Seminário Internacional ABCIC
O Estado da Arte da Fabricação em Concreto
e os Aspectos da Qualidade

SÃO PAULO - 1 de SETEMBRO 2011

Development of Prefabrication in Europe

Marco Menegotto
Chairman, *fib* Commission 6

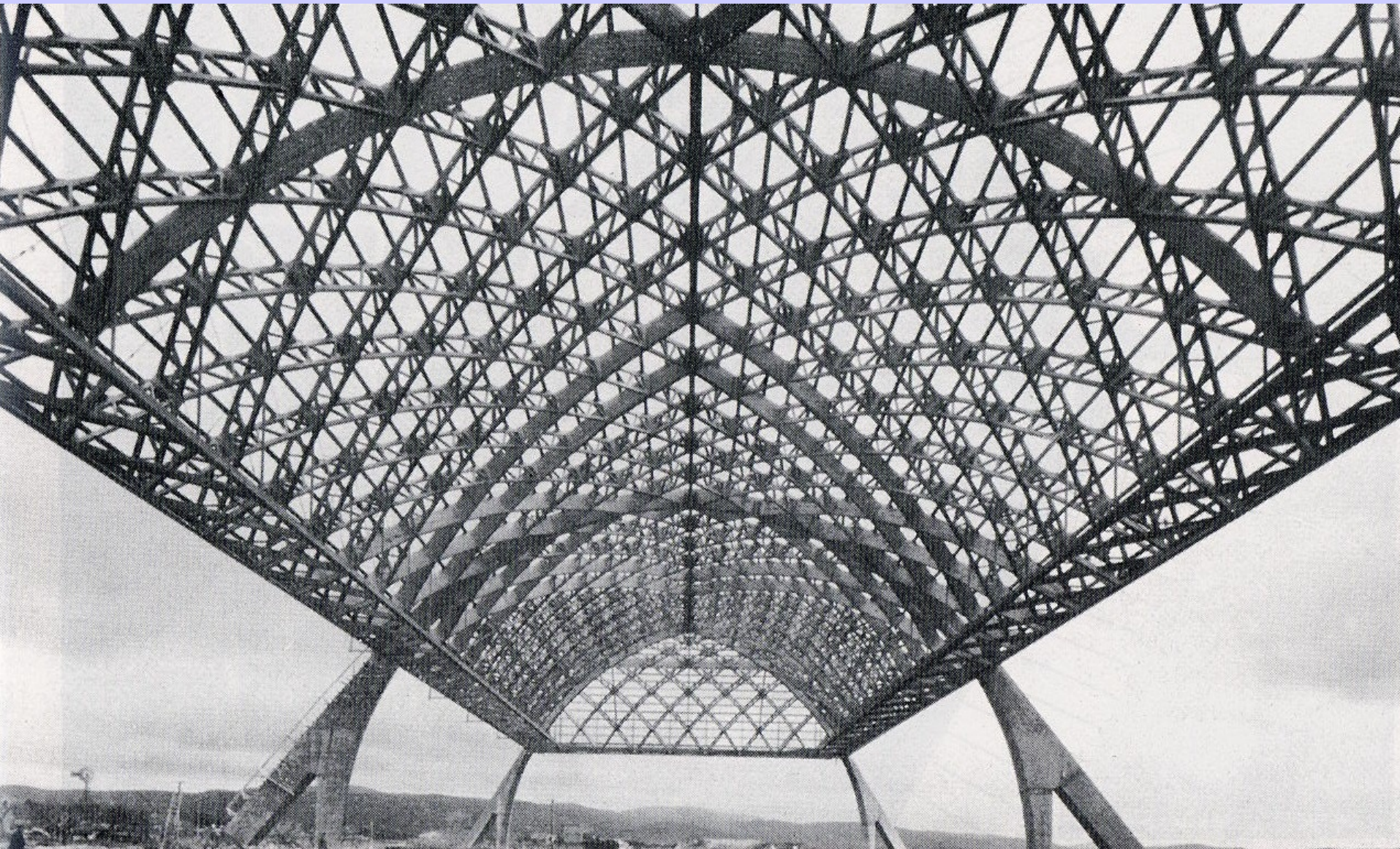
Historical Development

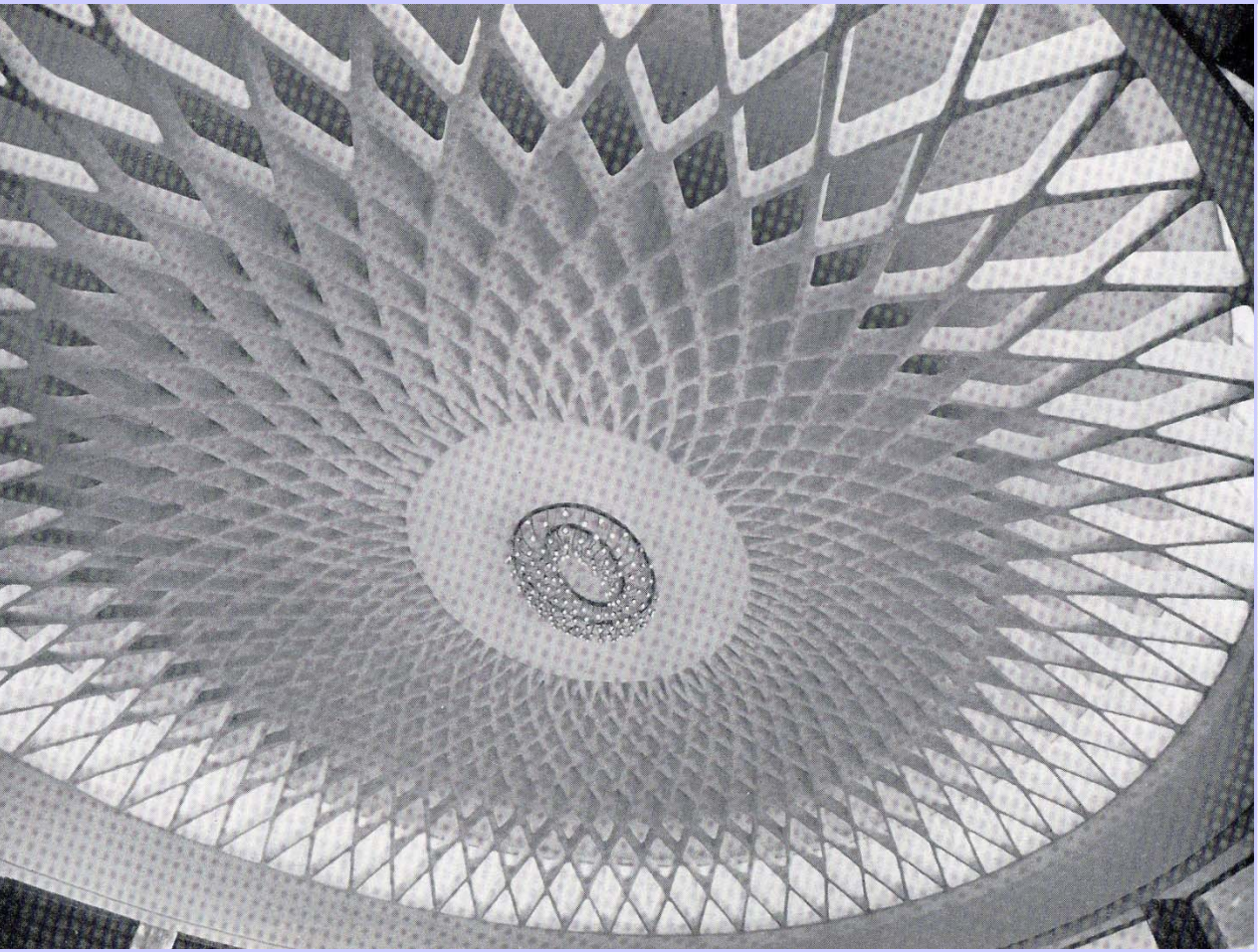
both prefabrication and in-situ construction have been used and re-used for structures along centuries

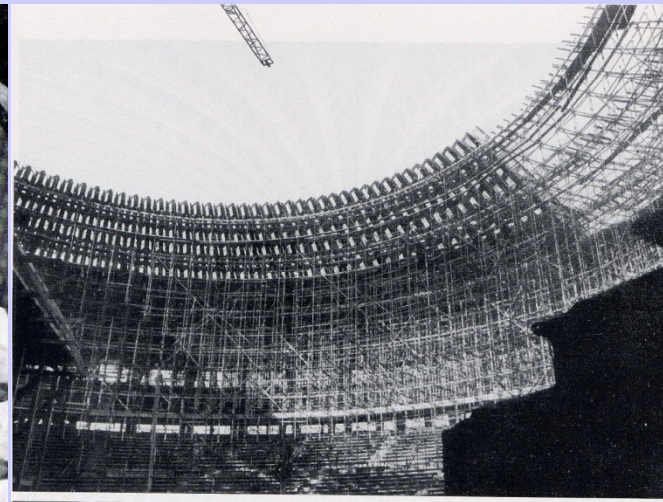
from precast to cast-in-situ
with multiple alterations
of structure and function
on a 20 centuries lifespan

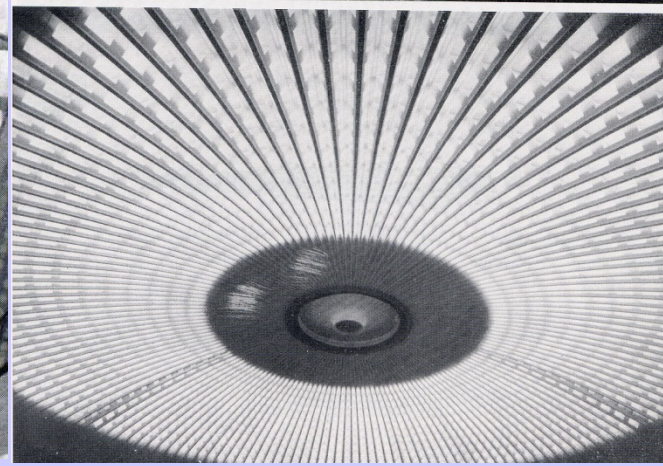
reuse after 15 centuries with other technique

P.L. Nervi’s
precast concrete hangars (1940)









again P.L. Nervi (1960)

by mid XXth century,
two new issues (ref. Italy):

- prestressing technology
- demand of utility buildings

stirred up industrial prefabrication of structures

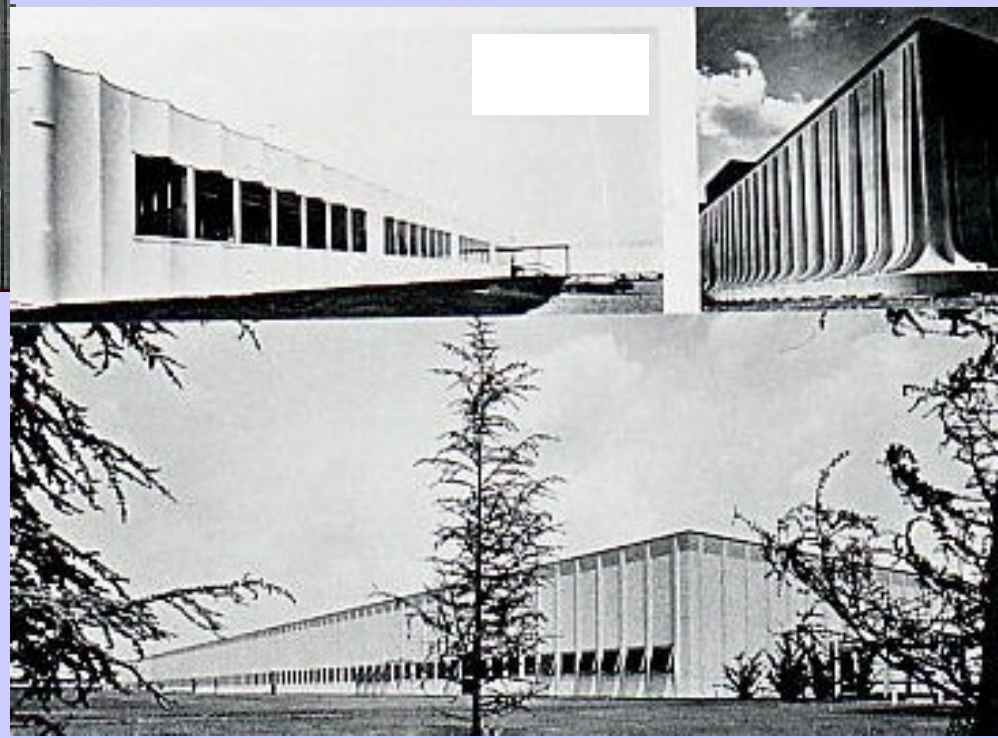
- skeletons:
  industrial halls, then other buildings:
  commercial… social… office… parking… dwelling…

(national development)

- load-bearing panels (imported systems)

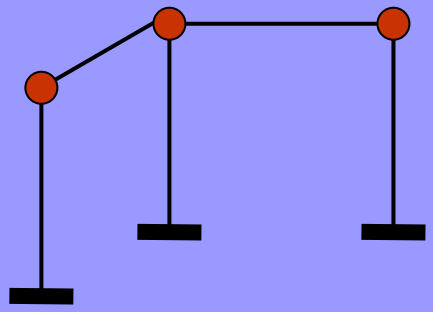
MODERN PREFABRICATION

since the 1950s:
tailored industrial buildings
with personalized look



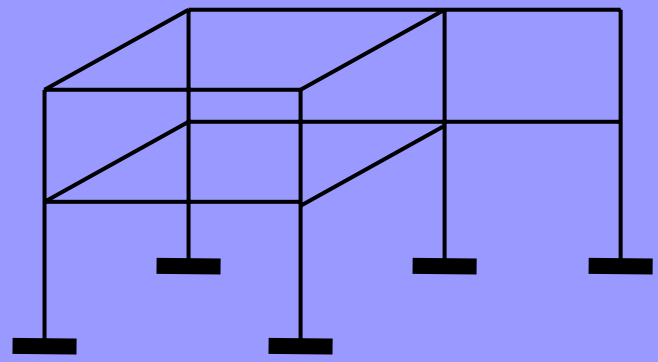
STRUCTURAL SCHEMES

(Emulating vs NonEmulating c-i-s continuity)



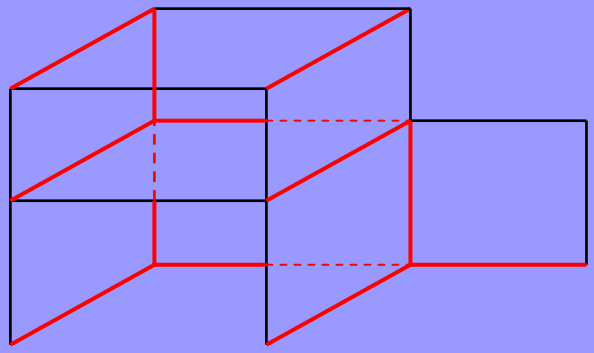
Pendulum

NE



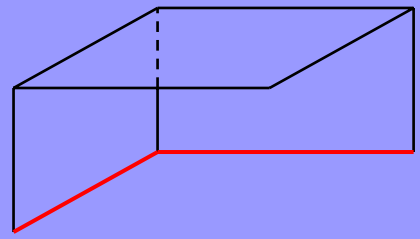
Frame

E



1.b.Panels

NE

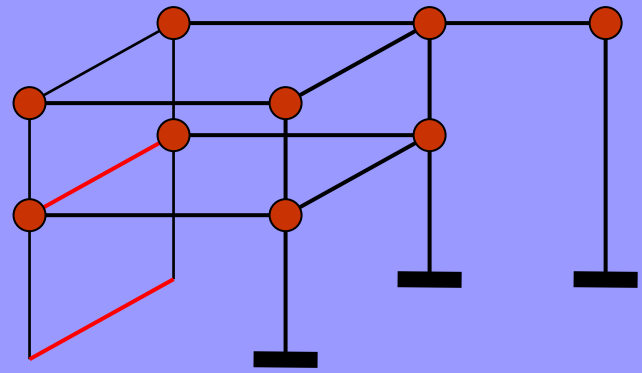


3D Components

hinge

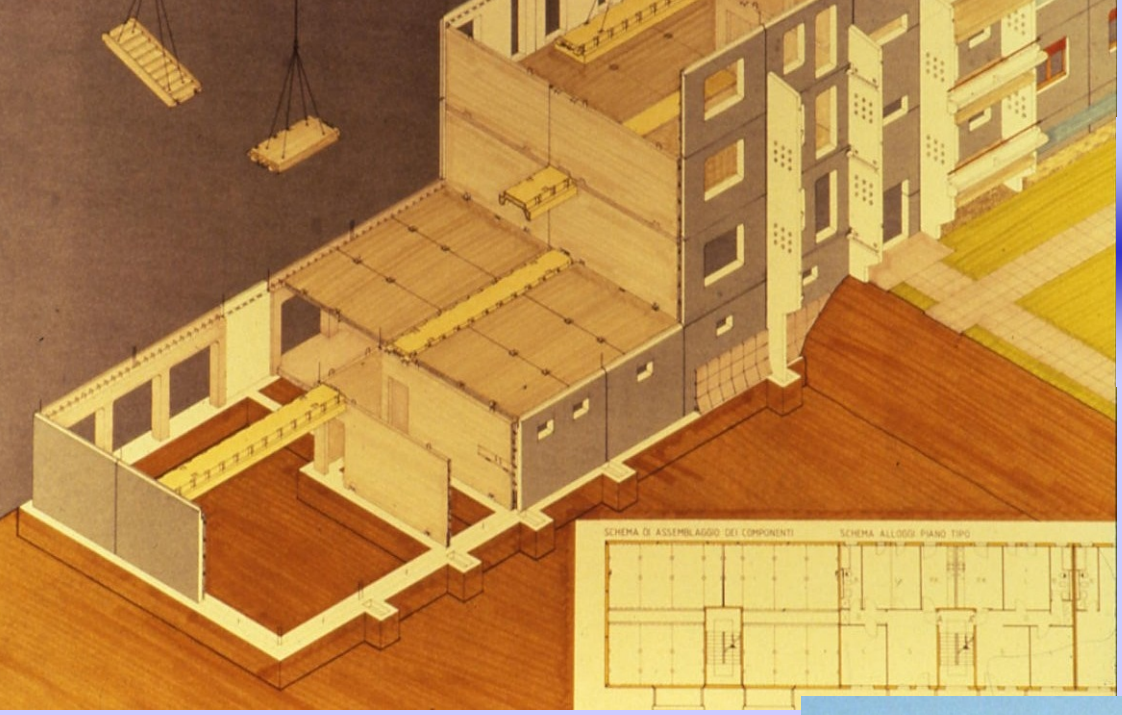
linear hinge

fixed end



Dual

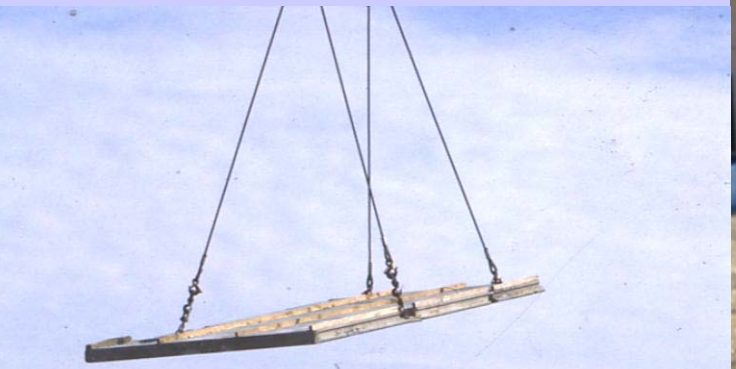
NE

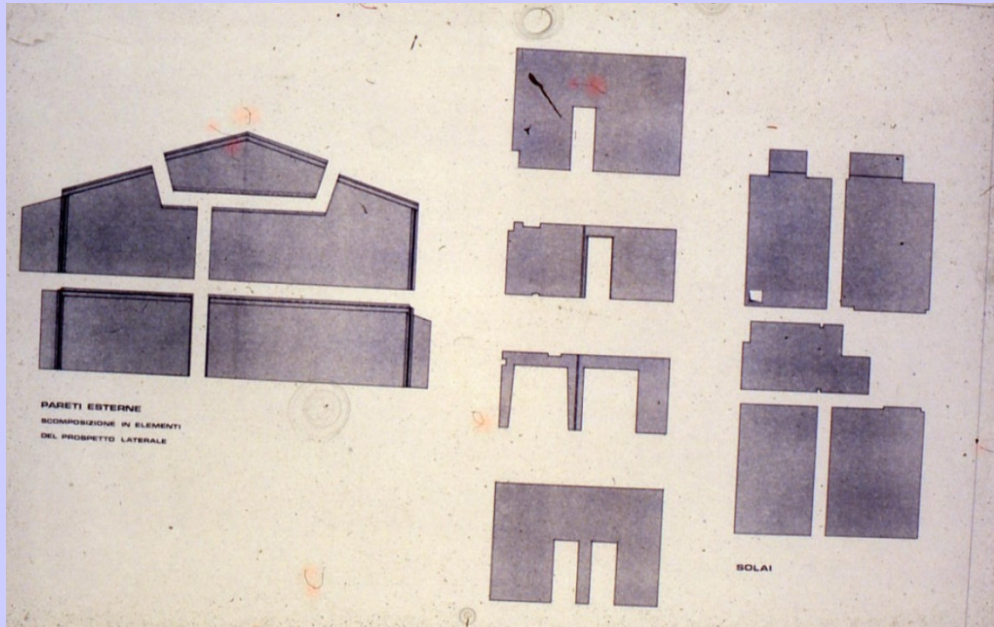


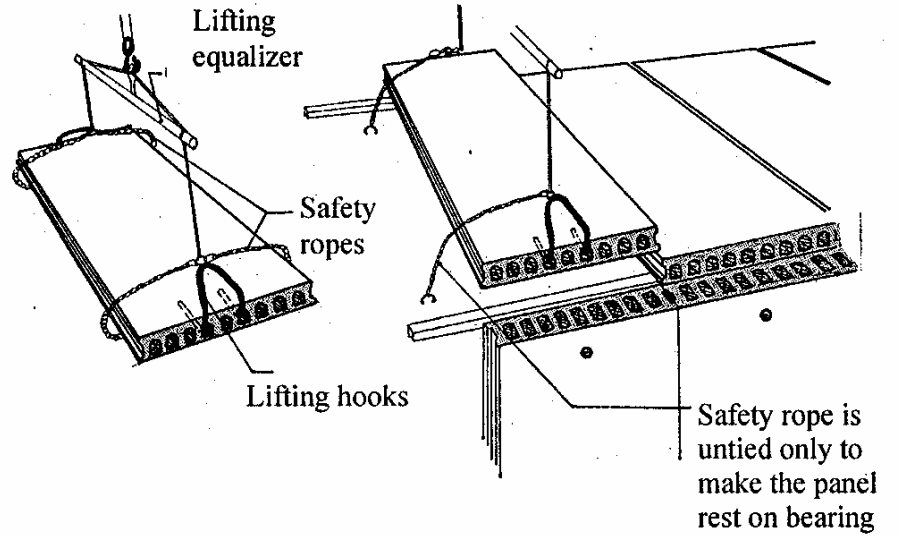
NE
LOAD-BEARING PANELS

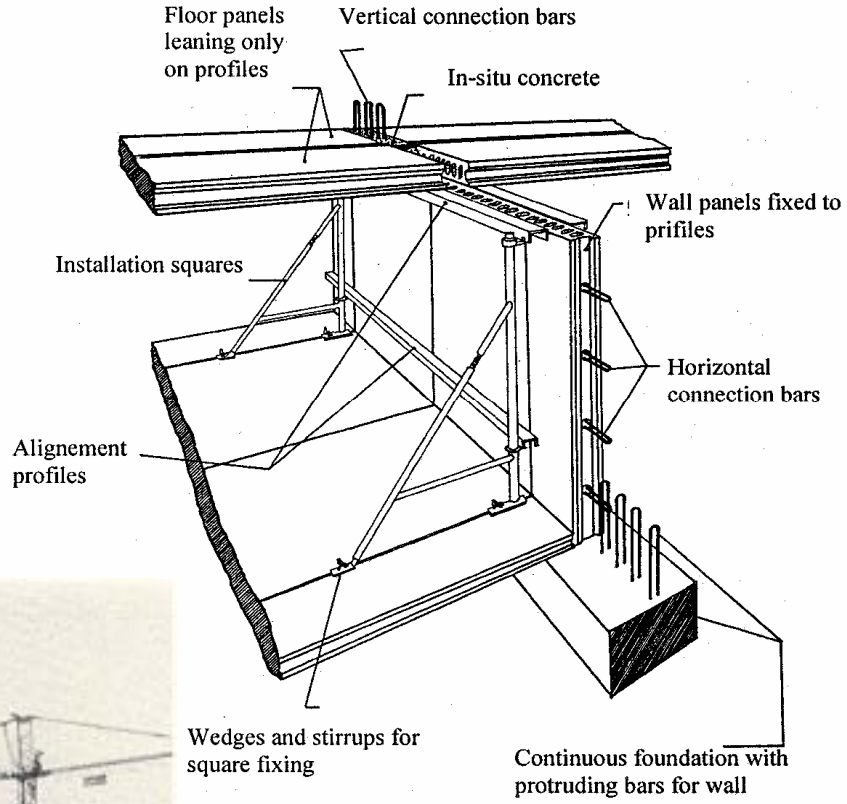
at start, rigid layout
and heavy appearence

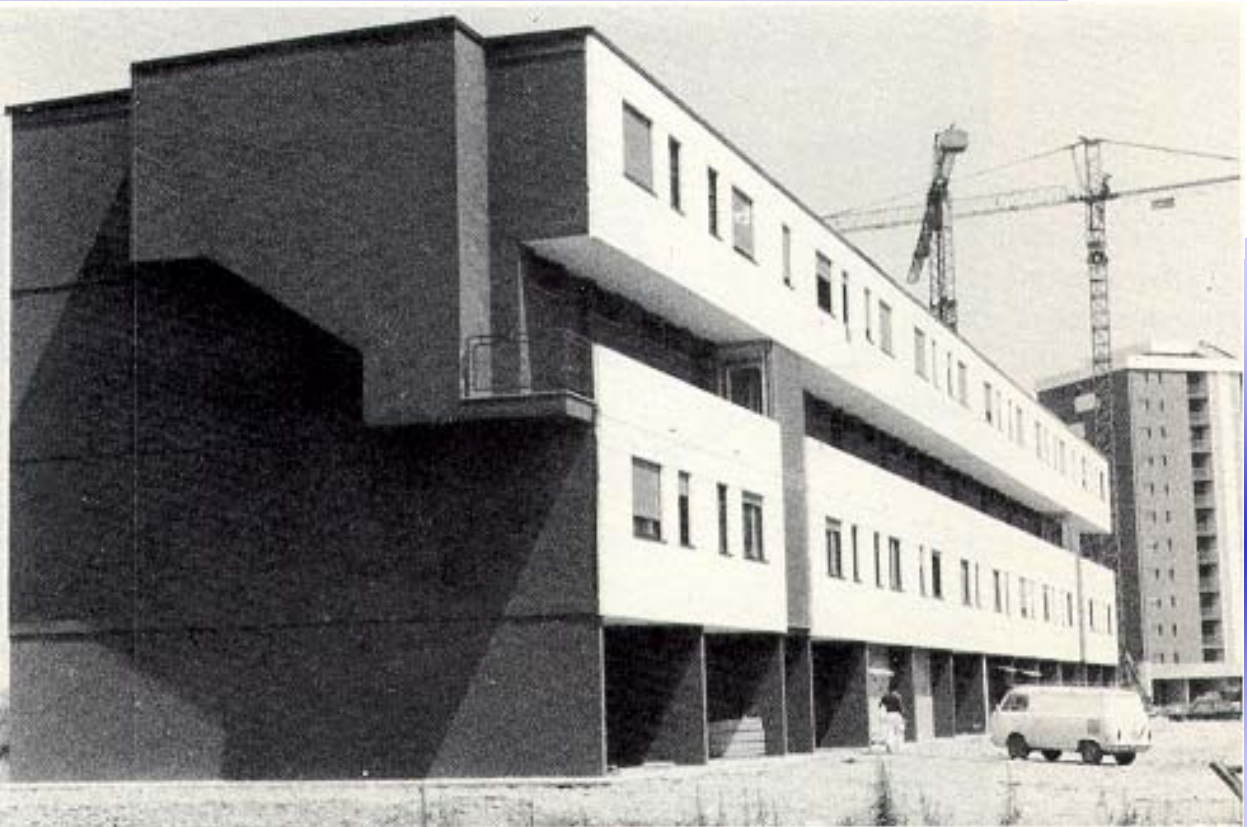
… search for variations




PARETI ESTERNE
SCOMPOSIZIONE IN ELEMENTI
DEL PROSPETTO LATERALE
SOLAI

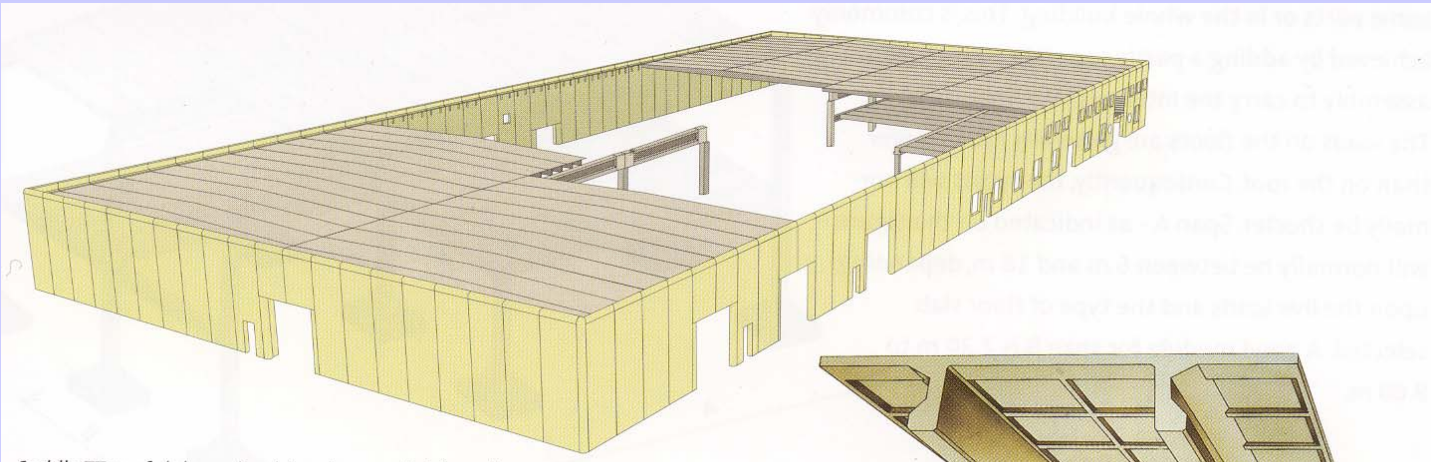




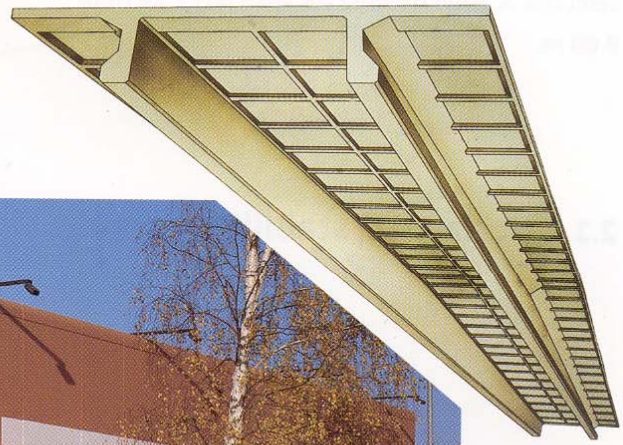


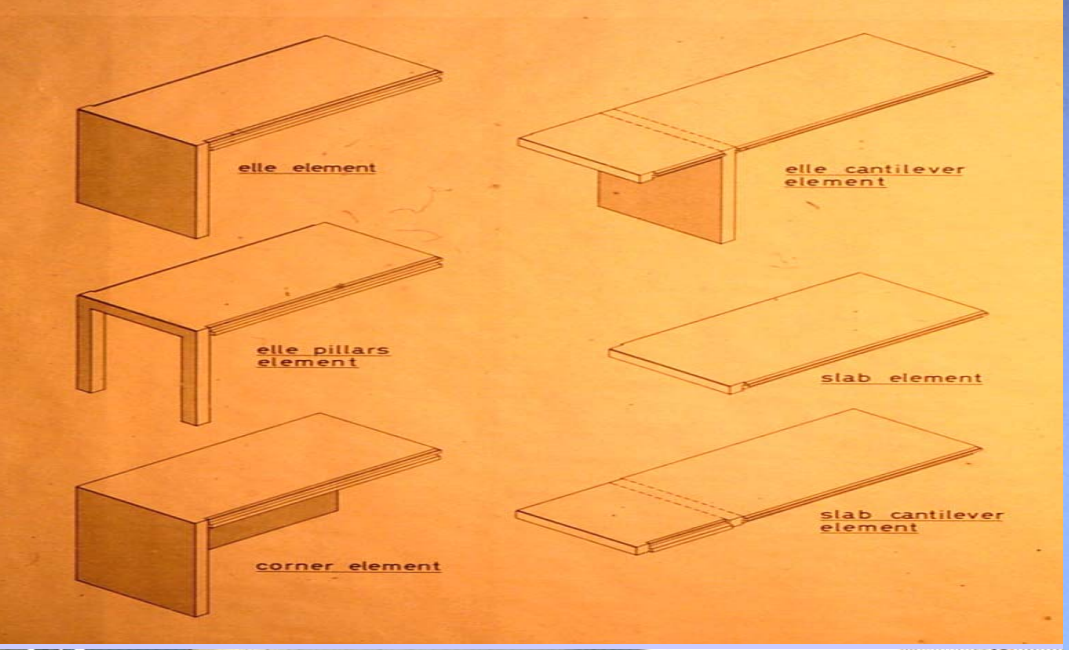
vertical and horizontal hollow-core panels

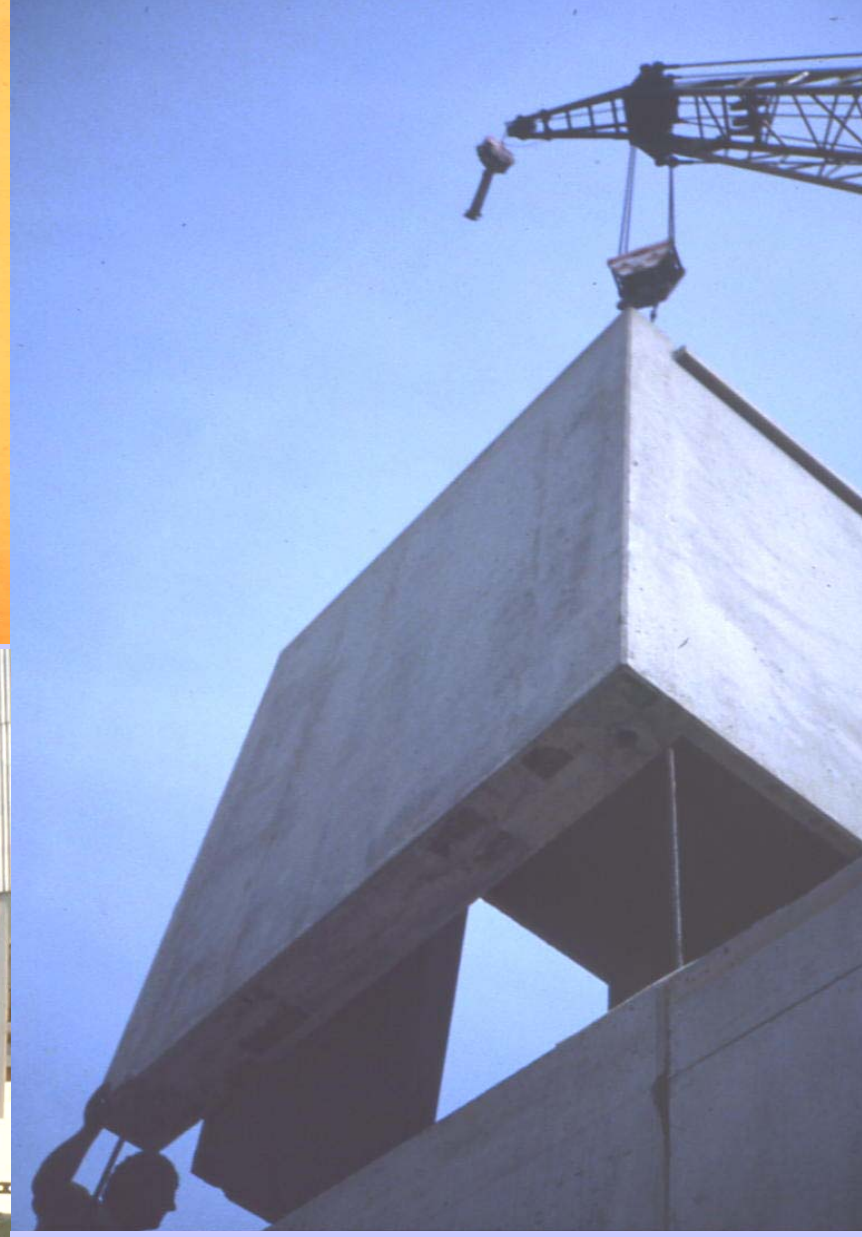
load-bearing sandwich walls + saddle roof units (Se)



Saddle TT-roof slabs on load-bearing sandwich walls







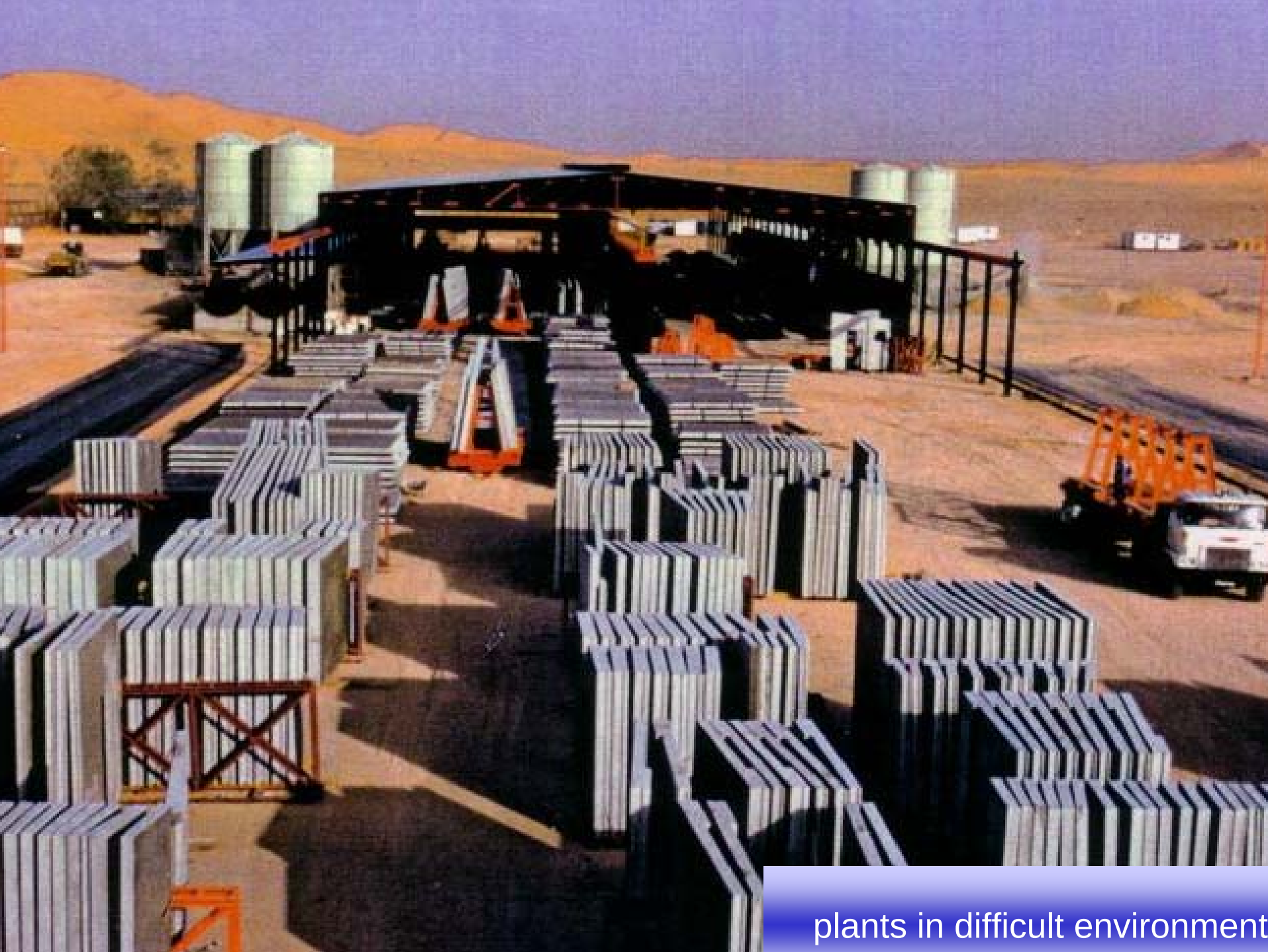
3D components

… assembled boxes (Gr)

Special Issues:

self construction with light bearing panels

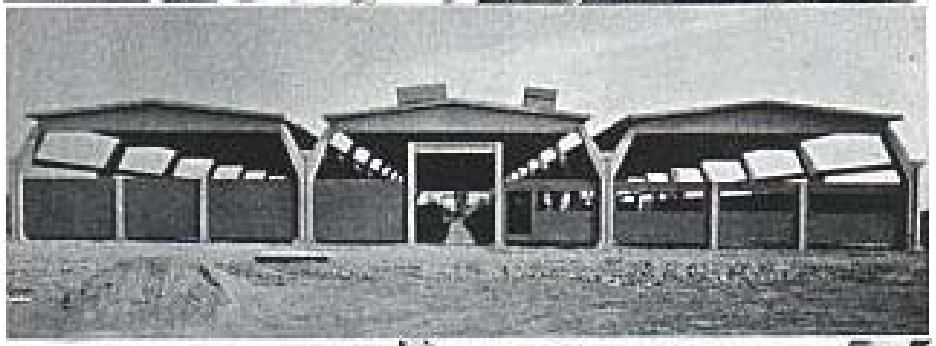
cellular concrete loadbearing panels for low-rise buildings in a desert

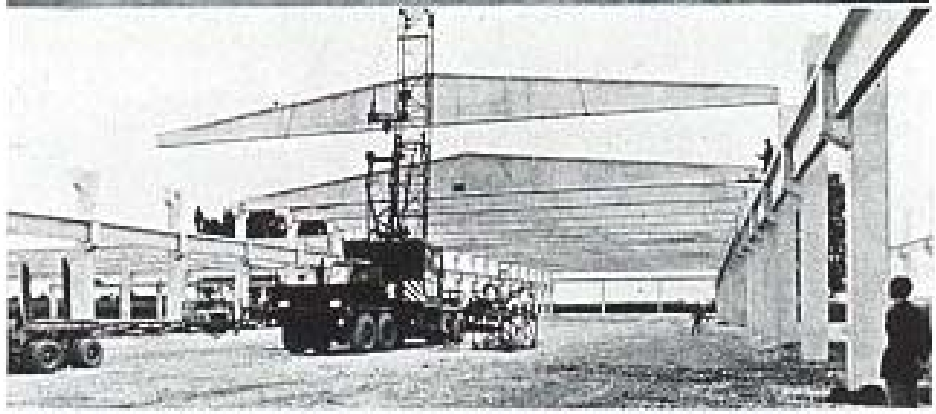


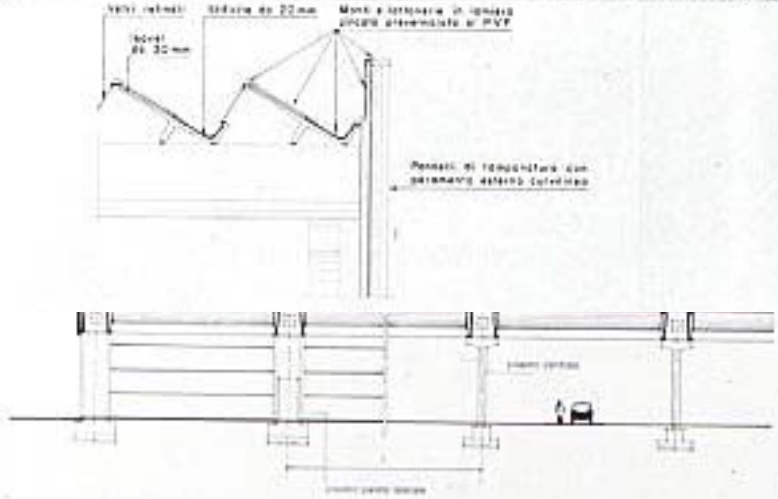
plants in difficult environment

NE
INDUSTRIAL HALLS
various types of elements

saddle (Δ) beams
I or **T** cross-section





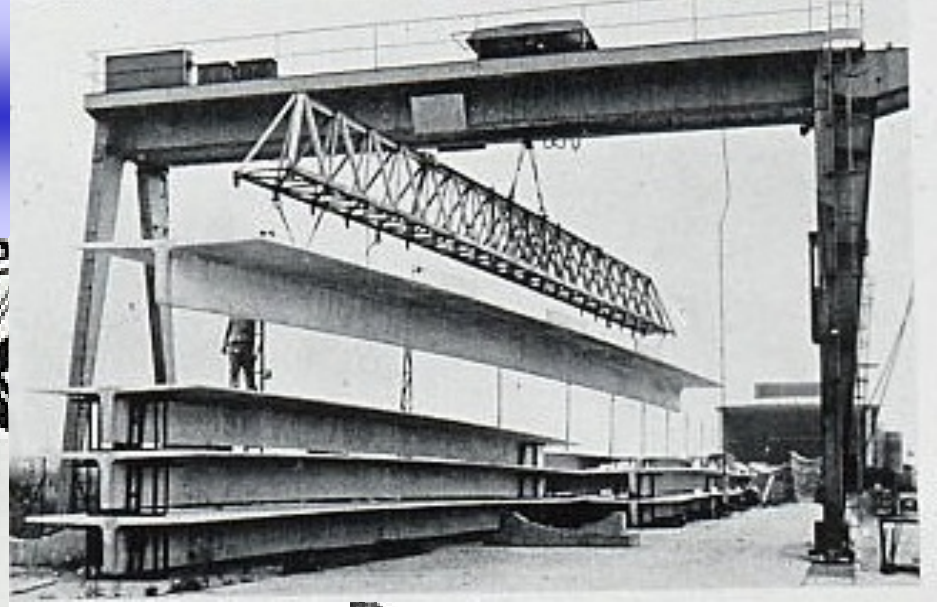


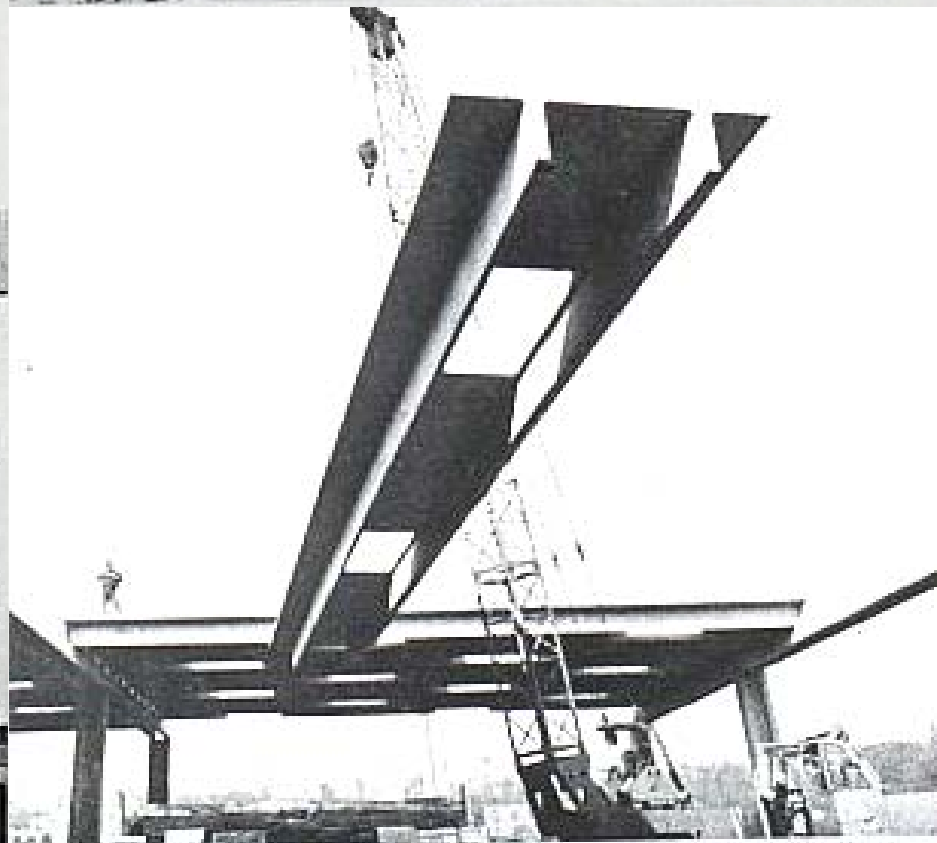
Δ-shed, Ω, Δ-**TT** beams;
corbel, cantilever, Y-columns

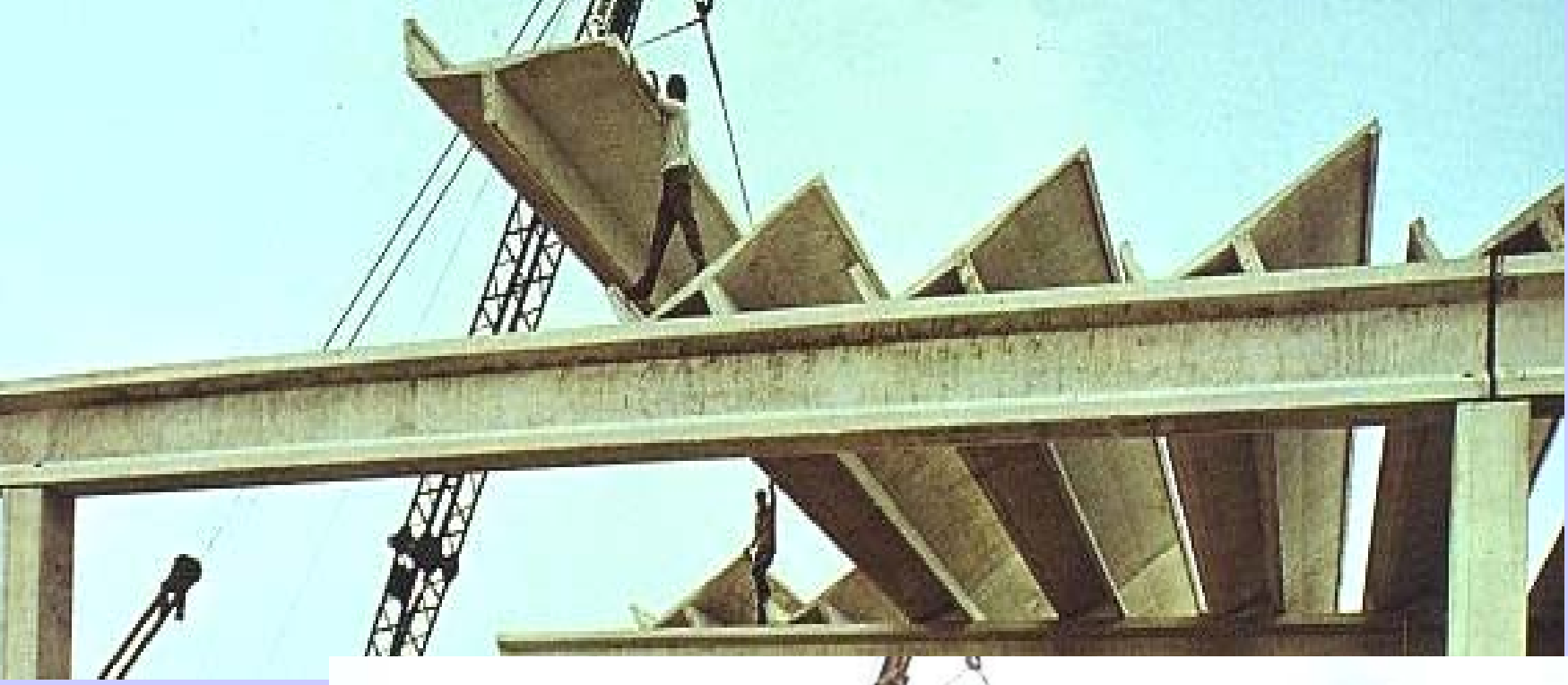
truss beams
multistorey columns

service storey deep beams

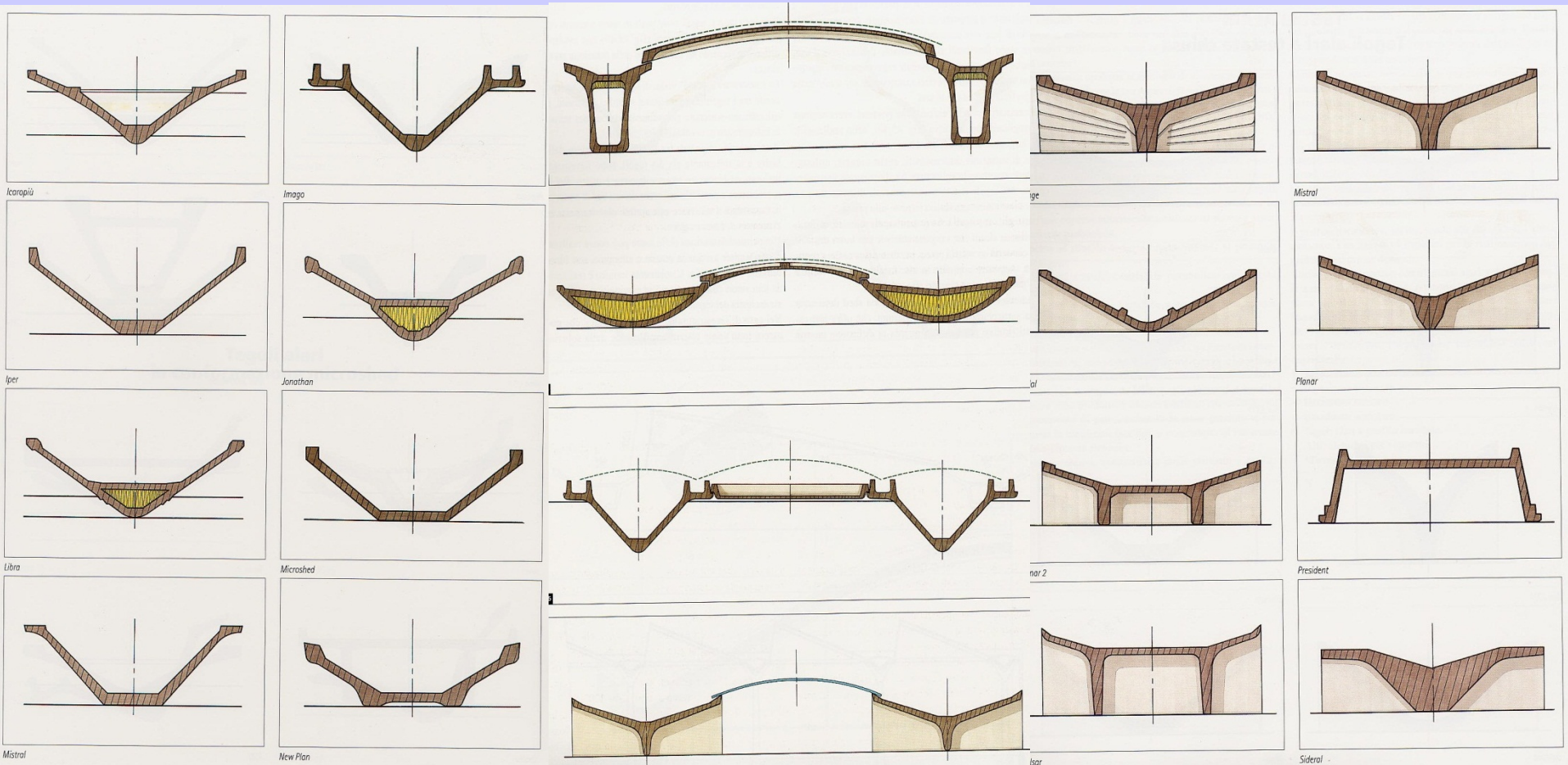
roofings





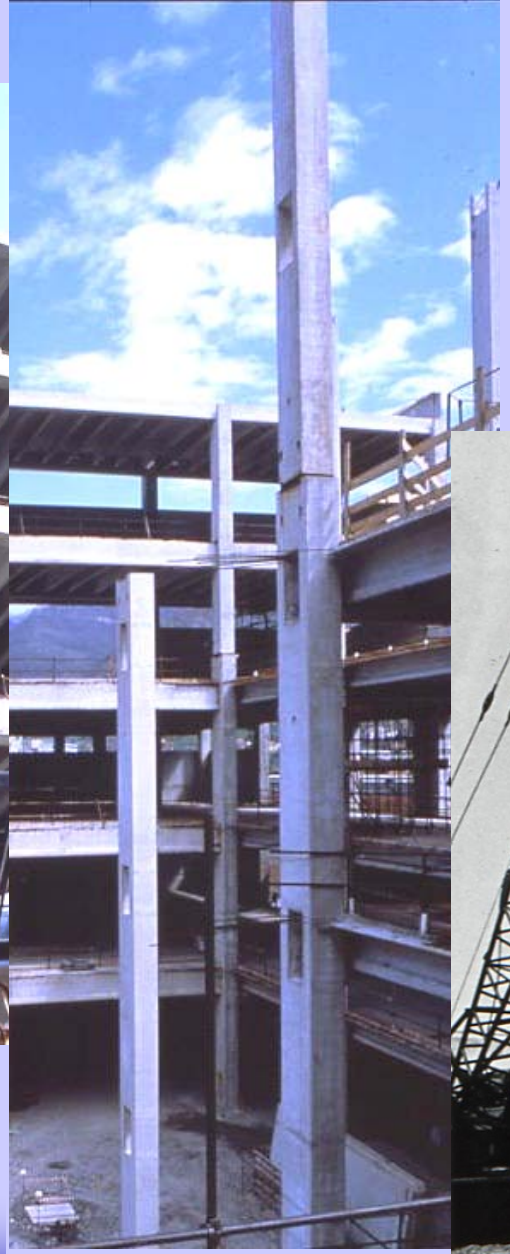


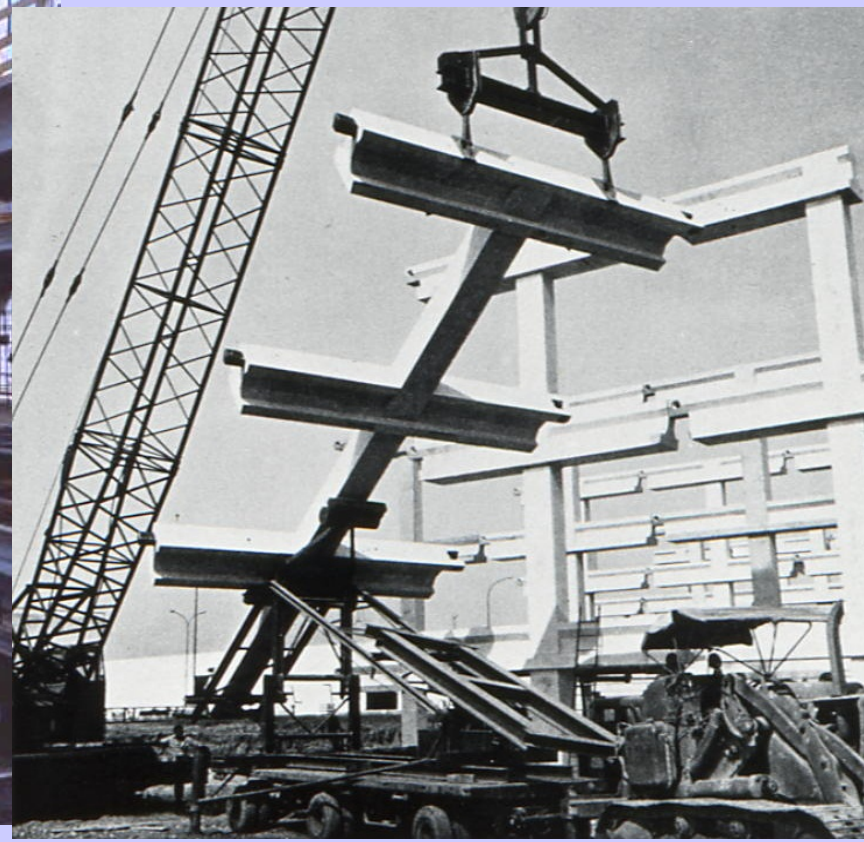
“winger” roofings




UGIA
VIBROCEMENTO PERUGIA
VERTICE
Boccolacci
BIESSE 2
VALDICHIANA
carni...pualita
HOTEL
BANCA

Emulating BUILDING FRAMES

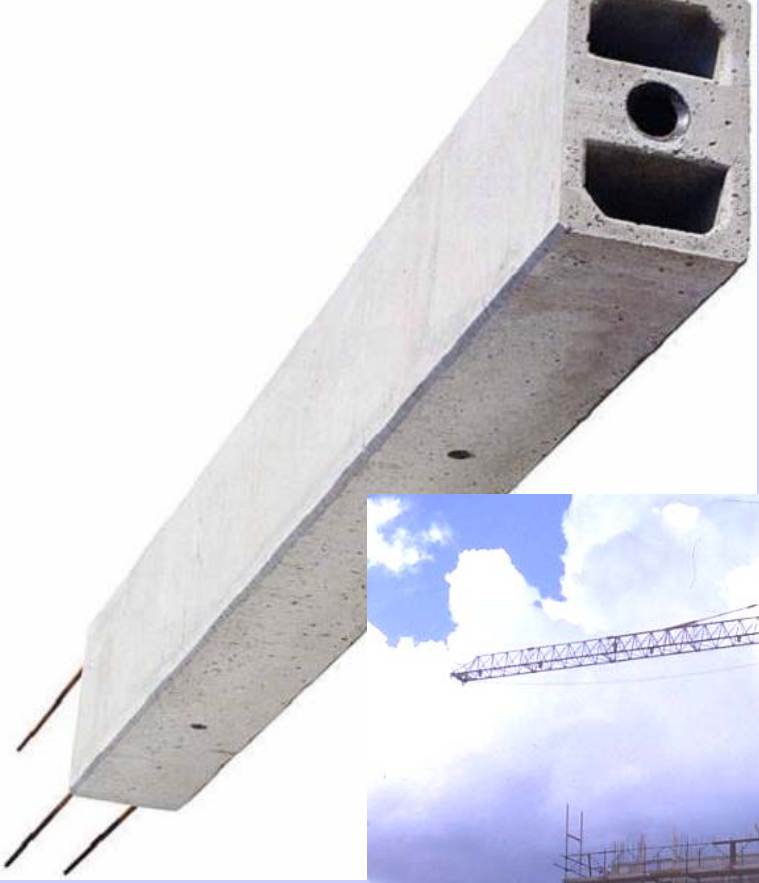




FULLY PRECAST…

(connections far from b/c joints)


MERLI



… PARTLY PRECAST

NE
DUAL

FLOOR SYSTEMS

early 1950’s precast prestressed floor patent

prestressed

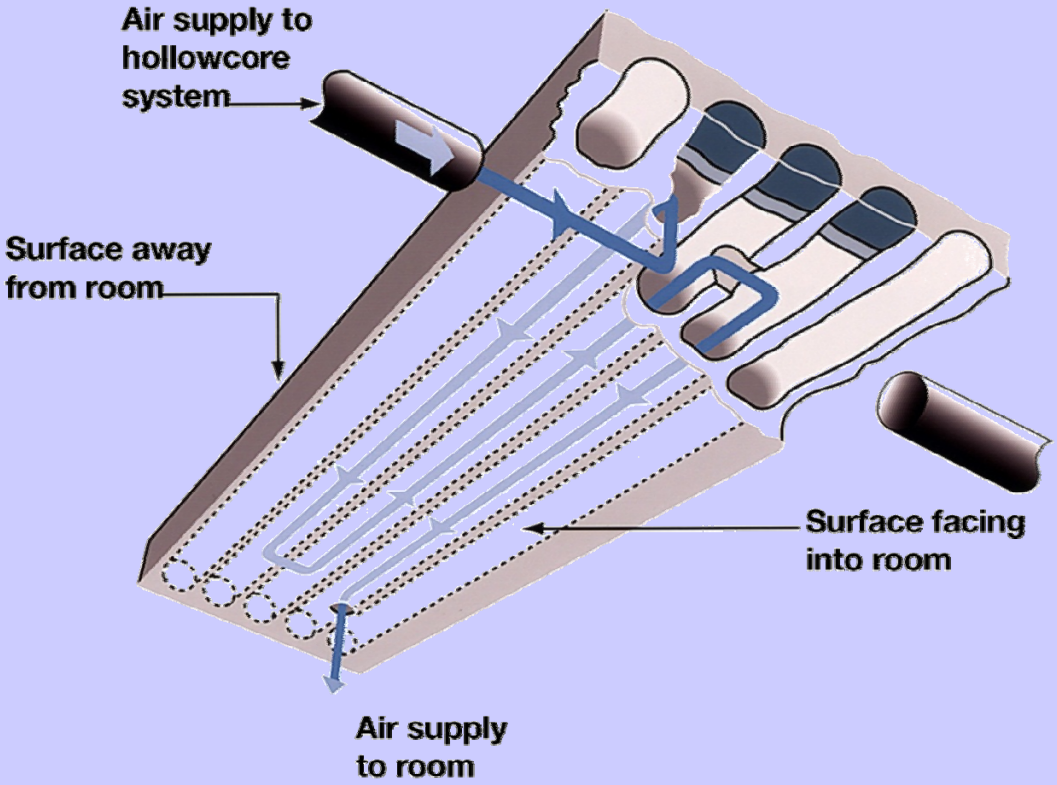
planks for composite slabs

reinforced

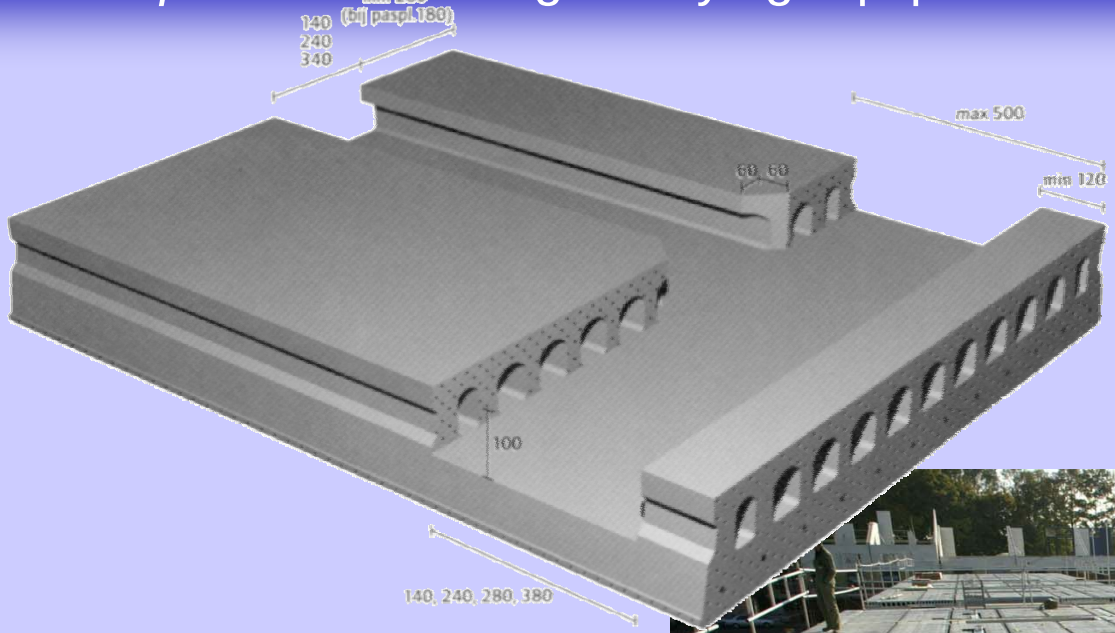
hollow-core slabs

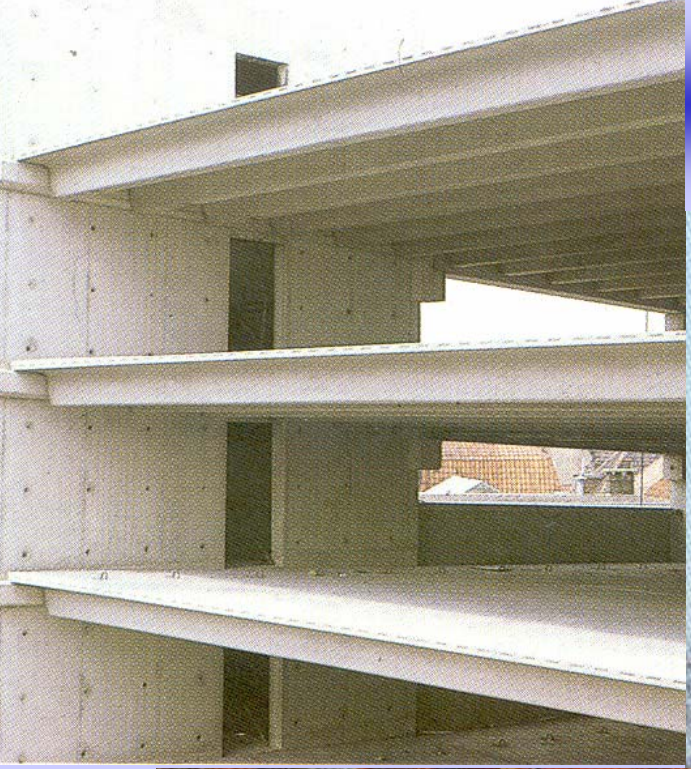
seismic waved joint

Thermo-deck: exploiting thermal mass of hollow-core slabs (Be)



Pipe-floor: allowing for laying equipments within the HC floor depth (NL)





TT slabs (composite or not)

stairs slabs

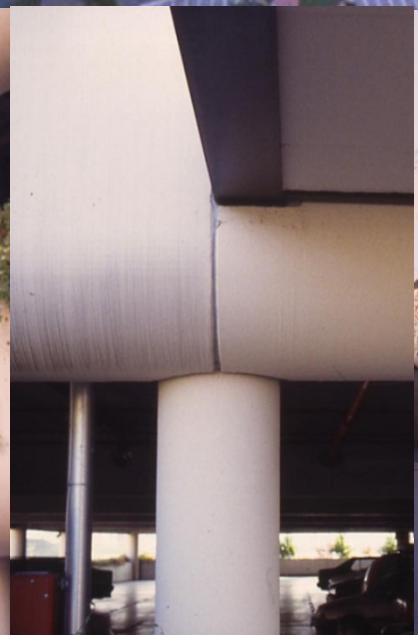
INDUSTRIAL FRAMES


RDB
RDB


11
14
16

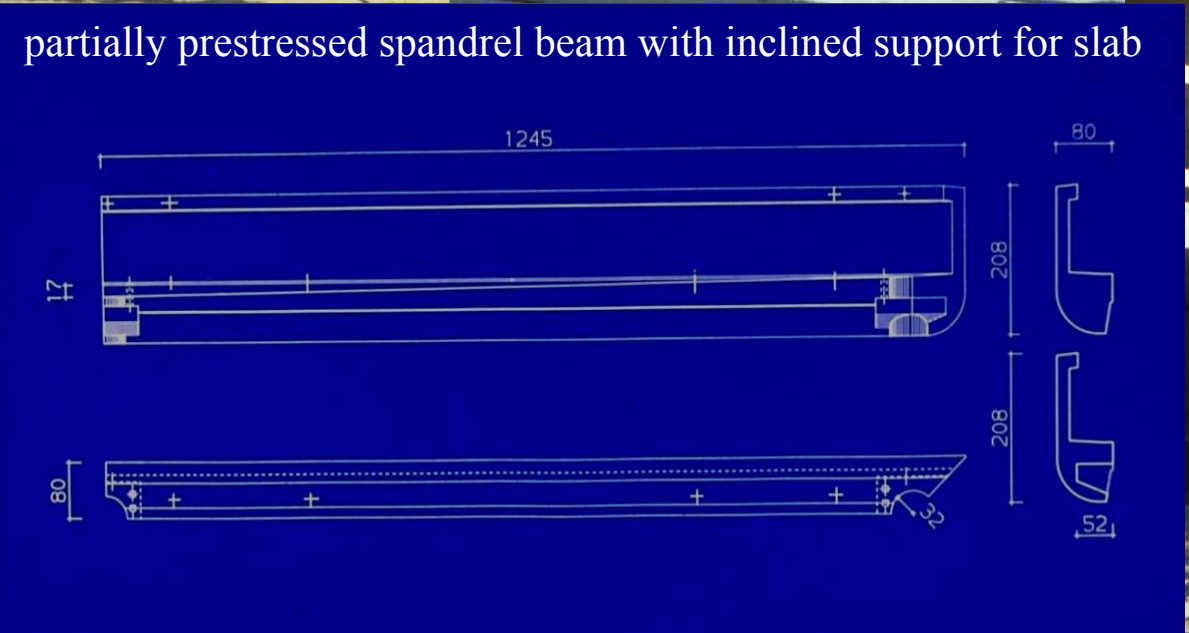
complex precast frames (pipe rack)

CAR PARKS



flexibility in production of varied precast units

partially prestressed spandrel beam with inclined support for slab



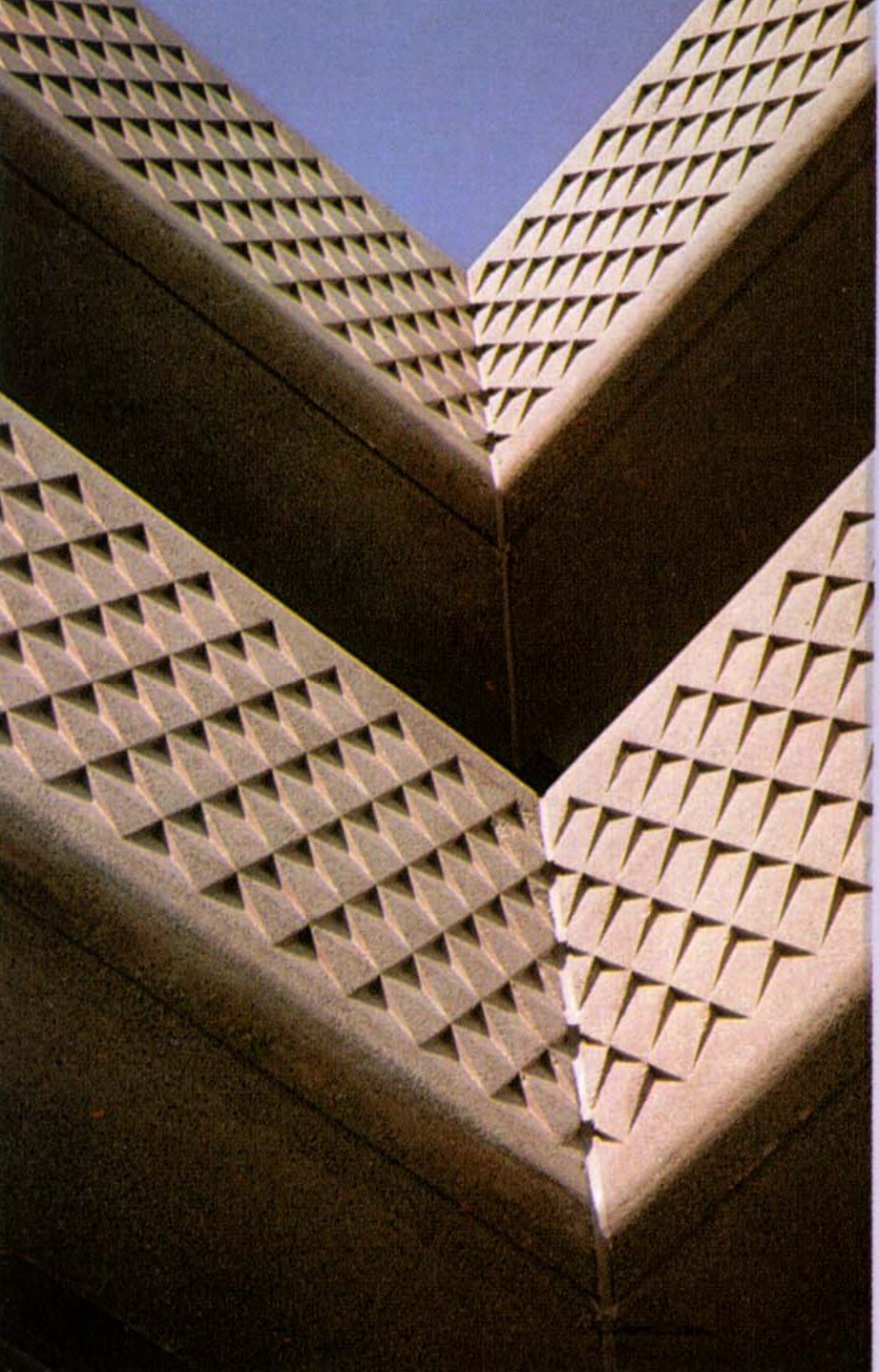
adaptability
to irregular layouts

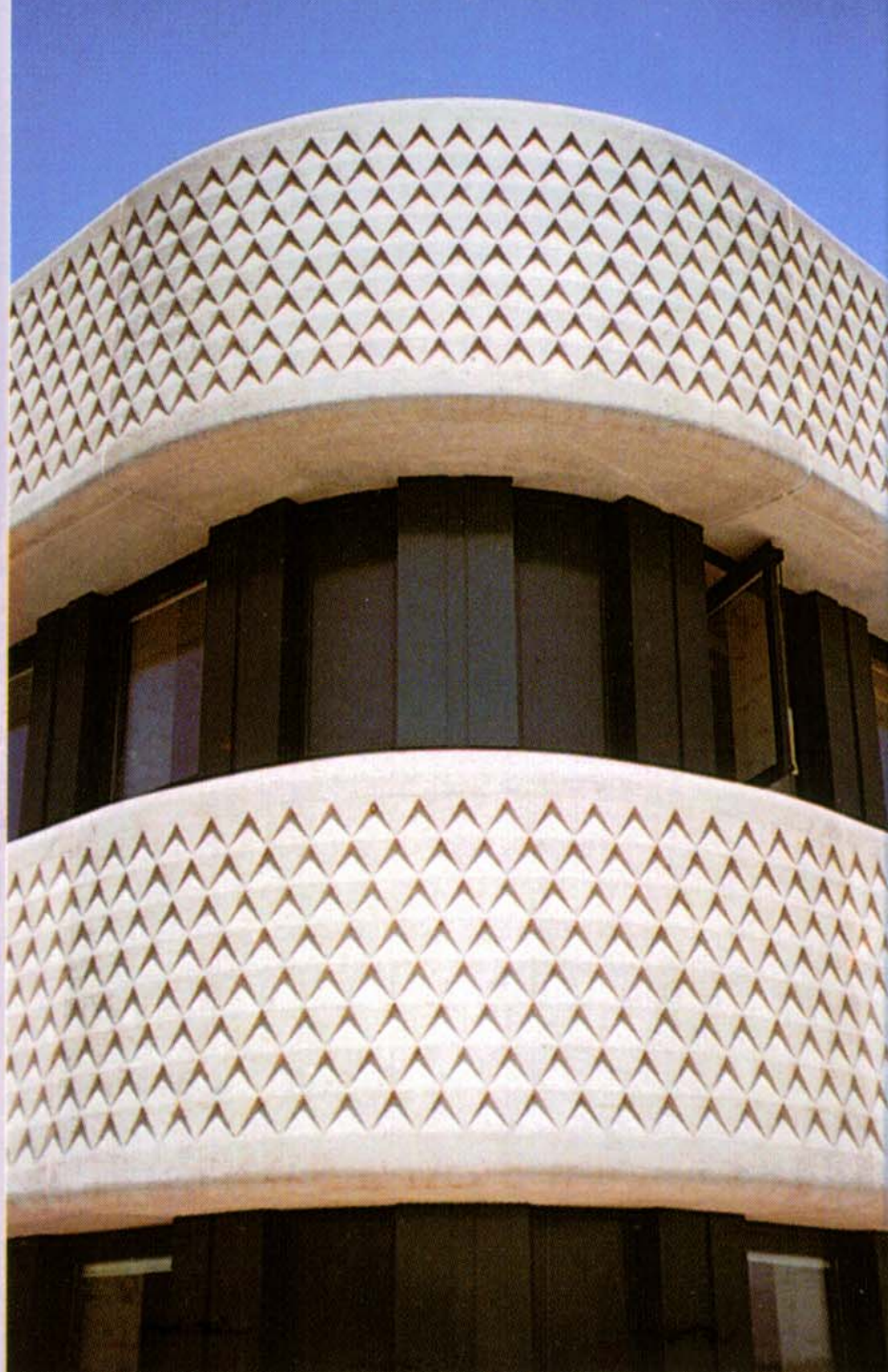
OFFICE BUILDINGS

office building façades (Be)

recently,
much attention to
aspect
claddings
finishes


0-24
LIBERO
FARMACOSTA

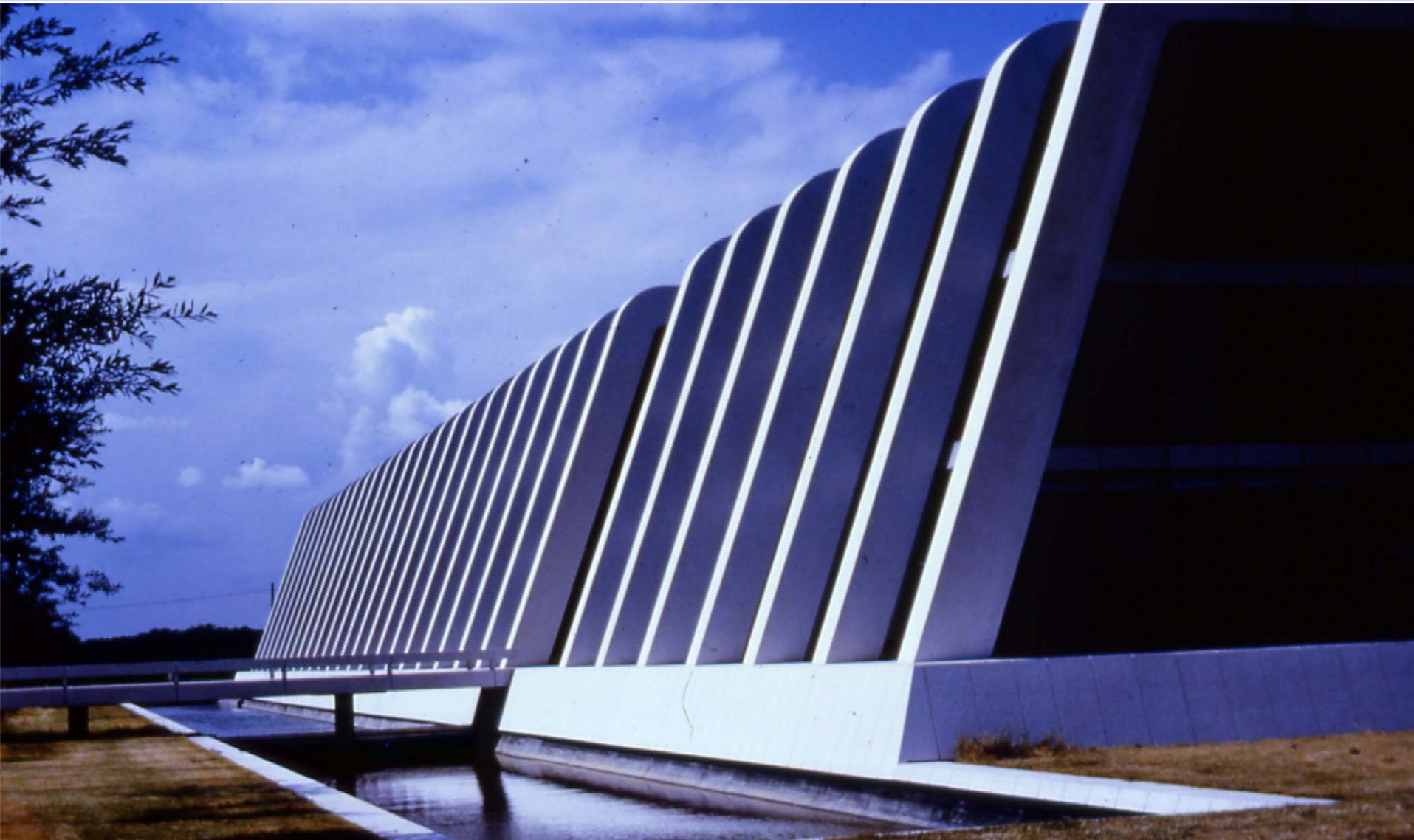





B4
B5
B5

cladding example (UK)

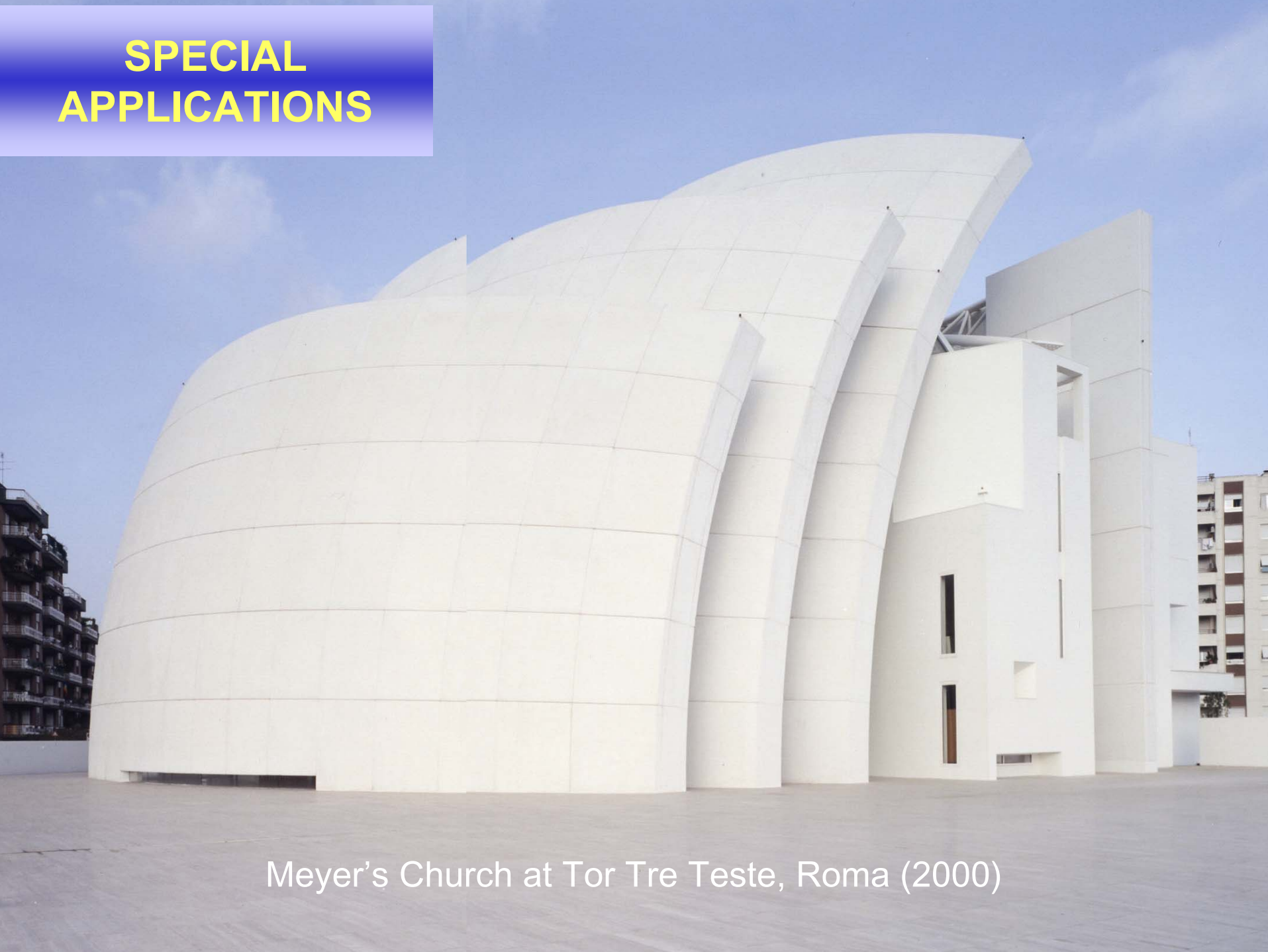
prize winner (UK)



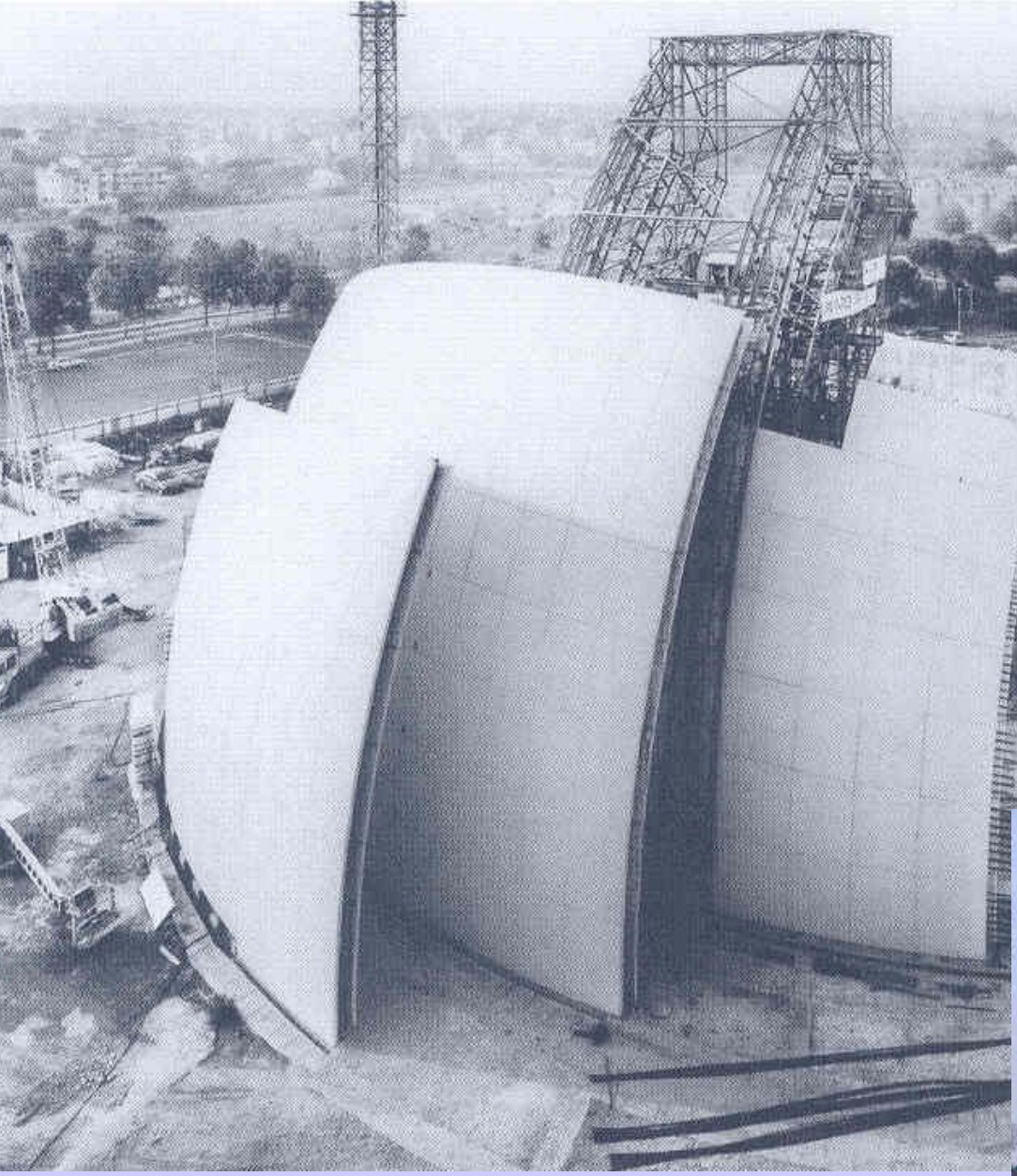
Split-wall façades (Be)

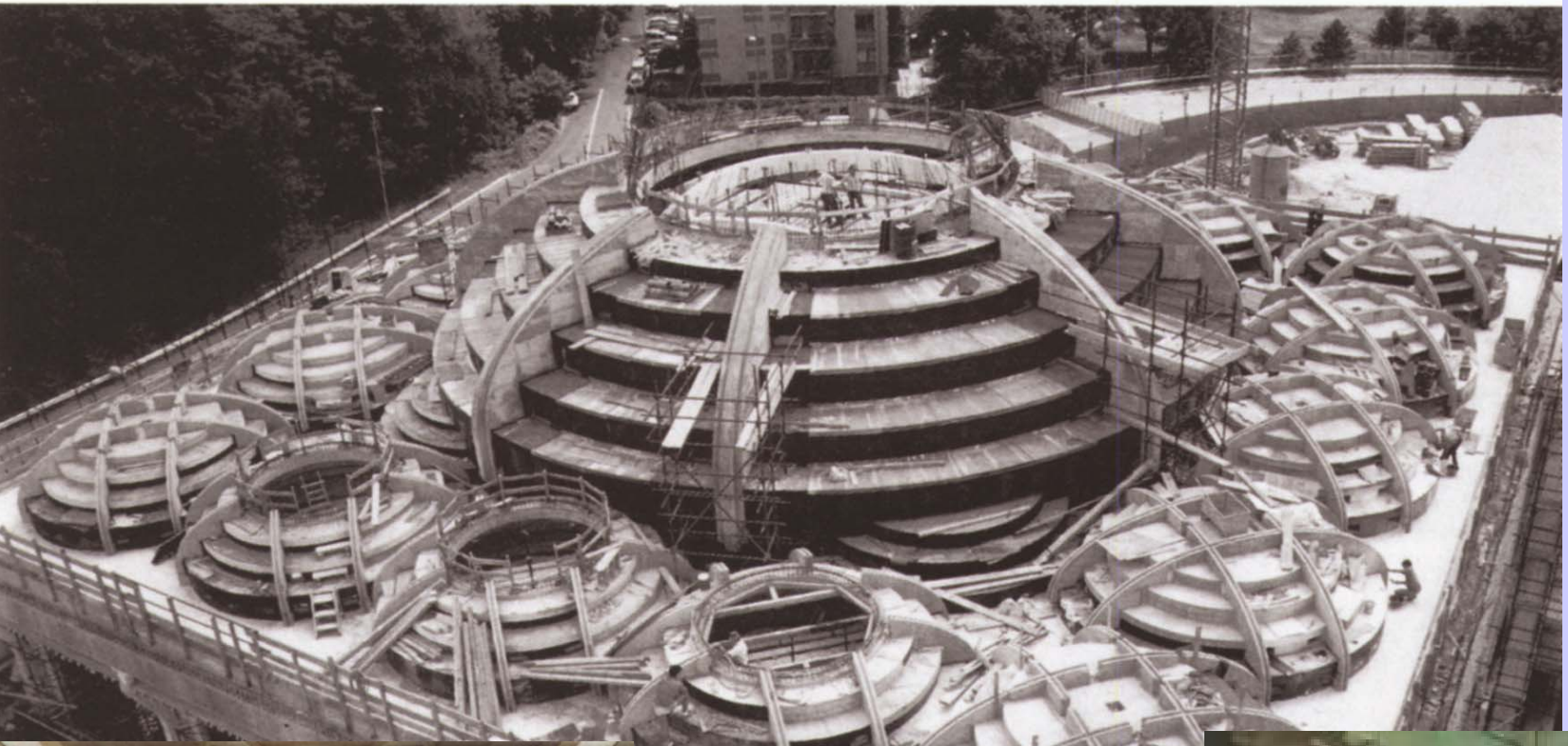
Outstanding prefabricated buildings today (NL)

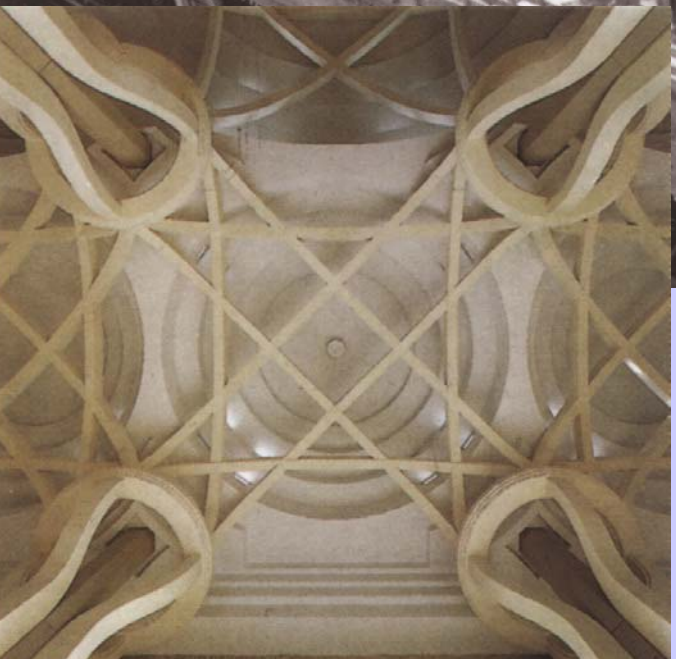
SPECIAL APPLICATIONS



Meyer’s Church at Tor Tre Teste, Roma (2000)







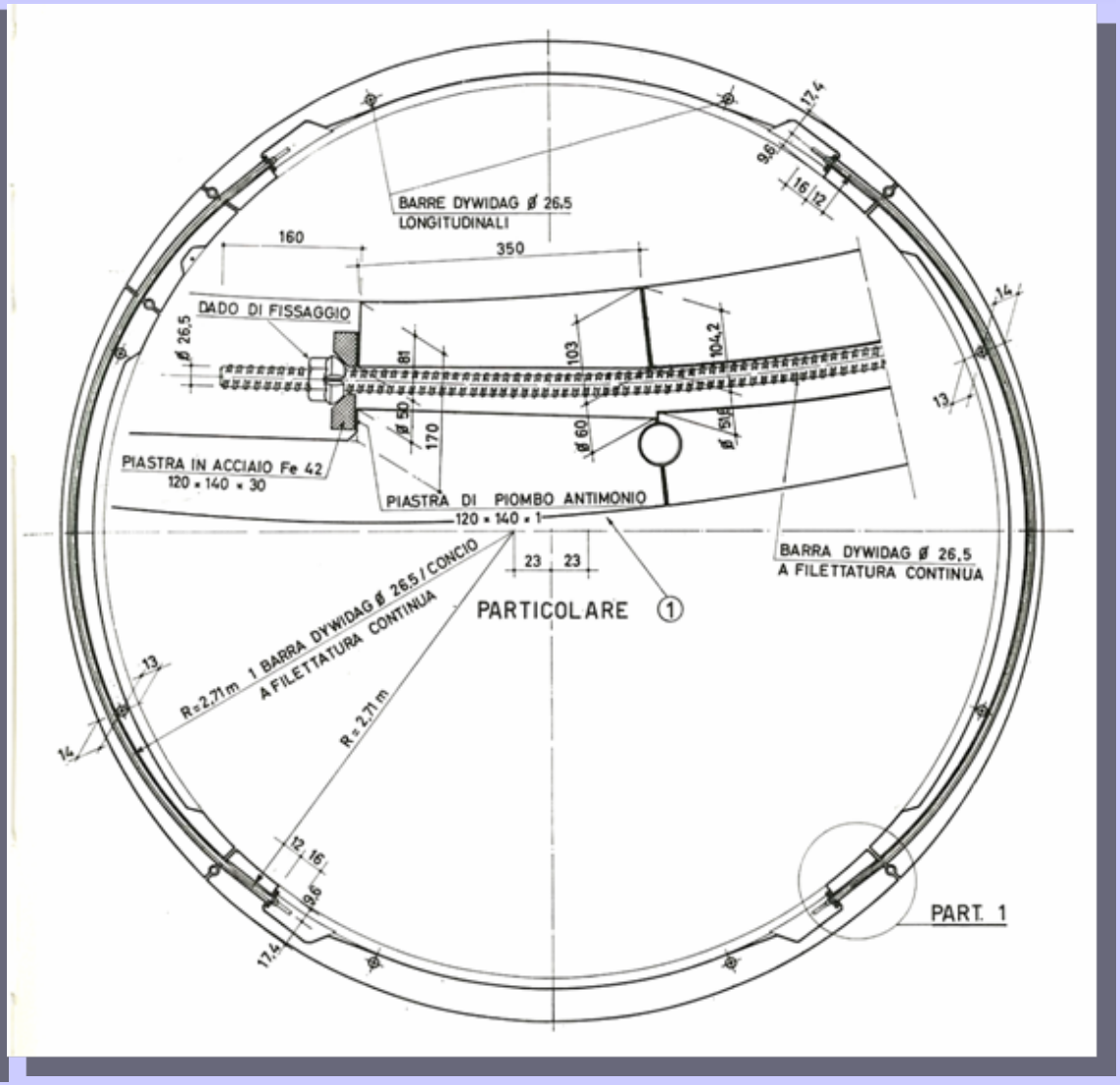
Mosque of Rome

(1980s)

Football Stadion Bari

HS Railway viaducts

TUNNELS LINING



Underground metro Roma - former system
multiple ring shapes, ribbed and prestressed at tunnel sides (1960s)

Underground metro Roma - present system
universal ring: single shape, tapered, for straight or curved in plan / elevation
solid, non prestressed (2009)


10.11.2008


PASCUCCI
PASCUCCI
22/6/2010 10:01


15/9/2010 16:39

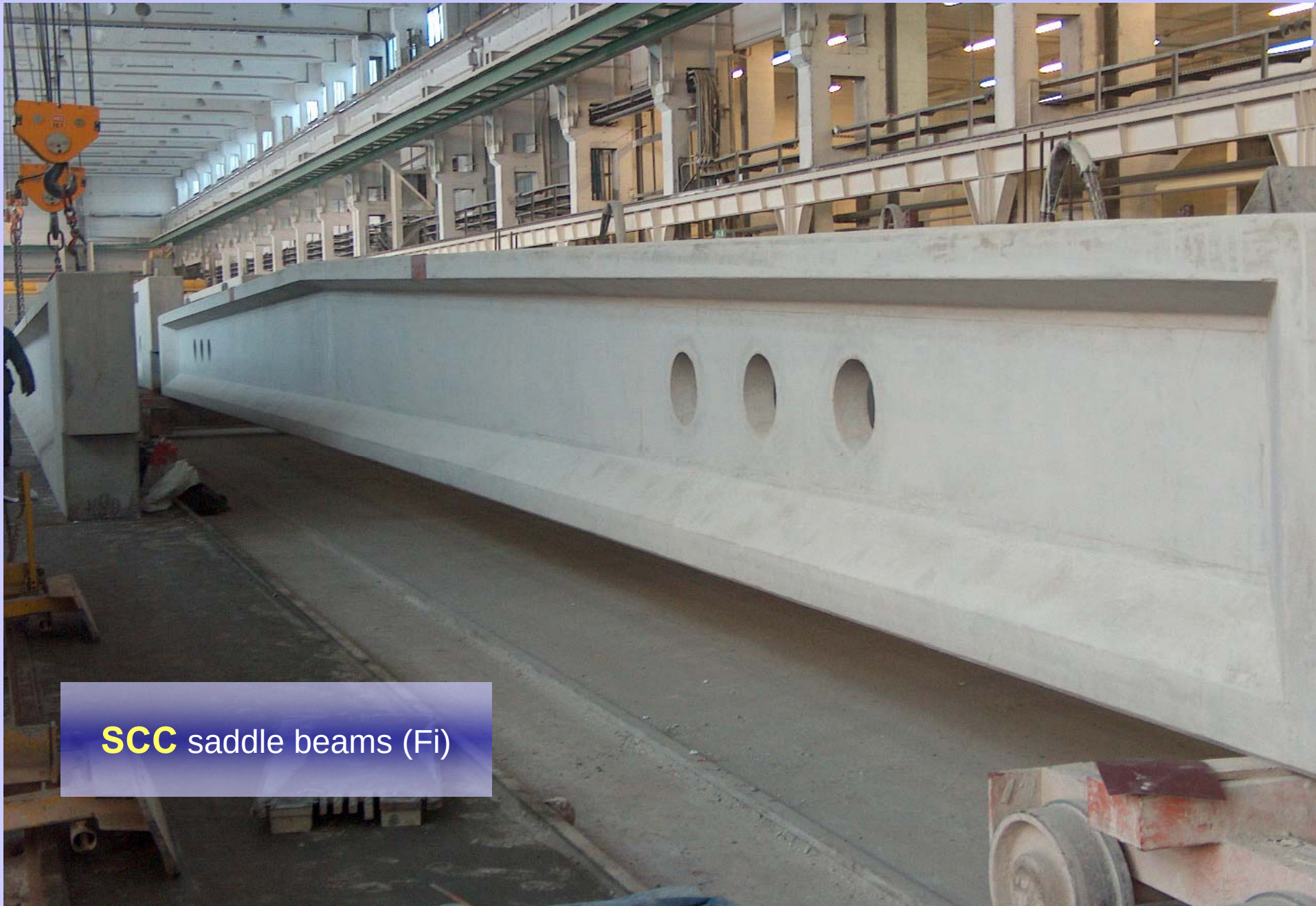

7/9/2010 11:24

ADVANCED MATERIALS

HSC precast columns (Be)

HSC
segmental
towers (Be)

ADVANCED MATERIALS



SCC saddle beams (Fi)

SCC precast arches (NL)

SCC precast sheet piles (NL)

STANDARDISATION

EUROPEAN COMMUNITY

EUROPEAN COMMITTEE FOR STANDARDISATION - CEN

role of ***fib***

Official Standards in Europe

Official standards for structural design in Europe

are still issued by the *National Authorities*

of the individual Countries, with different legal enforcement

A process of harmonization and unification is advanced, aimed at eliminating technical barriers among the member States

Structural Eurocodes (ECs) and other standards: common structural design rules

Subsequent editions of National Standards (NS) in all countries

are becoming closer and closer to the ECs

therefore among each other, too

Eurocodes can yet be adopted as NS by Countries,

implemented with limited sets of Nationally Determined Parameters (NDP)

related to safety levels or classes

in special National Annexes to each EC

CPD / CPR

Directive of the Council of the European Communities 89/106/EEC
"Construction Products Directive" (CPD)
now replaced by the "Construction Products Regulation" (CPR)

states that products placed on the market shall be "fit for the intended use"
i.e., such that the construction works they belong satisfy the
"Essential Requirements" (ER):

1 – MECHANICAL RESISTANCE AND STABILITY
2 – SAFETY IN CASE OF FIRE
3 – HYGIENE, HEALTH AND ENVIRONMENT
4 – SAFETY IN USE
5 – PROTECTION AGAINST NOISE
6 – SAVING OF ENERGY & THERMAL INSULATION
7 – SUSTAINABLE USE OF NATURAL RESOURCES

Task of Structural Eurocodes:
RULES to meet ER 1 and partly ER 2

1995-2005

Complete set of Eurocodes EN: a success,
the starting point having been some 30 National standardisation systems of different cultural political technical economical and language background!
however … they resent of a certain drafting by adding

2010

CEN received a new mandate (n. 446) for revising and redrafting the ECs
possibly easier to draft them more homogeneous and user-friendly

at present

“coexistence period” between NS and EC.

finally (2018?)
Eurocodes (with NDP) are deemed to replace totally all National Standards

Present Eurocodes

10 Eurocodes, each divided into several “Parts”

EN 1990	Basis of Structural Design	Eurocode 0	EC0
EN 1991	Actions on Structures	Eurocode 1	EC1
EN 1992	Design of Concrete Structures	Eurocode 2	EC2
EN 1993	Design of Steel Structures	Eurocode 3	EC3
EN 1994	D of Composite S+C Structures	Eurocode 4	EC4
EN 1995	Design of Timber Structures	Eurocode 5	EC5
EN 1996	Design of Masonry Structures	Eurocode 6	EC6
EN 1997	Geotechnical Design	Eurocode 7	EC7
EN 1998	D o Struct’s for EQ Resistance	Eurocode 8	EC8
EN 1999	Design of Aluminum Structures	Eurocode 9	EC9

Total number of Parts forming the Eurocodes: 58

Possible new Eurocodes envisaged, e.g.:

EN xxxx	Glass structures
EN yyyy	Existing structures assessing / retrofitting
EN …	

Product Standards & **Technical Approvals**

Beside Eurocodes, dealing with *construction works*
CEN also issues specific **Product Standards** (**PS**), which are *harmonised* European Standards (hEN):
once approved by majority they become mandatory in all Countries who shall withdraw possible conflicting NS

Particular products not falling into the scope of a CEN TC
can be given an **European Technical Approval** (ETA) ,
following specific procedure established by EOTA

Possible aspects in PS or ETA concerning structural safety (ER1)
must agree or be consistent with the relevant EC

Both PS and ETA
can be reference and provide conditions for the "**CE Marking**"
official attestation of conformity to the ERs.

STANDARDS hENs FOR PRECAST CONCRETE PRODUCTS

after request from

BIBM – BUREAU INTERNATIONAL DU BETON MANUFACTURÉ

to

CEN – EUROPEAN COMMITTEE FOR STANDARDIZATION

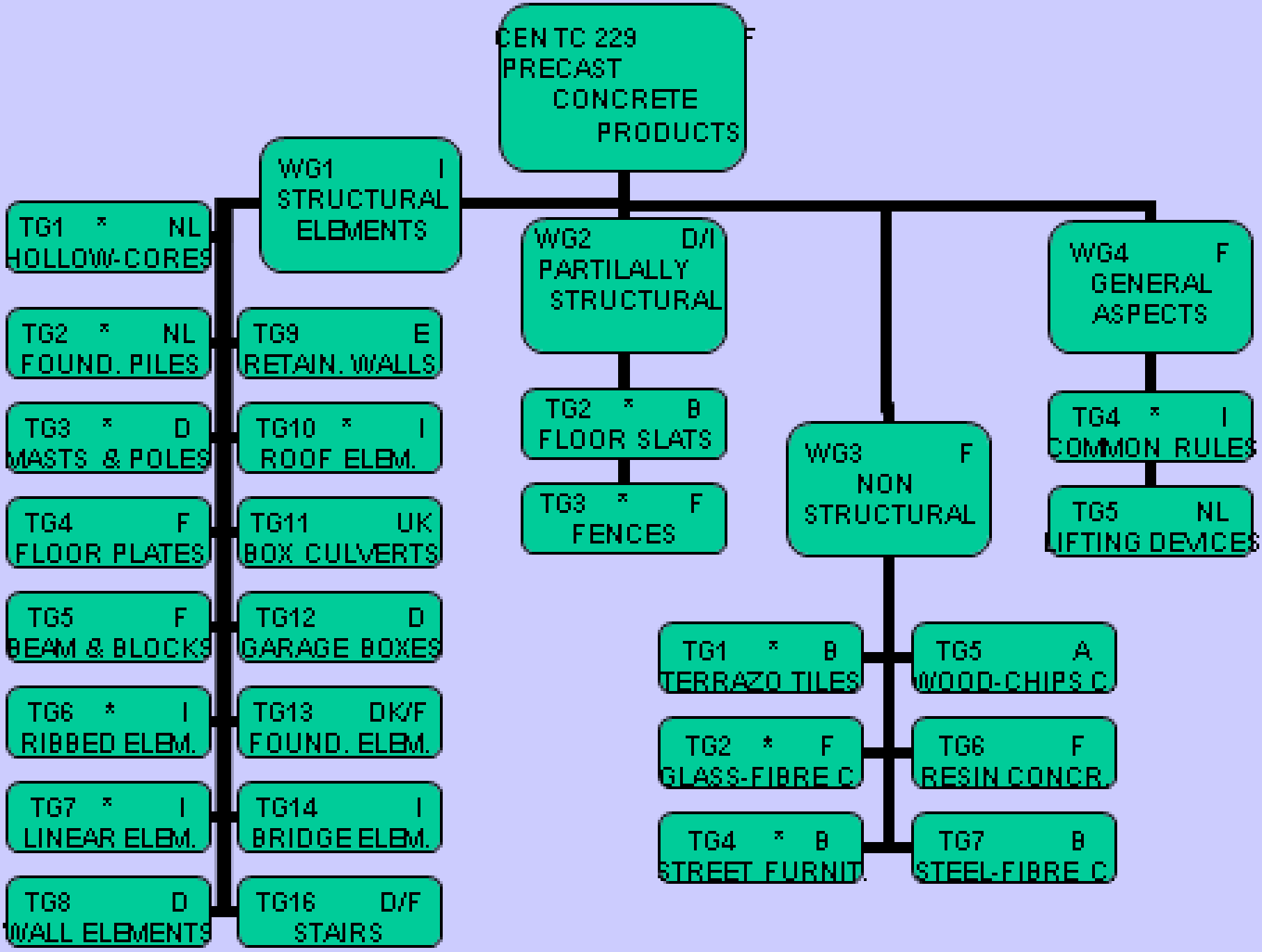
for a dedicated Technical Committee

CEN TC 229: PRECAST CONCRETE PRODUCTS

started 1989 (Mandate M100)

Program is almost completed

since 2007, corresponding provisions in NS are being withdrawn


CEN TC 229 F
PRECAST
CONCRETE
PRODUCTS
WG1 I
STRUCTURAL
ELEMENTS
WG2 D/I
PARTIALLY
STRUCTURAL
WG3 F
NON
STRUCTURAL
WG4 F
GENERAL
ASPECTS
TG1 * NL
HOLLOW-CORES
TG2 * NL
FOUND. PILES
TG3 * D
MASTS & POLES
TG4 F
FLOOR PLATES
TG5 F
BEAM & BLOCKS
TG6 * I
RIBBED ELEM.
TG7 * I
LINEAR ELEM.
TG8 D
WALL ELEMENTS
TG9 E
RETAIN. WALLS
TG10 * I
ROOF ELEM.
TG11 UK
BOX CULVERTS
TG12 D
GARAGE BOXES
TG13 DK/F
FOUND. ELEM.
TG14 I
BRIDGE ELEM.
TG16 D/F
STAIRS
TG2 * B
FLOOR SLATS
TG3 * F
FENCES
TG1 * B
TERRAZO TILES
TG2 * F
GLASS-FIBRE C.
TG4 * B
STREET FURNIT.
TG5 A
WOOD-CHIPS C.
TG6 F
RESIN CONCR.
TG7 B
STEEL-FIBRE C.
TG4 * I
COMMON RULES
TG5 NL
LIFTING DEVICES

hENs on structural precast concrete products

Name	Title	Date of Availability	Withdraw National Standard
EN 1168:2005 EN 1168+A1:2008 EN 1168+A2:2009	Hollow Core Slabs	01/03/2006 01/01/2009 01/12/2009	01/03/2008 01/01/2010 01/12/2010
EN 12737+A1:2007	Floor Slats for livestock	01/01/2009	01/01/2010
EN 12794:2005 EN 12794+A1:2007 EN 12794+A1+AC:2008	Foundation Piles	01/01/2006 01/02/2008 01/08/2009	01/01/2008 01/02/2009 01/08/2009
EN 12839:2001	Fences	01/03/2002	01/03/2003
EN 12843:2004	Masts and Poles	01/09/2005	01/09/2007
EN 13224:2004 EN 13224+A1:2007	Ribbed Elements	01/09/2005 01/03/2008	01/09/2007 01/03/2009
EN 13225:2004 EN 13225+AC:2006	Linear Elements	01/09/2005 01/01/2008	01/09/2007 01/01/2008

hENs on structural precast concrete products (cont'd)

Name	Title	Date of Availability	Withdraw National Standard
EN 13693:2004	Special Roof Elements	01/06/2005	01/06/2007
EN 13747:2005 EN 13747+AC:2006 EN 13747+A1:2008	Floor Planks	01/05/2006 01/01/2008 01/08/2009	01/05/2008 01/01/2008 01/08/2010
EN 13978-1:2005	Box Garages	01/03/2006	01/03/2008
EN 14843:2007	Stairs	01/01/2008	01/01/2009
EN 14844:2006 EN 14844+A1:2008	Box Culverts	01/05/2007 01/08/2009	01/05/2008 01/08/2010
EN 14991:2007	Foundation Elements	01/01/2008	01/01/2009
EN 14992:2007	Wall elements	01/01/2008	01/05/2010
EN 15037-1:2008	Beams for beam-block systems	01/01/2010	01/01/2011
EN 15050:2007	Bridge Elements	01/02/2008	01/02/2009
EN 15258:2008	Retaining Walls	01/01/2010	01/01/2011

hENs on structural precast concrete products under way

Name	Title	Date of Availability	Withdraw National Standard
EN 15037-2:2009	Concrete blocks for beam-block systems		
EN 15037-3:2009	Clay blocks for beam-block systems		
EN 15037-4:2010	Polistyrene blocks for beam-block systems		
EN 15037-5:	Lightweight blocks for beam-block systems		

EN 13369: COMMON RULES
for PRECAST CONCRETE PRODUCTS

resume the clauses valid for all standards

represent a **reference for all Precast Concrete PS**

as well as for Products lacking a specific standard

it is not hEN but items recalled in a hEN become there harmonised

CONTENT

Some Standards on Precast Concrete Products by other CEN TCs

CEN TC177

Standards under Mandate M100:

EN 1520:2002

Prefabricated reinforced components of lightweight aggregate concrete with open structure

Pr EN 12602:

Prefabricated reinforced components of autoclaved aerated concrete

CEN TC 50

Standard under Mandate M111 (road equipment):

EN 40-4:2005 – Lighting columns - Part 4:

Requirements for reinforced / prestressed concrete lighting columns

INTERACTION BETWEEN PRECAST CONCRETE hENs and EUROCODES ENs

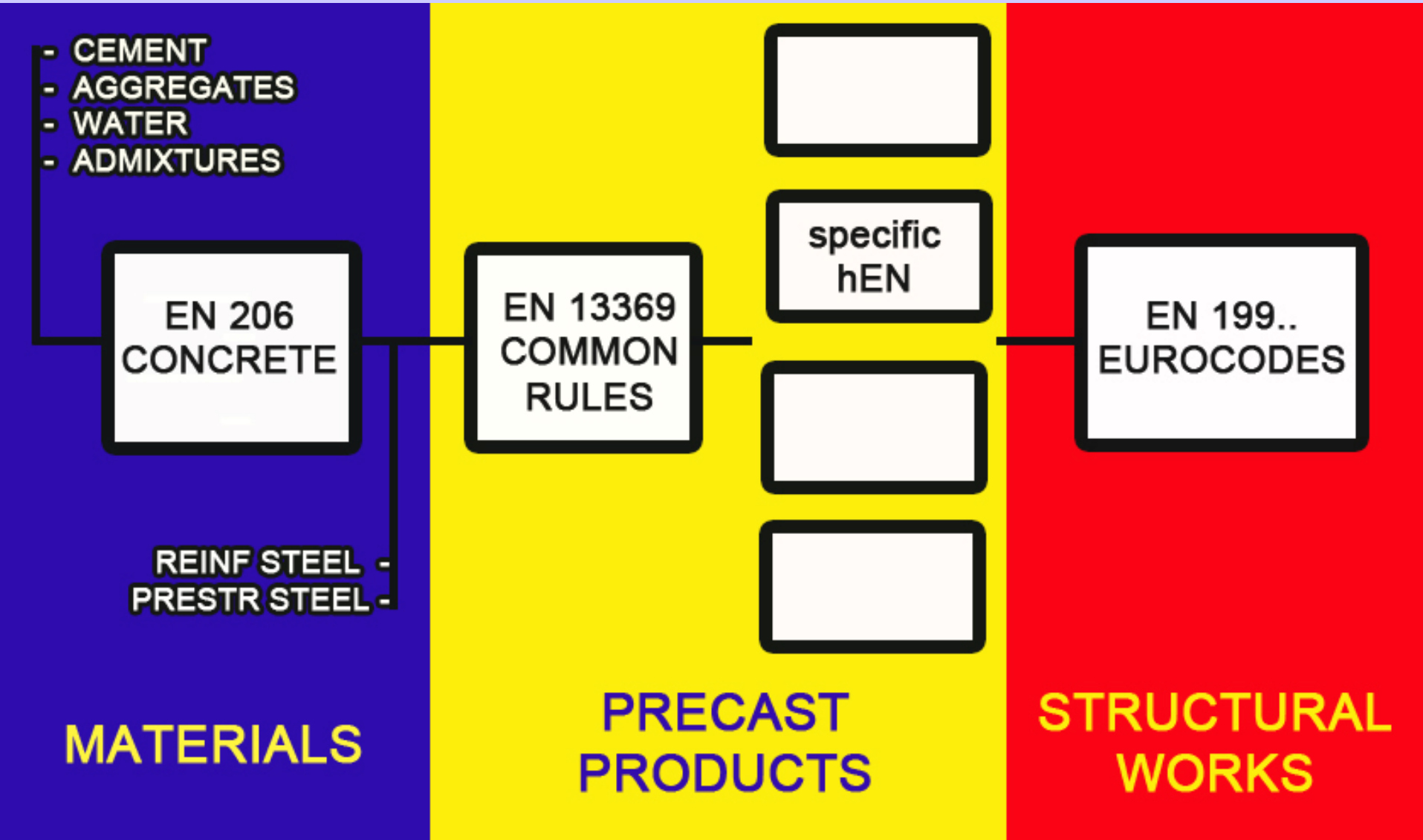
hENs MAKE REFERENCE to ECs
for structural design requirements

hENs add SPECIAL ANNEXES
for specific design rules not covered by ECs

ECs add SPECIFIC RULES
following TC229 liaison request

AdHocGroup TC250 / TC229 checks
hENs and ECs FINAL DRAFTS for CONSISTENCY

DESIGN PATH FOR PRECAST STRUCTURES



the role of *fib* (CEB-FIP 1998 merger)

fib inherited the activities of **CEB** and **FIP** (both founded in the early 1950s) who made them converge into a common forum the research into concrete developed since the beginning of 20th century in Europe and worldwide by National associations and scientific institutions

fib keeps promoting and coordinating research and pre-normative work by means of its 10 Commissions, with about 40 TG and about 10 SAG

fib edits technical publications in form of *Bulletins* of various levels: Model Codes, Recommendations, Guides or Manuals, SoA Reports, Technical Reports and a quarterly Journal "*Structural Concrete*".

With its predecessors, ***fib*** has played and plays important role in structural standardization, particularly in Europe.
Mainly Eurocode 2 but also EC0, EC1 and EC8,
as well as Precast Concrete PS, would haven't been possible without CEB/FIP/***fib*** preparatory studies and pre-normative documents

In parallel to the start of
PREFABRICATION INDUSTRY and R&D

1955 – birth of

FIP Commission "Prefabrication"

1998 – CEB-FIP merger into ***fib***

(International Federation for Structural Concrete)

***fib* Commission 6 "Prefabrication"**

membership from 30 Countries of 5 Continents
fruitful and friendly cooperation of
Profession, Industry, University

2011– 40 activemembers working in

Aims

to enhance the progress of Precast Concrete:
stimulate, promote, coordinate R&D internationally
to disseminate knowledge:
Seminars, Courses, Educational material,
SoA Reports, Guides to Good Practice, Technical Reports
to contribute to Recommendations, Pre-normative, Codes

Scope

Subjects ***directly*** related to Precast Concrete:
elements, connections, systems, production, handling, assembling, demounting, …

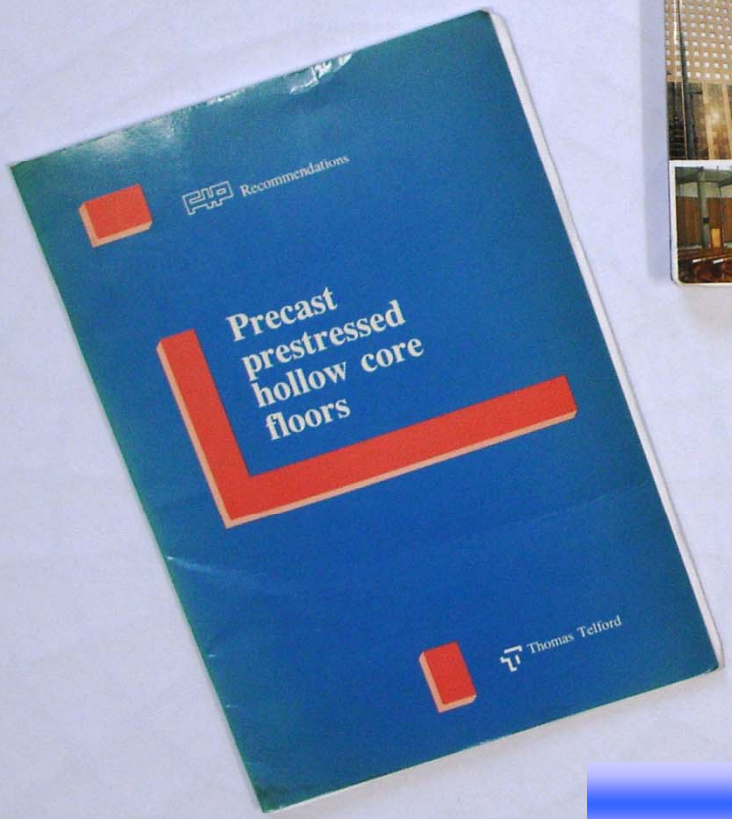
as well as ***indirectly*** related:
materials technology, structural analysis, building physics, equipment, sustainable development, …

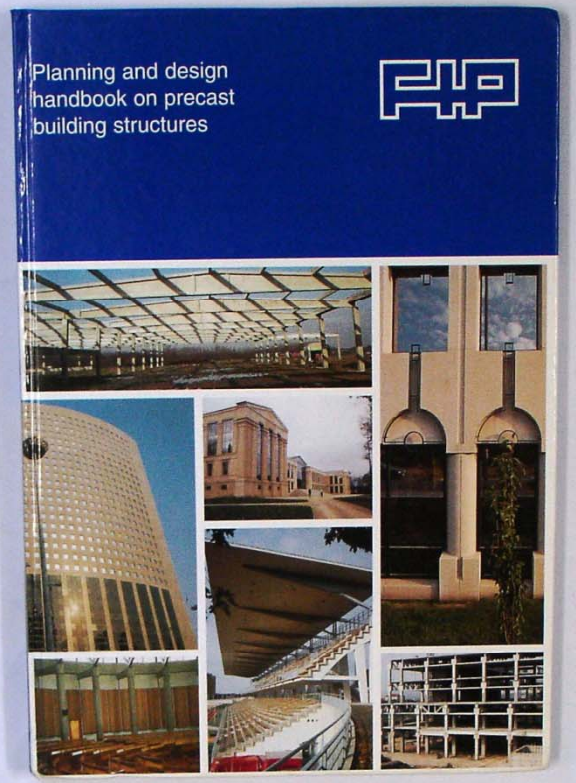
Areas of Interest

Structural efficiency
Flexibility in use
Best use of materials
Speed of construction
Quality consciousness
Durability
Friendliness toward environment
Sustainability
Life-cycle design

COMMISSION'S 6 TASK GROUPS

6.1 Prestressed Hollow-Core Floors
6.2 Structural Connections
6.3 P/C in Mixed Construction (dis)
6.4 Precast Bridges (dis)
6.5 P/C Railway Track Systems (dis)
6.6 New Model Code
6.7 Affordable Housing
6.8 Treatment of Imperfections in P/C Elements (dis)
6.9 Design of P/C Building Structures for Accidental Loading
6.10 Design Provisions for Moderate Seismic Areas
6.11 P/C Sandwich Panels
6.12 New Handbook
6.13 Quality Control for P/C
+ Activity in other Commissions' TGs:
e.g., Environment, Seismic, …





publications

Commission's Publications within FIP

GGP: Recommendations for Segmental Construction in Prestressed Concrete, FIP/9/1, Feb 1978

TR: Proposal for a Standard for Acceptance and Verification of Epoxy Bonding Agents for Segmental Construction, FIP/9/2, March 1978

TR: Bridge Decks with Pretensioned Precast Beams, FIP/9/3, August 1978

TR: Shear at the Interface of Precast and In-situ Concrete, FIP/9/4, August 1978

TR: Losses of Prestress in Tendons due to Steam Curing of Concrete, FIP/5/5, September 1978

GGP: Shear at the Interface of Precast and In-situ Concrete, FIP/9/6, January 1982

GGP: Design, Manufacture and Erection of Architectural Concrete Elements, FIP/9/5, February 1982

GGP: Acceleration of Concrete Hardening by Thermal Curing, FIP/9/7, March 1982

TR: Design Philosophy for Precast Buildings of Two or More Storeys, FIP/9/8, June 1982

TR: Ductility of Tie Connections for Concrete Components in Precast Structures, FIP/9/9, Oct 1982

TR: Design Principles for Hollow-Core Slabs regarding Shear, Transverse Load-bearing Capacity, Splitting and Quality Control, FIP/9/10, October 1982

FIP SoA: Prefabricated Thin-Walled Concrete Units, Th. Telford, London, 1984

FIP Rec: Design of Multi-Storey Precast Concrete Structures, Th. Telford, London, 1986

FIP TR: Precast Concrete Piles, Th. Telford, London, 1986

FIP SoA: Concrete Railway Sleepers, Th. Telford, London, 1987

FIP Rec: Precast Prestressed Hollow-Core Floors, Th. Telford, London, 1988

FIP HB: Planning and Design of Precast Building Structures, SETO Ltd, London, 1994

FIP Rec: Design of Thin-Walled Units, *fib*, May 1998

FIP GGP: Composite Floor Structures, *fib*, May 1998

Commission's Publications within *fib*

GGP: Special Considerations for Precast Prestressed Hollow-Core Floors
fib Bulletin 6, Jan 2000

SoA: Precast Concrete in Mixed Construction, ***fib*** Bulletin 19, June 2002

SoA: Environmental Issues in Prefabrication, ***fib*** Bulletin 21, January 2003

SoA: Seismic Design of Precast Building Structures, ***fib*** Bulletin 27, Oct 2003
(**by C7**, with contribution of C6)

SoA: Precast Concrete Bridges, ***fib*** Bulletin 29, November 2004

SoA: Precast Concrete Railway Track Systems, ***fib*** Bulletin 37, Sept 2006

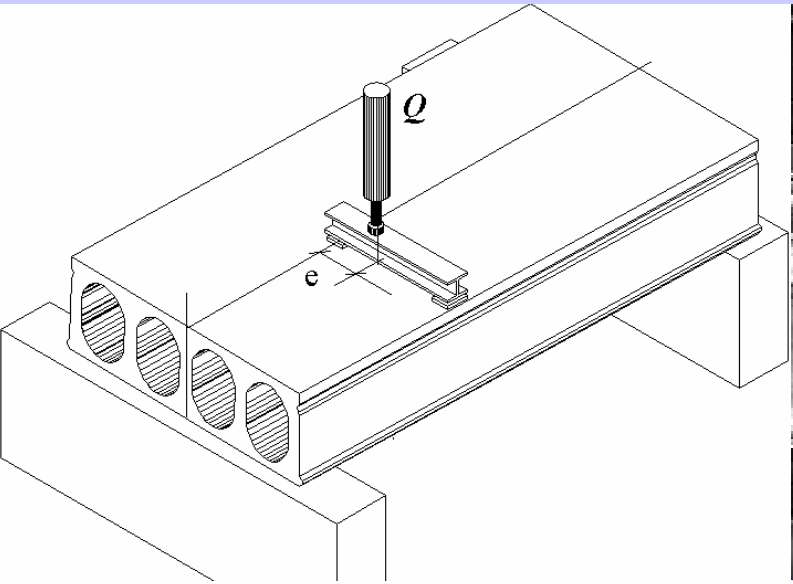
SoA: Treatment of Imperfections in Precast Structural Elements, ***fib*** Bull 41, Nov 2007

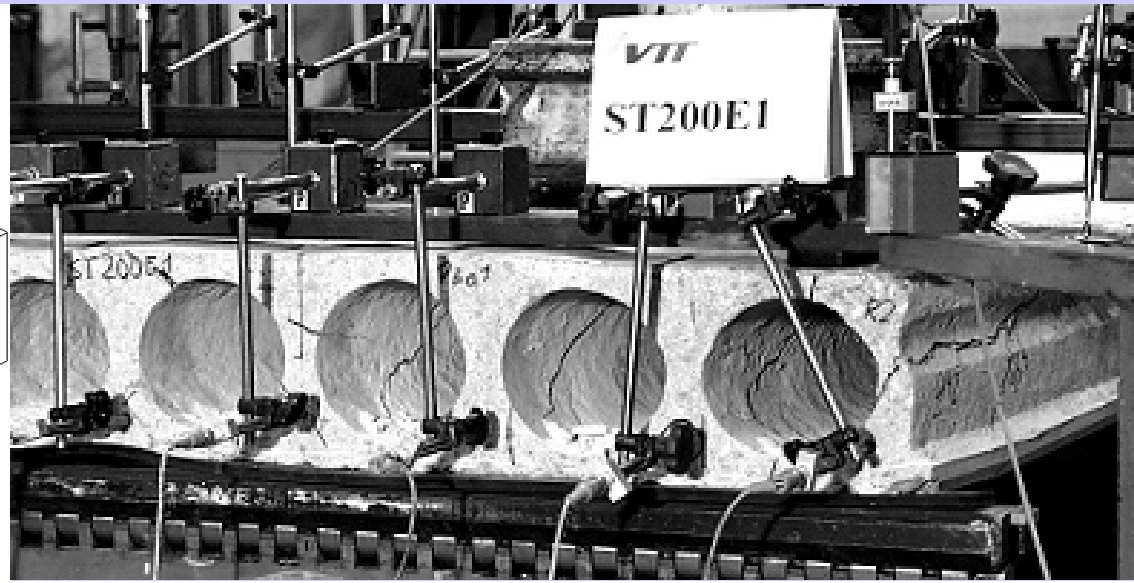
GGP: Structural Connections for Precast Concrete Buildings, ***fib*** Bulletin 43, Feb 2008

SoA: Prefabrication for Affordable Housing, ***fib*** Bulletin 60, Aug 2011

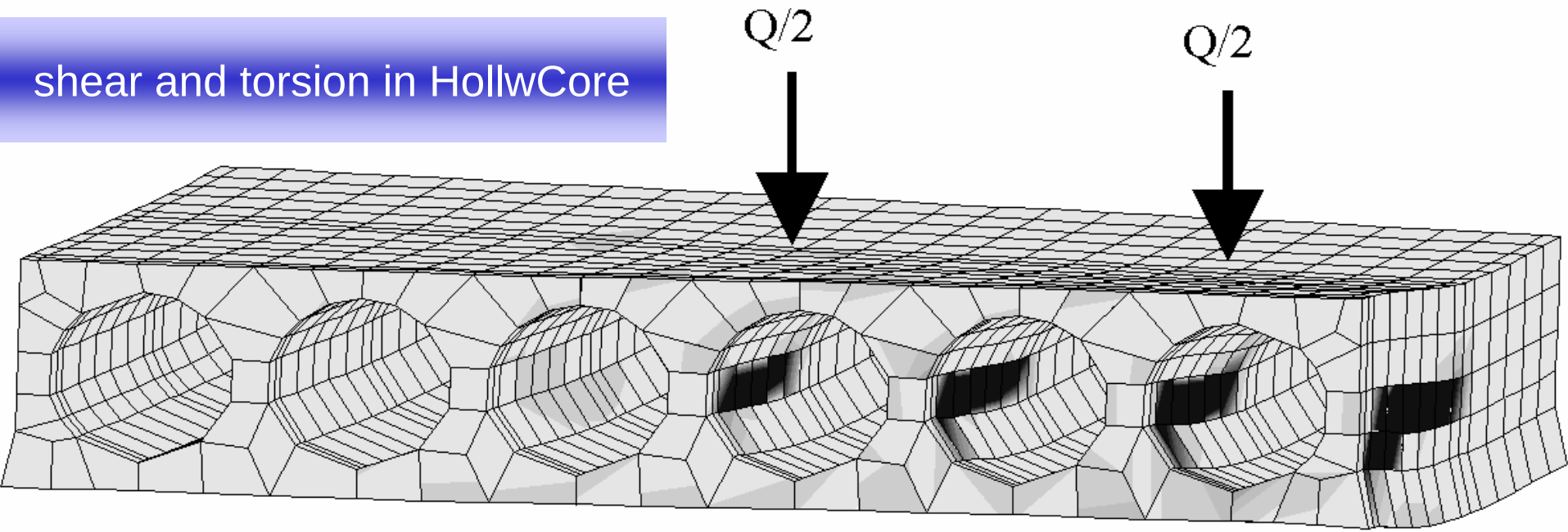
GGP: Design of Precast Structures against Accidental Actions, ***fib*** Bulletin xx, (2012)

TG Hollow-Core Slabs

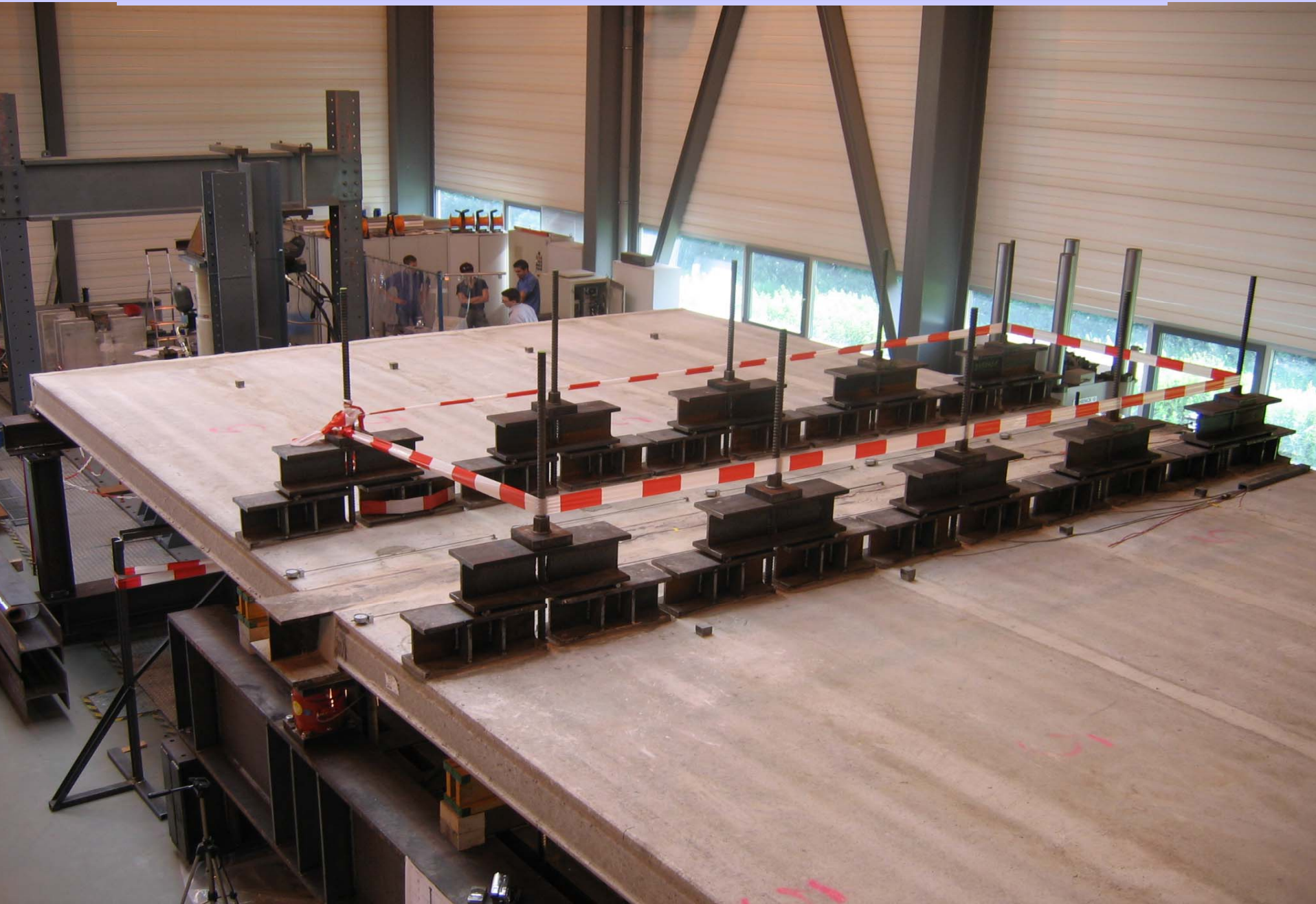




shear and torsion in HollwCore

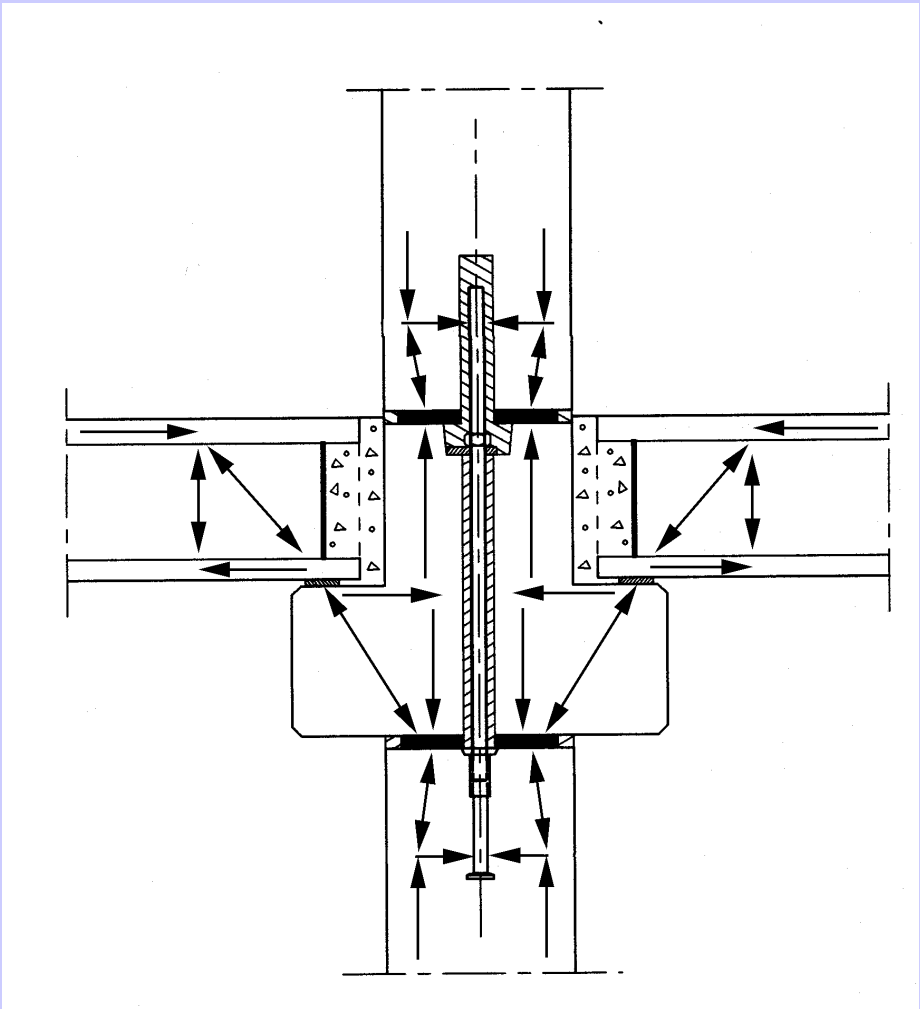


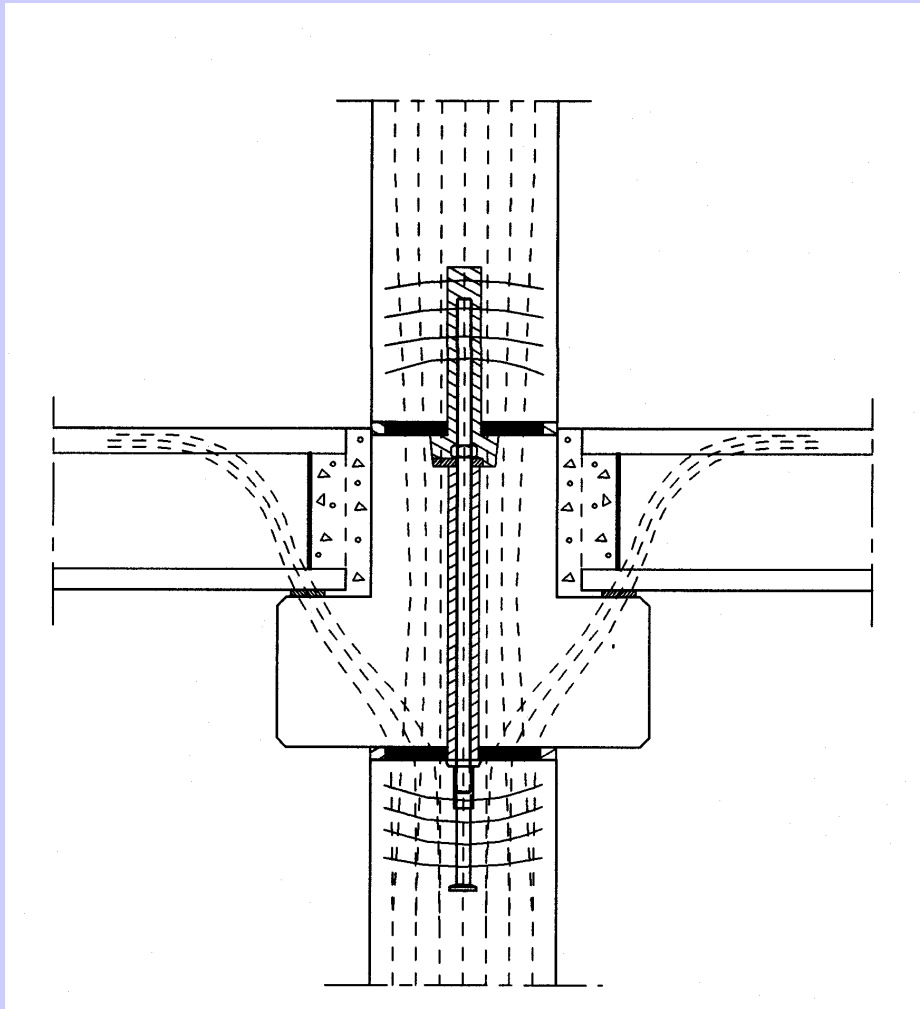
Hollow Core Slabs on Flexible Supports



Innovation
in Production

TG Connections





TG Mixed Construction

precast concrete and steel profiles
segmental post-tensioned beam

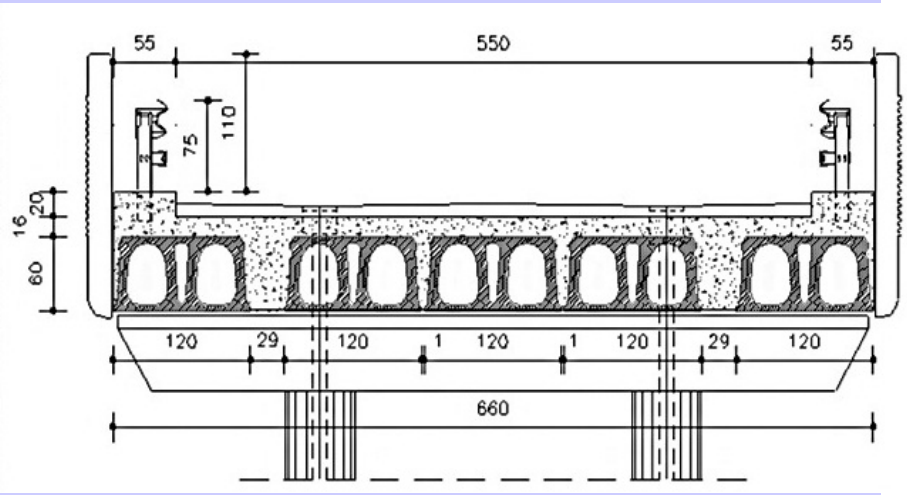
with c-i-s concrete

with steelwork

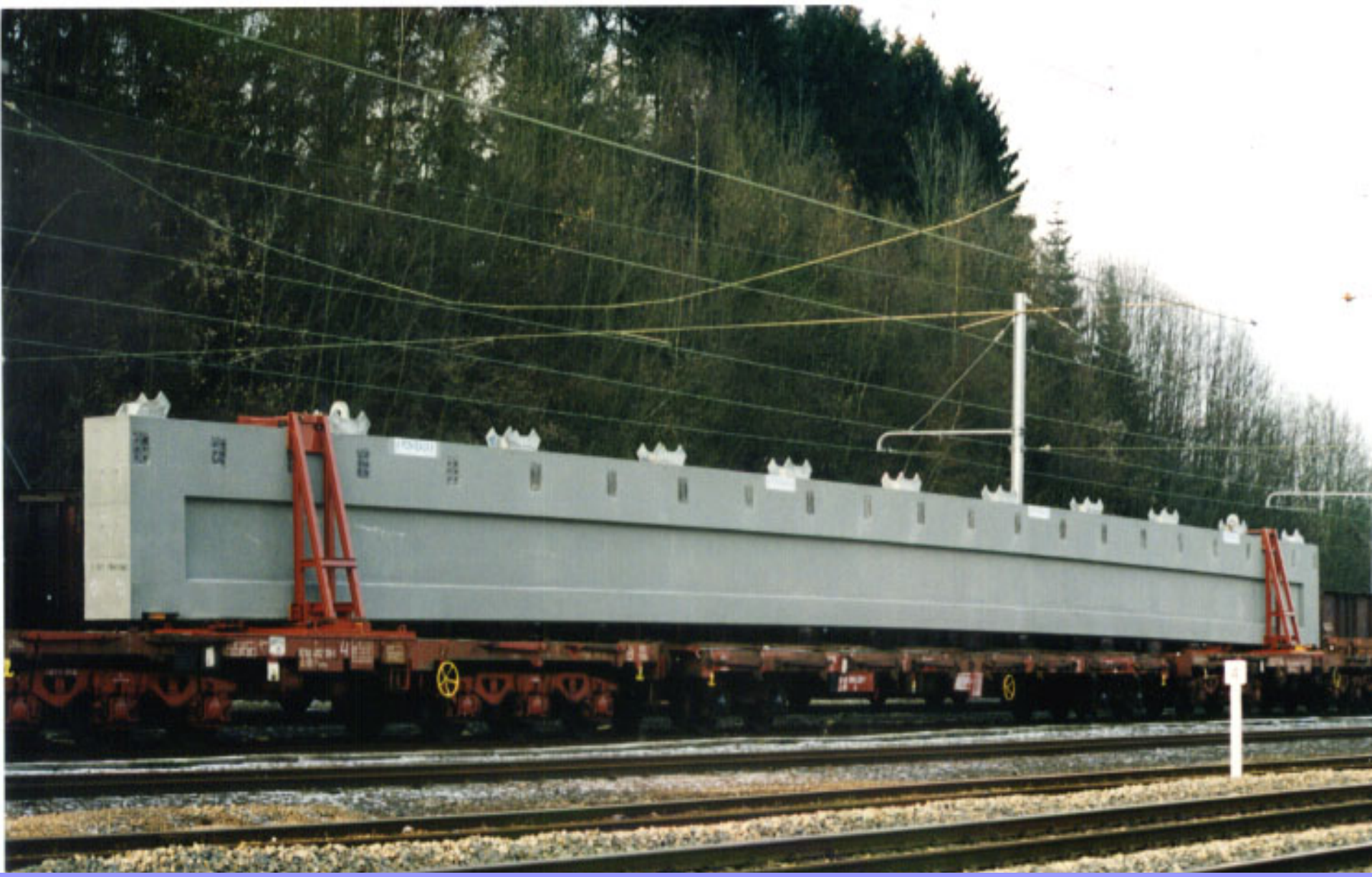
with timber + others

TG Precast Bridges


C.I.L.T.
GENOVA


55
550
55
75
110
16
20
60
120
29
120
1
120
1
120
29
120
660

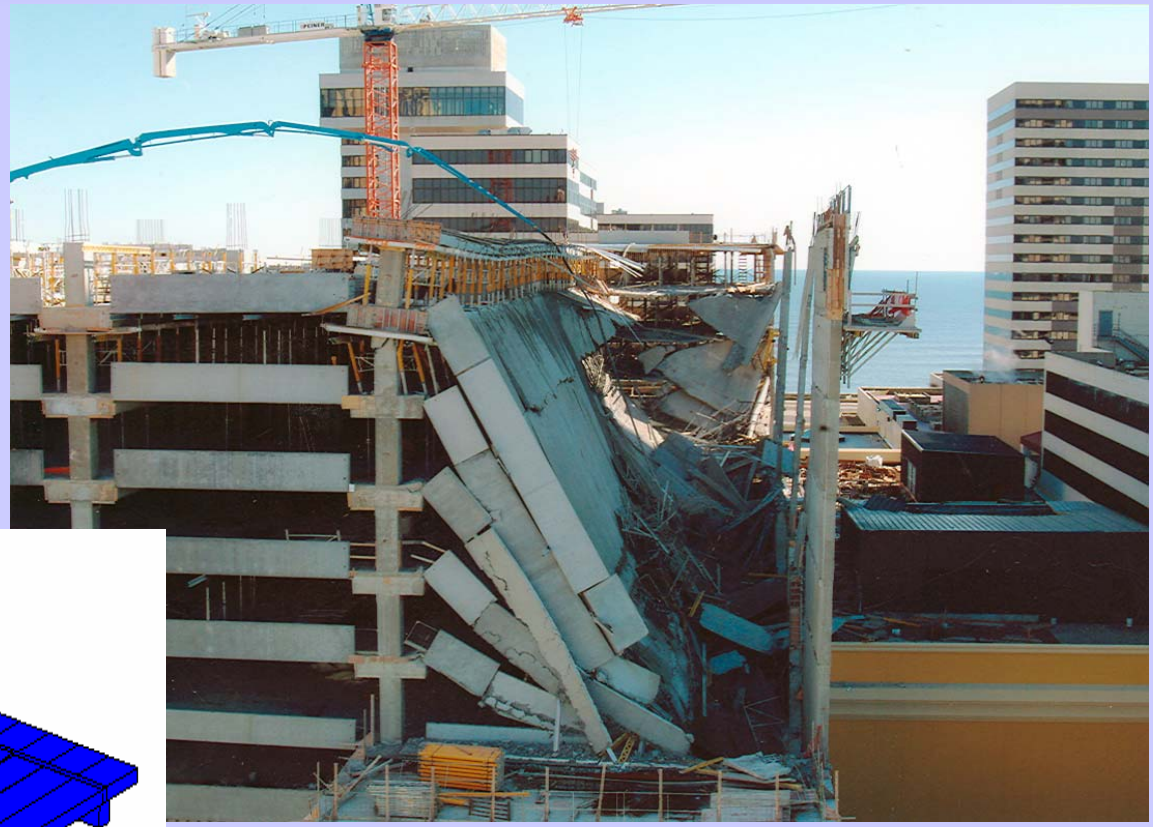
Travi in cap prefabbricato (fino a 40-45m)

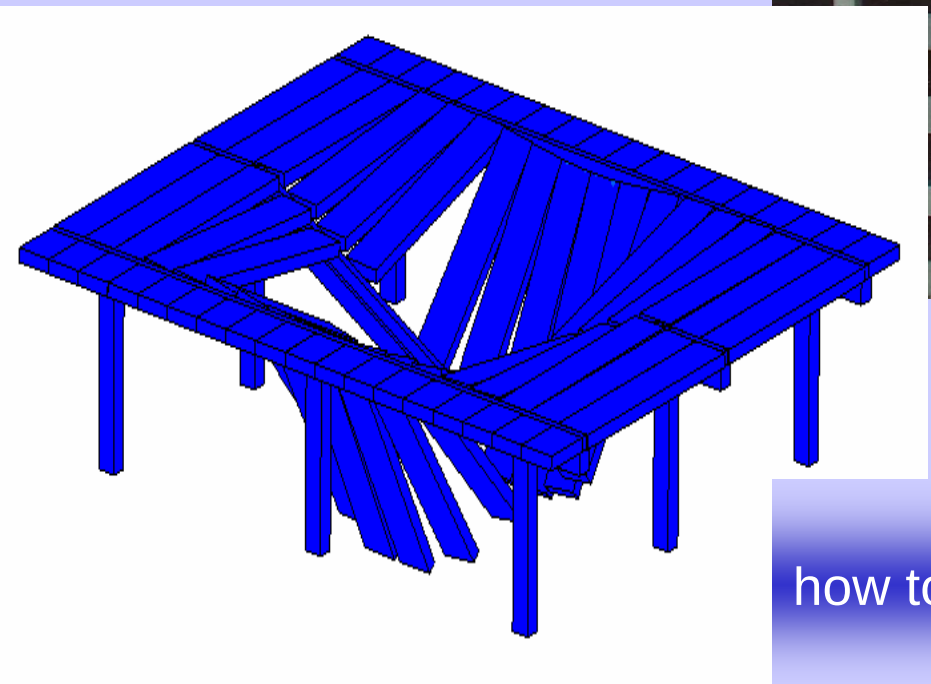


precast HSC beams (Be)

TG Railway Track Systems

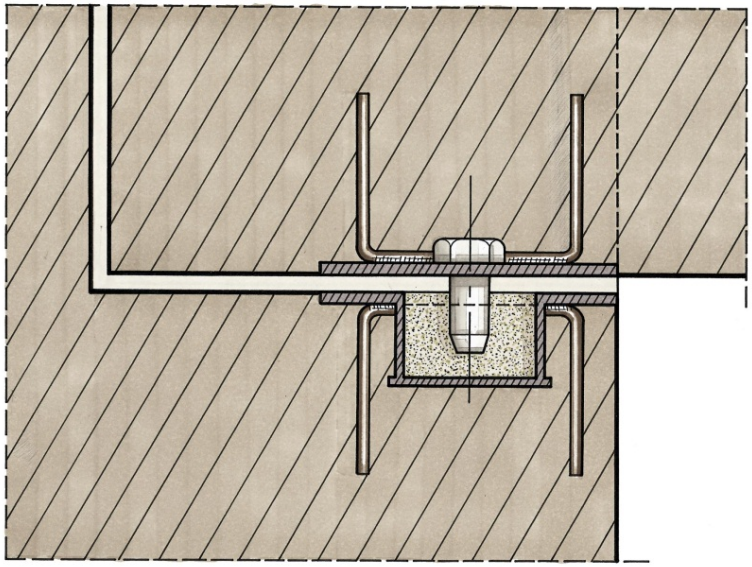
TG Accidental Actions

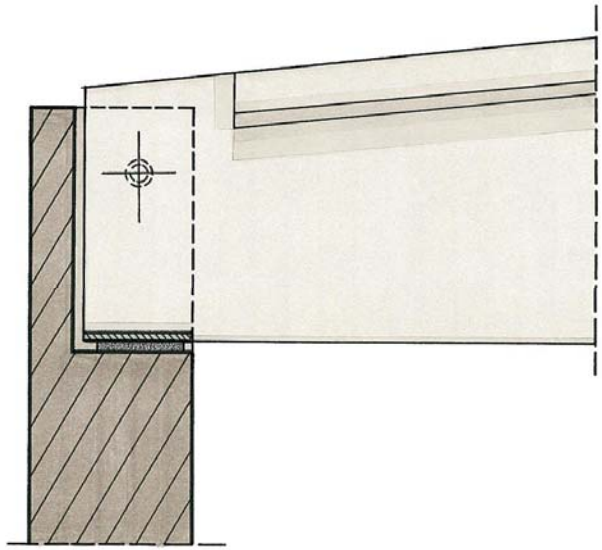


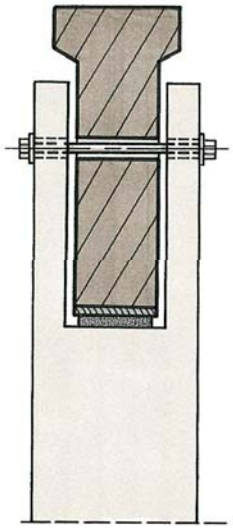


how to mitigate the risk of progressive collapse

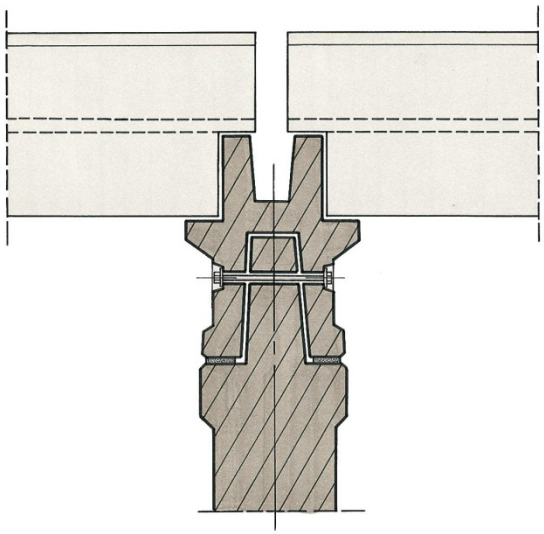
TG Structures in Seismic Areas

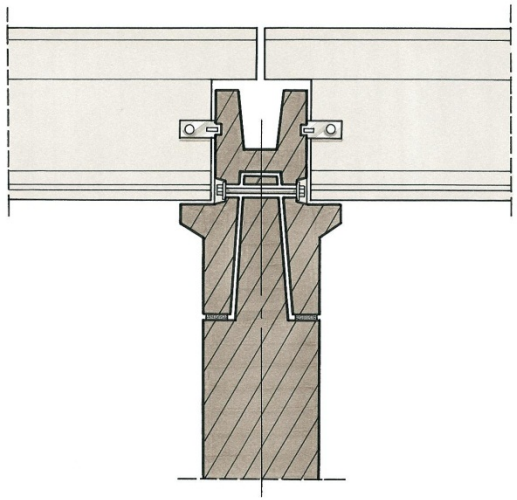


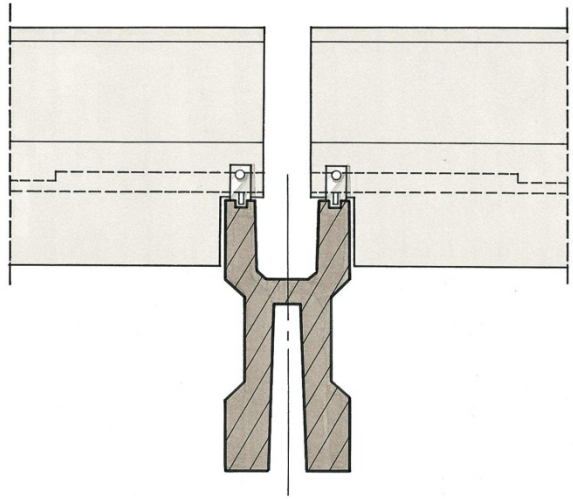




retainers





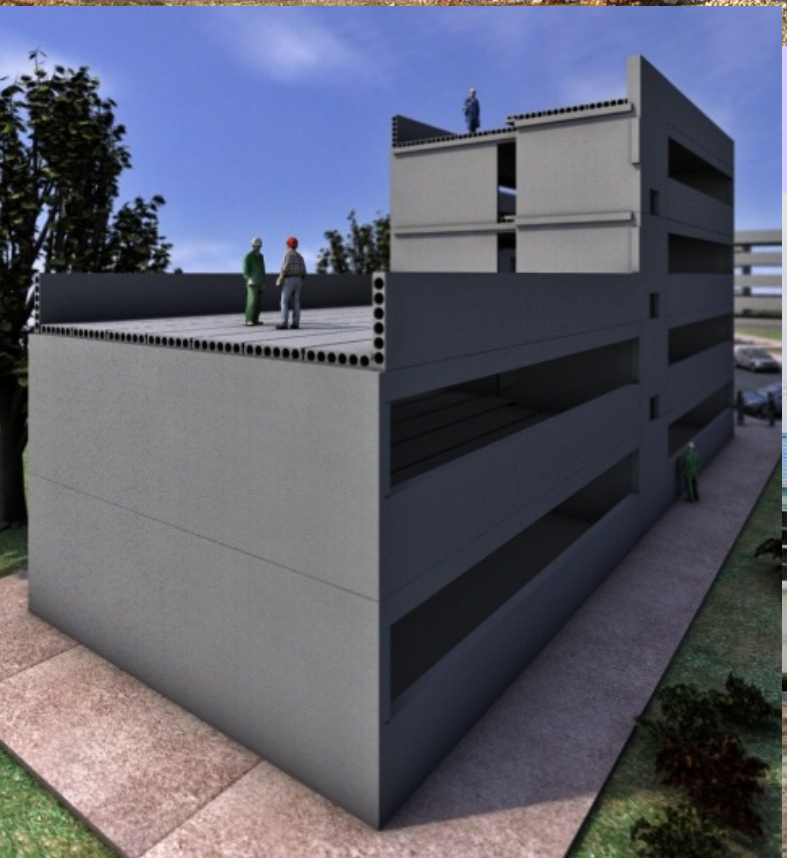


seismic action on precast frames...

postensioned joints (rocking)

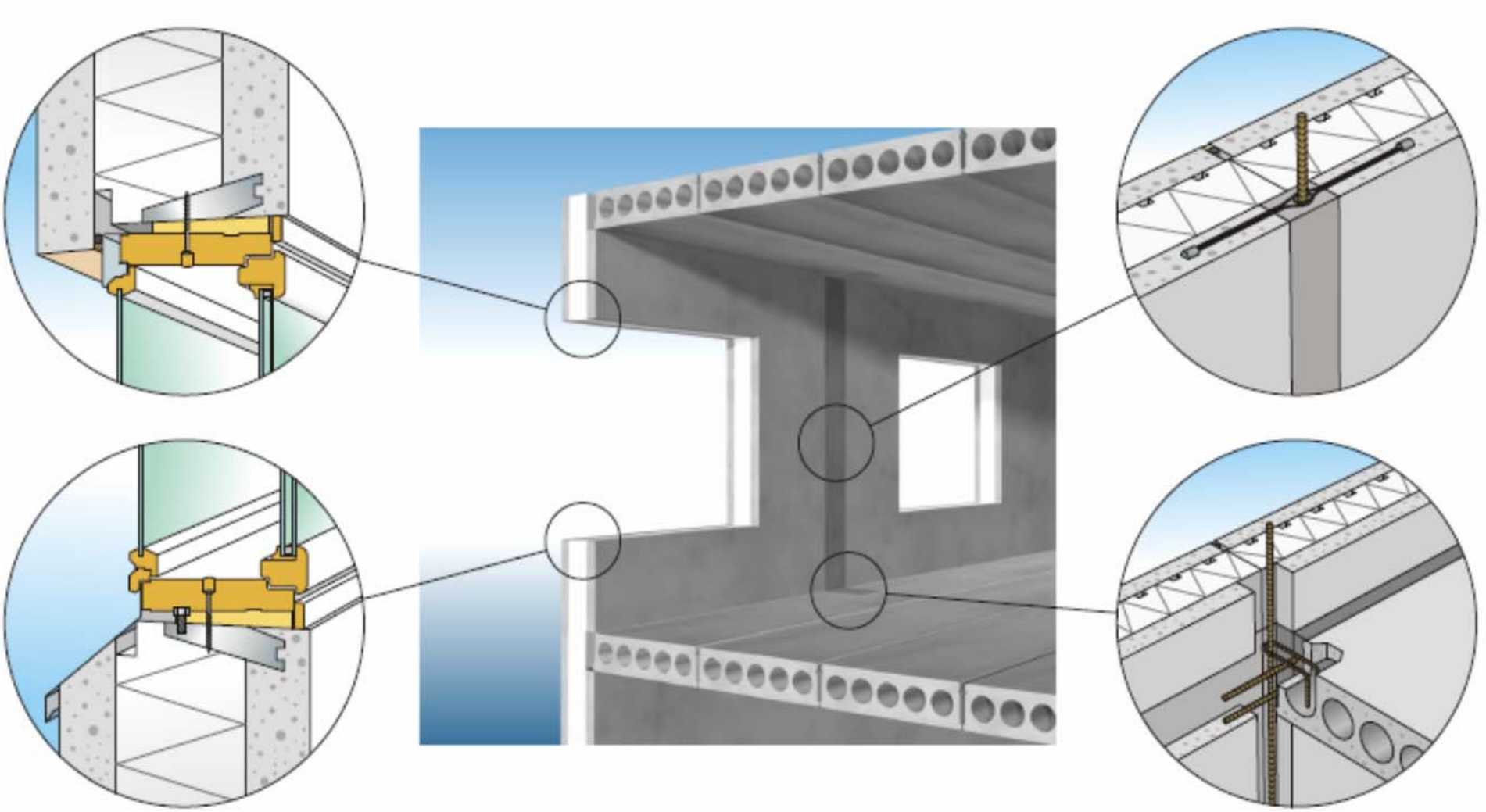
floors as seismic diaphragms

TG Affordable (low-cost) Housing



TG Sandwich Panels

bearing capacity and
thermal insulation (Fi)



… connections and fastenings

and … back to history

ancient remains met by new precast structure

What about 60 years of industrial prefabrication? was it worth?

Definitely Yes:

in many cases it proved the convenient choice

for economy, speed, good look, environment …

fib C6 has been trying to contribute all time along, too!

MUITO OBRIGADO!