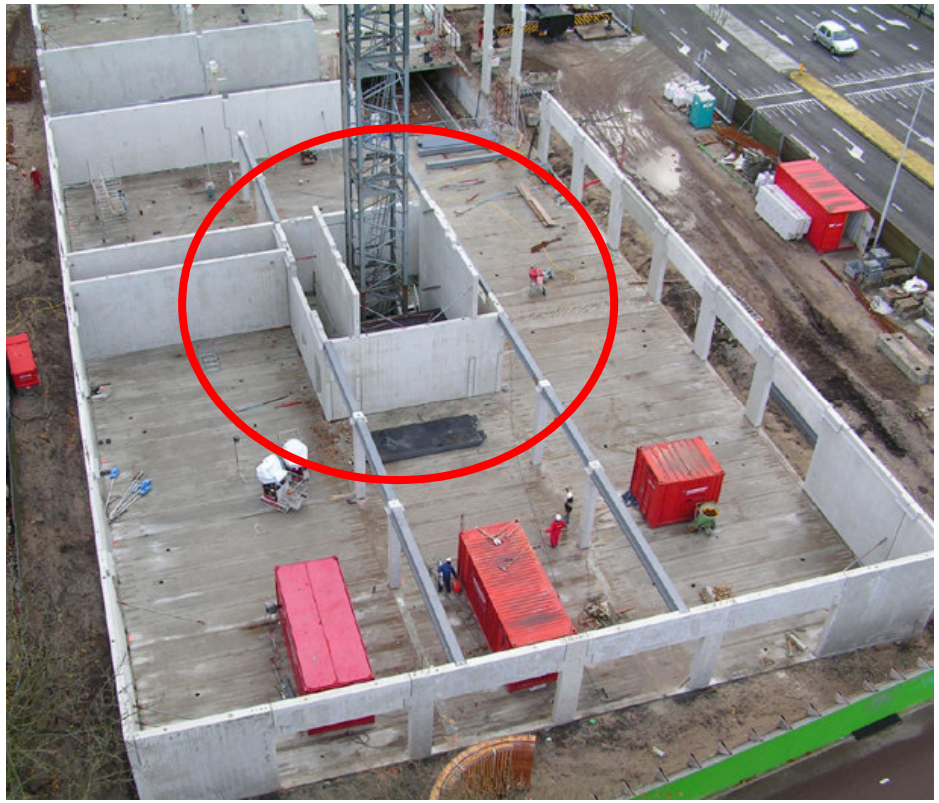
Execution / erection aspects

Lifting with two cranes

Introduction

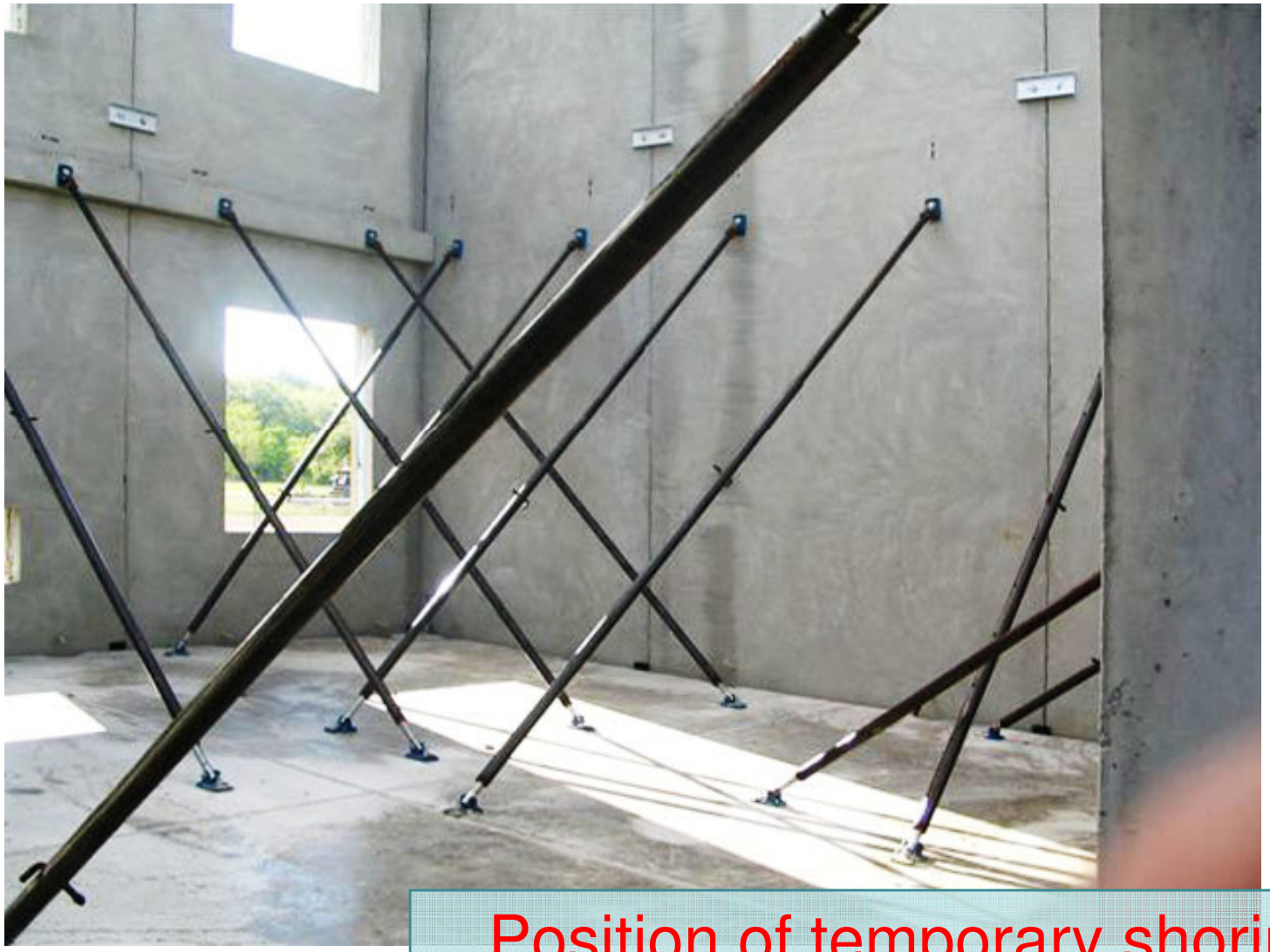
Introduction





Tower cranes inside the building

Introduction



Position of temporary shoring

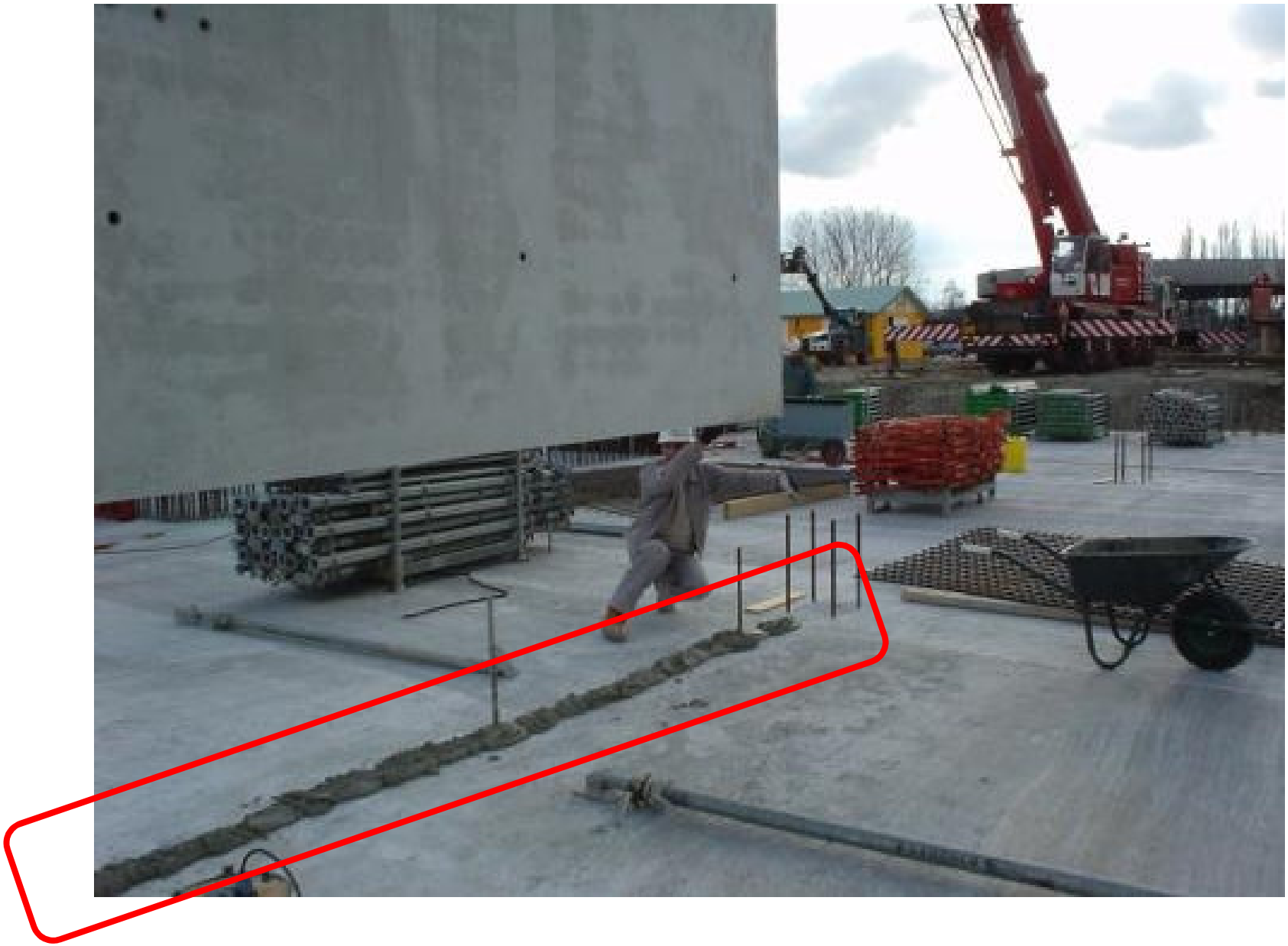
Execution / erection aspects

Filling of horizontal joints with grout:

1. Place in mortar bed
2. Fill joint by hand placement
3. Pump grout in joint
4. Fill joint with flowable grout

- Good joint filling has to be achieved.
- Grouting procedure has to be specified.
- Proper execution and quality control is required
- Easy access to the joint should be possible

Execution / erection aspects



Execution / erection aspects

Problem:

Mortar is coming out of joint.

This has to be cleaned.

Execution / erection aspects

Execution / erection aspects

Execution / erection aspects

Pouring grout in tubes

Execution / erection aspects


THE END

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